Oak Ridge Reservation

Annual Site Environmental Report

2023

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Cover Image

Courtesy of Y-12 National Security Complex

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Oak Ridge Reservation Annual Site Environmental Report 2023

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Acronyms and Abbreviations

A	ACM	asbestos-containing material
	AFFF	aqueous film-forming foams
	AFV	alternative fuel vehicle
	ANSI	American National Standards Institute
	AOEC	Agent Operations Eastern Command
	ARAP	Aquatic Resources Alteration Permit
	AROD	amended record of decision
	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
	BMP	best management practice
C	CAA	Clean Air Act
	CAP-88 PC	Clean Air Act Assessment Package-1988 (software)
	CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
	CFE	carbon platform-free electricity
	CFR	*Code of Federal Regulations*
	CFTF	Carbon Fiber Technology Facility
	CNS	Consolidated Nuclear Security, LLC
	COLEX	column exchange
	COVID-19	Coronavirus Disease 2019
	CRD	contractor requirements document
	CRK	Clinch River kilometer
	CROET	Community Reuse Organization of East Tennessee
	CWA	Clean Water Act
	CWTS	Chromium Water Treatment System
	CX	categorical exclusion
	CY	calendar year
D	D&D	decontamination and decommissioning
	DCE	dichloroethene/dichloroethylene
	DCS	derived concentration standard
	DMRQA	Discharge Monitoring Report Quality Assurance Study
	DOD-ELAP	US Department of Defense Environmental Laboratory Accreditation Program
	DOE	US Department of Energy

	DOECAP	DOE Consolidated Audit Program
	DU	depleted uranium
E	EA	environmental assessment
	EC	environmental compliance
	EC&P	environmental compliance and protection
	ECD	Y-12 Environmental Compliance Department
	ED	effective dose
	EESP	Energy Efficiency and Sustainability Program
	EFK	East Fork Poplar Creek kilometer
	EFPC	East Fork Poplar Creek
	EISA	Energy Independence and Security Act of 2007
	EJ	environmental justice
	EM	DOE Office of Environmental Management
	EMDF	Environmental Disposal Facility
	EMP	Environmental Monitoring Program
	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
	EPSD	UT-Battelle Environmental Protection Services Division
	EPT	ephemeroptera, plecoptera, and trichoptera (taxa)
	e-RICE	emergency reciprocating internal combustion engine
	ES&H	environment, safety, and health
	ESH&Q	environment, safety, health, and quality
	ESPC	Energy Savings and Performance Contract
	ESS	ORNL Environmental Surveillance System
	ETTP	East Tennessee Technology Park
	EU	exposure unit
F	FCK	First Creek kilometer
	FFK	Fifth Creek kilometer
	FFS	focused feasibility study
	FLC	Federal Laboratory Consortium
	FMD	ORNL Facilities Management Division
	FONSI	Finding of No Significant Impact
	FWS	US Fish and Wildlife Service
	FY	fiscal year
G	GHG	greenhouse gas
	GP	guiding principle
	GSA	General Services Administration

H	HBCU	Historically Black Colleges and Universities
	HFIR	High Flux Isotope Reactor
	HPSB	high-performance sustainable building
	HQ	hazard quotient
	HVC	ORNL Hardin Valley Campus
I	IC	inhibition concentration
	ISMS	integrated safety management system
	ISO	International Organization for Standardization
	Isotek	Isotek Systems, LLC
L	LEED	Leadership in Energy and Environmental Design
	LLW	low-level radioactive waste
	LPF	Lithium Processing Facility
M	M&E	material and equipment
	MAPEP	Mixed Analyte Performance Evaluation Program
	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
	MCL-DCs	maximum contaminant level-derived concentrations
	MEI	maximally exposed individual
	MEK	Melton Branch kilometer
	MAPEP	Mixed Analyte Performance Evaluation Program
	MIK	Mitchell Branch kilometer
	MLLW	mixed low-level waste
	MOA	memorandum of agreement
	MSRE	Molten Salt Reactor Experiment
	MT	meteorological tower
N	NAAQS	National Ambient Air Quality Standards
	NELAP	National Environmental Laboratory Accreditation Program
	NEPA	National Environmental Policy Act
	NESHAPs	National Emission Standards for Hazardous Air Pollutants
	NFPA	National Fire Protection Association
	NHPA	National Historic Preservation Act
	NNSA	National Nuclear Security Administration
	NPDES	National Pollutant Discharge Elimination System
	NPO	NNSA Production Office
	NRC	US Nuclear Regulatory Commission
	NRHP	National Register of Historic Places

	NTRC	National Transportation Research Center
	NWSol	North Wind Solutions, LLC
O	ODS	ozone-depleting substance
	OREM	DOE Oak Ridge Office of Environmental Management
	ORETTC	Oak Ridge Enhanced Technology and Training Center
	ORGDP	Oak Ridge Gaseous Diffusion Plant
	ORISE	Oak Ridge Institute for Science and Education
	ORNL	Oak Ridge National Laboratory
	ORO	DOE Oak Ridge Office
	ORR	Oak Ridge Reservation
	ORRL	Oak Ridge Reservation Landfills
	ORSSAB	Oak Ridge Site Specific Advisory Board
	OST	Office of Secure Transportation
P	P2	pollution prevention
	PCB	polychlorinated biphenyl
	PCBADL	Polychlorinated Biphenyl Annual Document Log
	PCCR	phased construction completion report
	PCE	tetrachloroethene
	PFAS	per- and polyfluoroalkyl substances
	PFOA	perfluorooctanoic acid
	PFOS	perfluorooctane sulfonate
	PM_{10}	particulate matter with an aerodynamic diameter ≤ 10 µm
	$PM_{2.5}$	fine particulate matter with an aerodynamic diameter ≤ 2.5 µm
	PWTC	Process Waste Treatment Complex
Q	QA	quality assurance
	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
	RCRA	Resource Conservation and Recovery Act
	RECs	renewable energy credits
	RMAL	Radiochemical Materials Analytical Laboratory
	ROD	record of decision
	RSI	Restoration Services, Inc.
	RTR	real-time radiography
S	SA	supplement analysis
	SARA	Superfund Amendments and Reauthorization Act

	SBMS	UT-Battelle Standards-Based Management System
	SC	DOE Office of Science
	SD	storm water outfall/storm drain
	SHPO	State Historic Preservation Office
	SNS	Spallation Neutron Source
	SODAR	sonic detection and ranging
	SOF	sum of fractions
	SOP	state operating permit
	SPCC	spill prevention, control, and countermeasures
	SPMD	semipermeable membrane devices
	SSP	site sustainability plan
	STP	sewage treatment plant
	SWEIS	sitewide environmental impact statement
	SWPP	storm water pollution prevention
	SWPPP	storm water pollution prevention plan
	SWSA	solid waste storage area
T	TCE	trichloroethene/trichloroethylene
	TDEC	Tennessee Department of Environment and Conservation
	TEMA	Tennessee Emergency Management Agency
	TMDL	total maximum daily load
	TMI	Tennessee Macroinvertebrate Index
	TRI	toxic chemical release inventory
	TRN	Technical Resilience Navigator
	TRO	total residue 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	UCOR	United Cleanup Oak Ridge LLC
	UPF	Uranium Processing Facility
	USDA	US Department of Agriculture
	UST	underground storage tank
	UT	University of Tennessee
	UT-Battelle	UT-Battelle, LLC
V	VARP	Vulnerability Assessment and Resilience Planning
	VC	vinyl chloride
	VOC	volatile organic compound
	WBK	Walker Branch kilometer

W	WCK	White Oak Creek kilometer
	WEPAR	West End Protected Area Reduction
	WFMP	*Oak Ridge Reservation Wildland Fire Management Plan*
	WM/WRM	weapon material/weapon-related material
	WOC	White Oak Creek
	WOD	White Oak Dam
	WQC	water quality criterion
	WQPP	water quality protection plan
	WRRP	Water Resources Restoration Program
Y	Y-12 or Y-12 Complex	Y-12 National Security Complex

Units of Measure and Conversion Factors*

Units of measure and their abbreviations

acre	acre	micrometer	µm
becquerel	Bq	miles per hour	mph
British thermal unit	Btu	millicurie	mCi
centimeter	cm	milligram	mg
curie	Ci	milliliter	mL
day	d	millimeter	mm
degrees Celsius	°C	million	M
degrees Fahrenheit	°F	million gallons per day	MGD
disintegrations per minute	dpm	millirad	mrad
foot	ft	millirem	mrem
gallon	gal	milliroentgen	mR
gallons per minute	gpm	millisievert	mSv
gram	g	minute	min
gray	Gy	nanogram	ng
gross square feet	gsf	nephelometric turbidity unit	NTU
hectare	ha	parts per billion	ppb
hour	h	parts per million	ppm
inch	in.	parts per trillion	ppt
joule	J	picocurie	pCi
kilocurie	kCi	pound	lb
kilogram	kg	pound mass	lbm
kilometer	km	pounds per square inch	psi
kilowatt	kW	pounds per square inch gauge	psig
linear feet	LF	quart	qt
liter	L	rad	rad
millibar	mb	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
metric tons of carbon	MTCO2e	wet weight	ww
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. This 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	× 0.946	L	L	× 1.057	qt
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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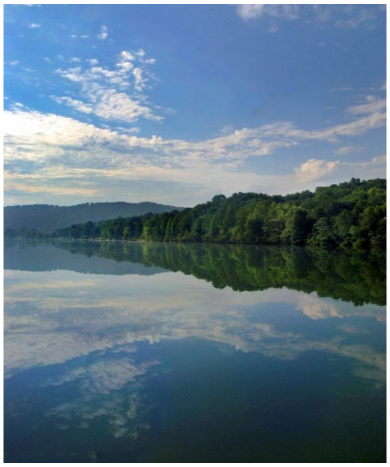
In Memoriam

Photo courtesy of Y-12

Merritt (Mick) Wiest
1951 – 2024

Mick Wiest was raised in Oak Ridge, Tennessee, by parents who worked on the Manhattan Project. Mick's strong interest in history has helped Y-12 comply with the National Historic Preservation Act, while also performing his primary duties related to the Clean Water Act. While at Y-12, he championed the preservation of the approximately 160-year-old, 100-foot-tall, Eastern Hemlock tree that is now part of a dedicated green space at the site. After 30 years of service, Mick retired from his environmental duties in 2017, after which he continued to be involved in many historical projects related to the city's history. He was instrumental in the formation of the Manhattan National Historical Park of Oak Ridge, helped to form the Oak Ridge Heritage and Preservation Association, and worked with the K-25 Preservation committee. He was remembered for his kindness, friendly demeanor, and ensuring environmental and cultural concerns were considered in project planning.



Located on the banks of the Clinch River, the Oak Ridge Reservation comprises three major facilities involved in every mission in the DOE portfolio. DOE is committed to enhancing environmental stewardship and managing the impacts its operations may have on the environment.

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). Today 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 and operating contractors and other prime contractors. This calendar year 2023 Oak Ridge Reservation Annual Site Environmental Report (ASER) contains information furnished to the DOE ORR integrating contractor by other contractors including UT-Battelle, LLC; Consolidated Nuclear Security, LLC; United Cleanup Oak Ridge LLC (UCOR); Oak Ridge Associated Universities; and Isotek Systems, LLC (Isotek). DOE and its contractors at ORR are committed to environmental protection, compliance, and sustainability, which includes the site's utmost efforts to ensure the validity and accuracy of monitoring data.

Chapter 3 of this report was prepared 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. Chapters 5, 6, and 7 were written by UT-Battelle, LLC, the ORNL management and operating contractor. These contractors are responsible for independently carrying out the various DOE missions at the three major ORR sites. They manage and implement environmental protection programs through environmental management systems that adhere to International Organization for Standardization Standard 14001, Environmental Management Systems. Chapters 3, 4, and 5 include detailed information on each contractor's environmental management systems, which interface with DOE's signature integrated safety management system (ISMS) to provide unified strategies for managing resources. ISMS incorporates safety in all aspects of work and helps ensure safety at all DOE 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.

DOE operations on ORR have the potential to release various 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. DOE is committed to enhancing environmental stewardship and managing the impacts its operations may have on the environment. To encourage the public to participate in matters related to ORR's environmental impact on the community, DOE solicits citizens' input on matters of significant public interest through multiple channels. DOE also offers access to information on 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 many 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.

Impacts

DOE ORR operations resulted in minimal impact to the public and the environment in 2023. Permitted discharges to air and water continued to be well below regulatory standards, and potential radiation doses to the public from activities on the reservation were much 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 2023 was estimated to be 0.6 mrem from air pathways, 0.8 mrem from water pathways (drinking water, fish consumption, swimming, recreation, and other uses), and 1 mrem from consumption of wildlife harvested on ORR. This is under 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 background radiation.

Environmental Monitoring

Each year extensive environmental monitoring is conducted across ORR. Site-specific environmental protection programs are implemented at ORNL, the Y-12 Complex, and

ETTP. ORR-wide environmental surveillance programs, which include locations and media both on and off the reservation, enhance and supplement data from site-specific efforts. In 2023 many thousands of samples and measurements of air, water, direct radiation, vegetation, fish, and wildlife were collected from across the reservation and analyzed for radioactive and nonradioactive contaminants. Sample media, locations, frequencies, and parameters were selected based on environmental regulations and standards, public and environmental exposure pathways, environmental permits, 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 and the Tennessee Department of Environment and Conservation, 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 ORR activities do not result in adverse impacts to the public or the environment.

Compliance with applicable regulations in 2023 for the three major ORR sites is summarized as follows:

- ETTP had no notices of environmental violations or penalties.
- Y-12 had nearly 100 percent compliance with water quality permit discharge limits for 2023 and no Clean Air Act violations or exceedances. Personnel from the Tennessee Department of Environment and Conservation Division of Solid Waste Management performed an unannounced Resource Conservation and Recovery Act hazardous waste compliance inspection of Y-12 from March 6–7, 2023. The inspections covered waste storage areas and records reviews. Two issues were identified: storage of three bags of spent aerosol cans for more than one year and one aerosol can puncturing device that was not closed securely. Immediate corrective actions were taken where possible. The issues and their causes are being reviewed to prevent recurrence.
- ORNL facilities include those on the Oak Ridge campus as well as off-campus entities such as the National Transportation Research Center and the Carbon Fiber Technology Facility. In 2023 there were no Clean Air Act violations by UT-Battelle, LLC, the ORNL managing contractor, and no Clean Air Act violations or exceedances by the other contractors who conducted activities at ORNL in 2023 (Isotek and UCOR). ORNL wastewater treatment facilities achieved a numeric permit compliance rate of 99.9 percent in 2023. One *Escherichia coliform* exceedance occurred in June 2023 at X01 (Sewage Treatment Plant) due to an operational issue with the disinfection system ozone diffuser. The diffuser has since been fixed.

Chapter 2 provides a more detailed summary of ORR environmental compliance during 2023. Chapters 3, 4, and 5 further discuss each site's compliance status for the year.

Environmental Management, Pollution Prevention, and Site Sustainability

Numerous environmental management, pollution prevention, and sustainability programs across ORR embody efforts to achieve enduring sustainability in facilities, operations, and organizational culture. The objectives of these programs are to conserve water and energy, minimize waste, and promote energy-efficient buildings, sustainable landscaping, green transportation, and sustainable acquisition. Consequently, these initiatives decrease the life cycle costs of programs and projects while also reducing risks to the environment. As described in Chapters 3, 4, and 5, ORR contractors achieved a high level of excellence in environmental management, pollution prevention, and sustainability programs in 2023.

Environmental Management

Since 1943 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 left some 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 underway at the reservation's three main facilities.

ETTP is positioned for Vision 2024—completion of all soil removal actions—having completed several Exposure Units (EUs) in 2023: EU-16, EU-19, EU-17, and EU-13. In addition, crews have been excavating the final section of contaminated material at EU-21 in the middle of the K-25 footprint, where more than 61,600 yd^3 of contaminated soil has been removed since 2021.

Y-12 achievements in 2023 included completing the Alpha-2 (Building 9201-2) deactivation, progress toward completion of the Beta-1 (Building 9204-1) deactivation, and continued construction of the Outfall 200 Mercury Treatment Facility.

Accomplishments in continuing demolition and deactivation were made at ORNL in 2023. These activities included the demolition of the 3005 facility and packaging of the reactor; deactivation of "Isotope Row" (facilities historically used to process radioisotopes) Buildings 3030, 3031, and 3032, with significant progress being made toward deactivation of Buildings 3029, 3118, and 3033; and completed deactivation of the Oak Ridge Graphite Reactor support facility 3003.

The Environmental Management Waste Management Facility received 5,211 waste shipments from ORR cleanup projects in 2023. Environmental Management Waste Management Facility operations also collected, analyzed, and disposed of approximately 3.53 million gallons of leachate treated by the Liquid and Gaseous Waste Operations Facility.

In FY 2023, the Transuranic Waste Processing Center completed contact-handled transuranic waste shipments of 159 m^3 to the Waste Isolation Pilot Plant in Carlsbad, New Mexico, 72.5 m^3 mixed low-level waste to treatment and disposal, and 1.8 m^3 of hazardous waste to treatment and disposal, eliminating 855 containers of the stored inventory.

Pollution Prevention and Sustainability

The three main ORR sites made significant strides in sustainability and pollution prevention in 2023, and highlights are summarized below.

Currently, there are 70 excess facilities at Y-12, with another 59 buildings and trailers to be excessed within the next 10 years. This progress aligns with meeting the DOE planned cleanup scope for Manhattan Project-era buildings at Y-12 that supported uranium enrichment, Beta-1 (9204-01), Alpha-2 (9201-02) and Alpha-4 (9201-04), which are currently undergoing deactivation. Alpha-2 is set for demolition starting in 2024.

In 2023, Y-12 experienced a slight uptick in energy intensity (a little over a half of a percentage above 2022). The upward trend in the site energy intensity figures is largely attributed to the site's teleworking policy expiring after the COVID-19 pandemic and the increase in hired employees.

Y-12 diverted 56.8 percent of municipal and 32 percent of construction and demolition waste from landfill disposal through reuse and recycle in 2023, and certified two buildings as High Performance Sustainable Buildings in FY 2023.

Site Scope 1 (on-site fuel burning) and Scope 2 (purchased electricity) emissions were reduced by 62.6 percent from the FY 2008 baseline.

ORNL implemented 29 ongoing and new pollution prevention projects during 2023, which eliminated more than 11.8 million kg of waste. As of the end of 2023, 80 percent of all ORNL vehicles are alternative fuel vehicles, with 88 percent of all replacements since 2020 being alternative fuel or electric vehicles. Also in 2023, 93 percent of the light-duty vehicles operated on alternative fuels, exceeding DOE fleet management goals. Water use intensity increased by 8.7 percent between 2022 and 2023, due to increased demands for cooling tower makeup water to support growth of high-performance computing systems. Calculated energy use intensity for FY 2023 was 237,514 Btu per gross square foot, a cumulative reduction of 34.7 percent since FY 2003 but an increase of 1.41 percent from FY 2022.

During 2023 at ETTP, the Sustainability Leadership Award-winning projects saved more than 1,325 MT of greenhouse gas emissions, 772,700 lbs of waste from landfills, and treated 16,029,000 gallons of wastewater. In addition to lessening the impact on the environment, these pollution prevention measures also saved approximately $7.8 million.

OREM continued planning for capital asset projects that will further advance ORR cleanup objectives. These include operation of the Outfall 200 Mercury Treatment Facility at Y-12 by 2025; completion of demolition activities at ORNL's Central Campus, Beta-1 and Alpha-2 by 2027; completion of processing, downblending, and disposing the remaining inventory of ^{233}U stored at ORNL by 2028; and construction completion of the first phase of the new Environmental Management Disposal Facility by 2029.

Signs such as this were common in the city of Oak Ridge during the Manhattan Project era and for years afterward.

1

Introduction to the Oak Ridge Reservation

It was not shown on any maps. No visitors were allowed without special approval. US Army guards were posted at the entrances to the city, and all residents were required to wear badges at all times outside their homes. Thus Oak Ridge existed for seven years, from 1942 to 1949, as a truly secret city. It was here and in supporting locations where humankind made the leap from candlepower to nuclear power in a single generation. The engineering marvel that materialized in the Secret City changed the world, helped end World War II, and launched life-saving diagnostic tools such as magnetic resonance imaging and nuclear medicine. Today the former Secret City exists in two parts: the City of Oak Ridge and the Oak Ridge Reservation (ORR). 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.

ORR covers a little over 50 square miles of land in Anderson and Roane counties and is home to two major US Department of Energy (DOE) operating facilities: the Oak Ridge National Laboratory (ORNL) and the Y-12 National Security Complex (Y-12). Other ORR facilities 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, laboratory, and support facilities; the government-owned, government-operated Agent Operations Eastern Command (AOEC) of the National Nuclear Security Administration (NNSA) Office of Secure Transportation (OST); the Transuranic Waste Processing Center (TWPC); and small government-owned, contractor-operated environmental cleanup facilities.

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 xxx and xxxi are included to help readers convert numeric values as needed for specific calculations and comparisons.

1.1. Background

The ORR Annual Site Environmental Report (ASER) is 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 Attachment 2 (DOE 2012) regarding the preparation of an integrated annual site environmental report.

Summary results in this report are based on data collected before and continuing through 2023. Not all results of the environmental monitoring associated with ORR are reported here, and this is not intended to be 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 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. Environmental surveillance data support environmental compliance and, when combined with data from effluent monitoring, also support chemical and radiation dose and exposure assessments of any potential effects of ORR operations 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. 900 BC to AD 1000). Their descendants still lived in the East Tennessee region when European settlers arrived in the late 1700s. The Cherokee Nation controlled the region at this time, but the 1791 Treaty of the Holston and the 1798 Treaty of Tellico allowed for European settlement, which forever altered the landscape. As settlements continued to grow in numbers, new counties were formed, including Roane County and Anderson County in 1801. Early European settlers of the area lived on farms or in four small communities named Elza, Robertsville, Wheat, and Scarborough. These villages served primarily as gathering centers and usually contained one or two churches and a general store. About one thousand families inhabited the area in the early 1940s (Souza 2001, Hogan 2021).

In 1939 President Franklin D. Roosevelt received the famous Einstein-Szilard letter informing him that German scientists were working on a nuclear weapon. In utmost secrecy, he formed the Advisory Committee on Uranium, a team of scientists and military officials tasked with researching uranium's potential role as a weapon, which later evolved into the Office of Scientific Research and Development. After the United States was thrust into World War II following the Japanese attack on Pearl Harbor, the Manhattan Project emerged in 1942 as a full-scale program to build an atomic bomb. The super-secret code name gave no indication of the classified activities it carried out, and the project was named for the location of its original headquarters at 270 Broadway in New York City's Manhattan district. In the summer of 1943, the project moved to East Tennessee where construction of America's first full-scale gaseous diffusion plant was underway, to fulfill the mission of isolating ^{235}U for the first atomic bomb.

The selection of the area now known as ORR for the nuclear development site was largely due to the vision of General Leslie Groves. The presence of abundant water from the Clinch River, a good source of labor in nearby Knoxville, railroad accessibility, and a supply of ample amounts of electricity from the Tennessee Valley Authority were viewed as key assets. Moreover, the parallel northeast-to-southwest valleys separated by 200- to 300-foot ridges were seen as useful to segregate the production areas and to provide protection in case of a catastrophe within any one of them. The federal government's acquisition of property for the uranium enrichment plants and a pilot scale nuclear reactor took place through eminent domain and immediately affected more than 3,000 individuals, many whose families had occupied homes and farms for generations. Although the families were compensated by the federal government, the urgency of the eviction was difficult for the landowners, who were forced to abandon their houses and crops. Many property owners also felt they were underpaid for the value of their homes and land, although many later successfully appealed the initial land valuations offered to them.

The site's wartime name was Clinton Engineer Works, and the area now known as Oak Ridge was the workers' city on the reservation's northern edge. Although Oak Ridge did not appear on any map until 1949, it quickly grew to a population of 75,000, becoming the fifth largest city in Tennessee. To the south of the residential area at the Y-12 Complex, an electromagnetic method separated ^{235}U 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 (Olwell 1999, Broad 2007, Reed 2014, Johnson 2018).

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 the current missions of these and several smaller ORR facilities and activities.

1.3. Location and Description

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. 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. ORR encompasses 32,465 acres of mostly contiguous, federally owned land in Anderson and Roane Counties, and is under the management of DOE (DOE 2023a).

1.3.1. Population

As reported in *US Department of Energy FY 2020 Economic Impact in Tennessee* (East Tennessee Economic Council), ORR supports approximately 43,000 members of the region's labor force. The Vintage 2023 US Census Population Estimate for the Knoxville Metropolitan Statistical Area, including Oak Ridge, was 946,264.[1] (Census Bureau 2024a). The combined US Census Vintage 2023 Population Estimate for the 10 counties surrounding ORR (Anderson, Blount, Campbell, Cumberland, Knox, Loudon, McMinn, Monroe, Morgan, and Roane) was 1,069,874 (Census Bureau 2024b). Knoxville, the nearest major city, is about 40 km (25 mi) to the east and had a population of 198,162 according to the US Census Vintage 2023 Population Estimate (Census Bureau 2024c). Other municipalities within about 30 km (18.6 mi) of ORR include Oliver Springs, Clinton, Rocky Top, Lenoir City, Farragut, Kingston, and Harriman.

[1] Vintage 2023 is the base population of the 2020 census plus estimates from the time series starting April 1, 2020, through July 1, 2023.

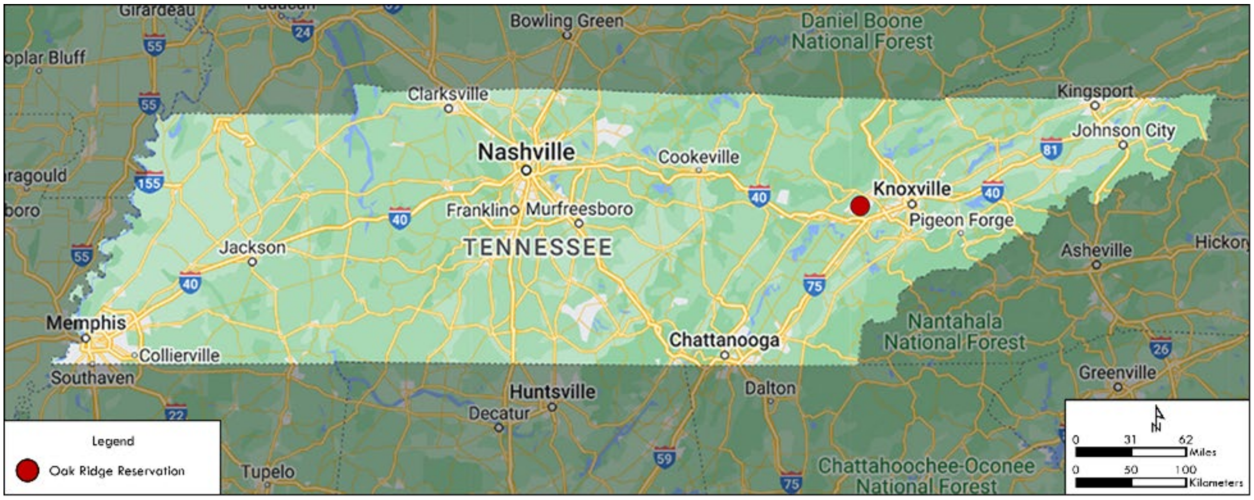


Figure 1.1. Location of the Oak Ridge Reservation in Tennessee

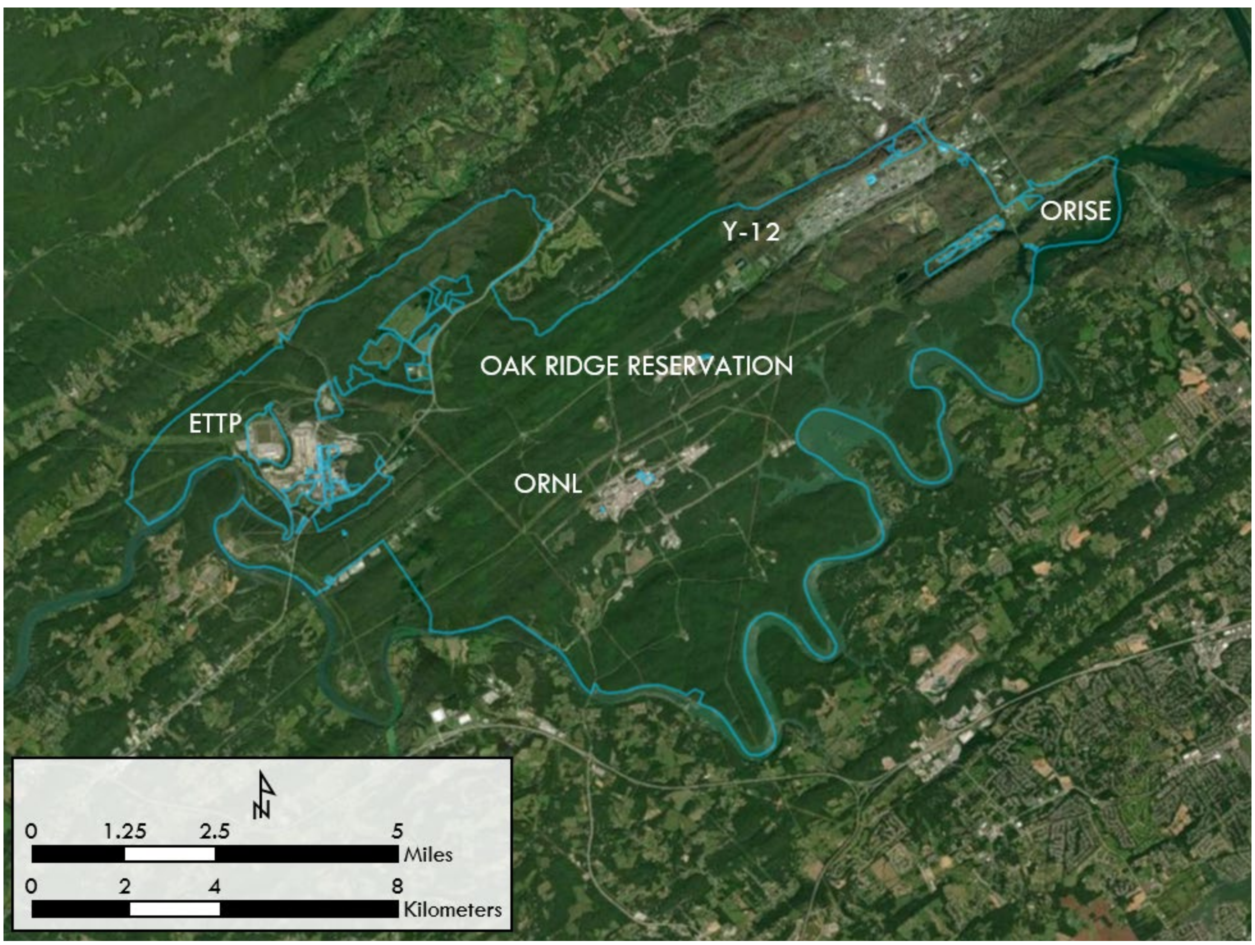


Figure 1.2. Map of the Oak Ridge Reservation

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 average temperature for 1991–2020 was 14.9°C (58.8°F). The average temperature for the Oak Ridge area in 2023 was 14.6°C (57.3°F). January temperatures were coldest in 2023, averaging 5.5°C (41.9°F). July was the warmest month, with an average temperature of 24.0°C (75.2°F). Monthly summaries of temperature averages, extremes, and 2023 values are provided in Appendix B, Table B.1.

Average annual precipitation in the Oak Ridge area for the 30-year period from 1991 to 2020 was 1,417.8 mm (55.82 in.), including about 14.5 cm (5.7 in.) of snowfall. Total precipitation during 2023 as measured at meteorological tower (MT)2 was 1200 mm (47.2 in.), which is 15 percent below the 30-year average of 1417.8 mm. Monthly summaries of precipitation averages, extremes, and 2023 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 2023 were greater than 98 percent for wind sensors at the ORNL towers MT3, MT4, and MT12. ORNL tower MT2 was down a portion of the year because of maintenance, but a recovery rate greater than 40 percent was recorded in 2023. Annual wind data recovery during 2023 exceeded 99 percent for ETTP tower MT13. Y-12 tower MT6, which was down most of the year for maintenance, recorded an annual recovery rate of 19.6 percent.

In 2023, wind speeds at ORNL Tower D (MT2) measured at 15 m (49 ft) above ground level averaged 1.4 meters per second (3.1 mph). This value was 2.1 meters per second (4.7 mph) 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.

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 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.

As of August 30, 2017, EPA designated Anderson, Knox, Blount, and Roane Counties as attainment areas for the $PM_{2.5}$ air quality standard. (ORR is located in Anderson and Roane Counties.) The greater Knoxville and Oak Ridge area is a NAAQS attainment area for all other criteria pollutants for which EPA has made attainment designations (EPA 2023).

1.3.4. Surface Water

The ORR area comprises 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. The Tennessee Valley Authority reported 49 inches of precipitation in 2023 for the Tennessee River Valley region (TVA 2024). 2023 was the first year since 2016 the 41,000 square-mile Tennessee River basin received below-normal rainfall and only the second year since 2012.

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 (WOC) drainage basin, which covers 16.5 km^2 (6.4 mi^2). The headwaters of WOC 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 WOC 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 WOC 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 liters per minute (1,000 gallons per minute). 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

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.

About 235 hectares (580 acres) of potential wetlands (jurisdictional and non-jurisdictional wetland areas) have been identified on ORR; most are classified as forested palustrine, scrub/shrub, and emergent wetlands (Parr and Hughes 2006). Wetlands identified to date range from several square meters at small seeps and springs to about 10 hectares (25 acres) at White Oak Lake. The Tennessee Department of Environment and Conservation's wetland mitigation aquatic resource alteration permits, required by Section 401 of the Clean Water Act (CWA 1972), entail monitoring restored or created wetland mitigation sites for 5 years. Activities and conditions in and around ORR wetlands are verified by site inspections when appropriate.

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 May 2024, Tennessee had 58 species listed under the federal Endangered Species Act (ESA 1973), including 25 endangered and 33 threatened species. The complete Tennessee Threatened and Endangered List–New Rules is available **here** (TDEC 2024a).

Birds, fish, reptiles and amphibians, 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. The only federally listed animal species known to occur on the ORR in recent years are bat species. Endangered gray bats have been detected in acoustic surveys and mist net captures for more than 30 years. Endangered Indiana bats and northern long-eared bats have been detected in acoustic surveys and mist net captures since 2013 (McCracken et al. 2015). Surveys conducted in 2022 indicate use of several caves on the ORR by gray bats and other bat species. Suitable roosting and foraging habitat for the three federally listed bat species is abundant across the ORR. Additional bat species found on the ORR include the tricolored bat (state-listed as threatened and proposed for federal listing), little brown bat (state-listed as threatened and under consideration for federal listing), Rafinesque's big-eared bat (state-listed as in need of management), and eastern small-footed bat (state-listed as in need of management) (TDEC 2024a, TDEC 2024b).

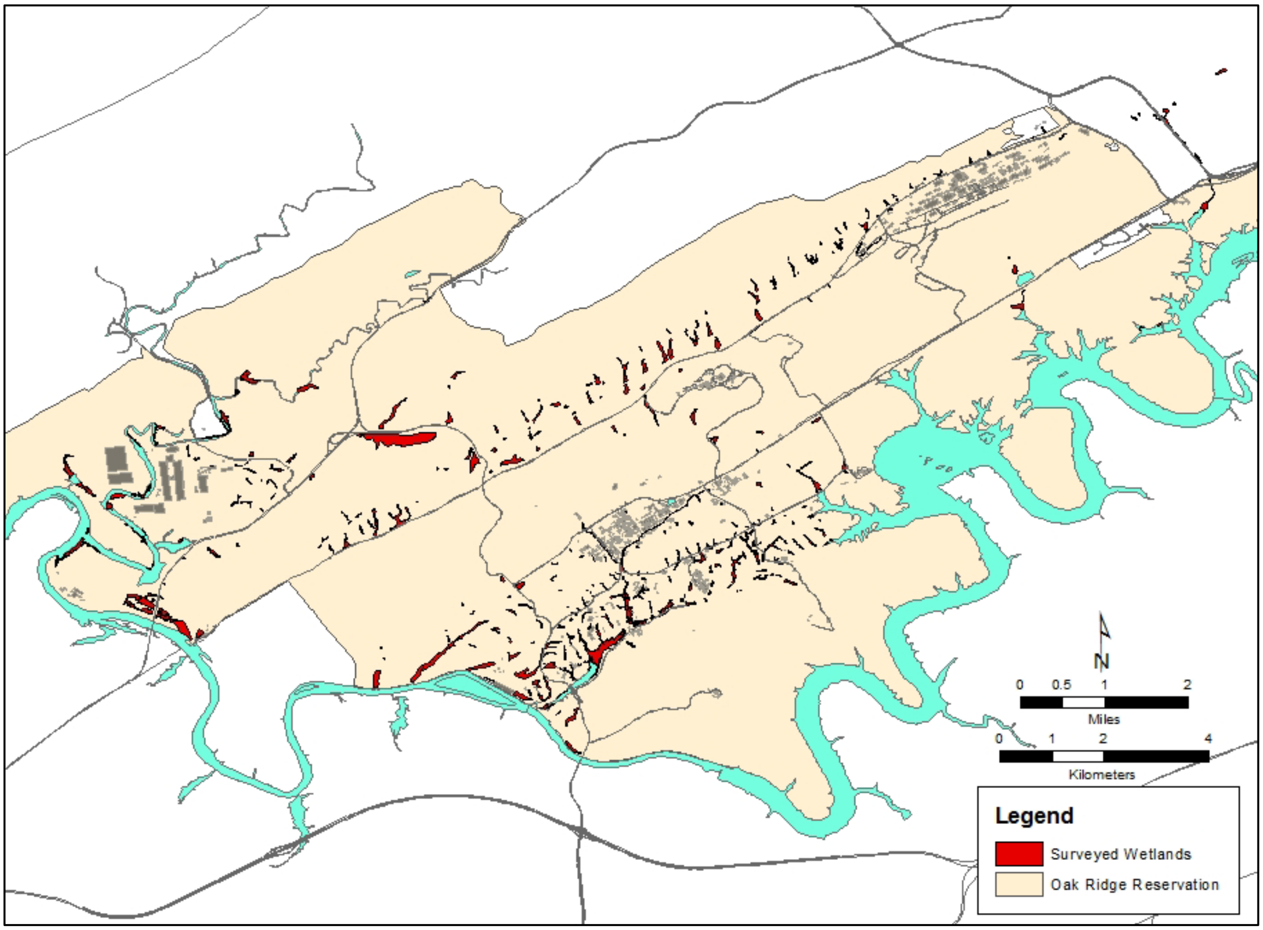


Figure 1.3. Location of Oak Ridge Reservation wetlands

Table 1.1. Animal species of special concern reported on ORR[a]

Scientific name	Common name	Status[b]			
		Federal	TN	NatureServe[c]	PIF[d]
FISH					
Phoxinus tennesseensis	Tennessee dace		NM	S3	
AMPHIBIANS AND REPTILES					
Cryptobranchus alleganiensis	Hellbender		E	S3	
Hemidactylium scutatum	Four-toed salamander		NM	S3	
Ophisaurus attenuatus longicaudus	Eastern slender glass lizard		NM	S3	
Pituophis melanoleucus	Northern pinesnake		T	S3	
BIRDS					
Swans, Geese, and Ducks					
Branta canadensis	Canada goose	BMC, OA		S5	
Aix sponsa	Wood duck	BMC		S5	
Mareca strepera	Gadwall	BMC		S4	

Table 1.1. Animal species of special concern reported on ORR[a] (continued)

Scientific name	Common name	Status[b]			
		Federal	TN	NatureServe[c]	PIF[d]
Mareca americana	American wigeon	BMC		S4	
Anas rubripes	American black duck	BMC		S3	IM
Anas platyrhynchos	Mallard	BMC		S5	
Spatula discors	Blue-winged teal	BMC		S2	
Anas crecca	Green-winged teal	BMC		S4	
Spatula clypeata	Northern shoveler	BMC		S4	
Anas acuta	Northern pintail	BMC		S4	
Aythya valisineria	Canvasback	BMC		S3	
Aythya americana	Redhead	BMC		S4	
Aythya collaris	Ring-necked duck	BMC		S5	
Aythya affinis	Lesser scaup	BMC		S4	
Grebes					
Podilymbus podiceps	Pied-billed grebe	BMC		S4	
Podiceps auritus	Horned grebe	BMC		S4	
Frigatebirds, Boobies, Cormorants					
Nannopterum auritum	Double-crested cormorant	BMC, OA		S2	
Bitterns and Herons					
Ixobrychus exilis	Least bittern	BMC	NM	S2	
Egretta caerulea	Little blue heron	BMC	NM	S2	
Nycticorax nycticorax	Black-crowned night heron	BMC		S2	
Butorides virescens	Green heron			S4	MA
Mycteria americana	Wood stork	T		S3	
Kites, Hawks, Eagles, and Allies					
Haliaeetus leucocephalus	Bald eagle	BMC[e]		S3	
Rails, Gallinules, and Coots					
Rallus limicola	Virginia rail	BMC		S1	
Porzana carolina	Sora	BMC		S1	
Fulica americana	American coot	BMC		S2	
Tringa solitaria	Solitary sandpiper	BMC, BCC		S5	
Tringa flavipes	Lesser yellowlegs	BMC, BCC		S5	
Scolopax minor	American woodcock	BMC		S4	MA
Grouse, Turkey, and Quail					
Colinus virginianus	Northern bobwhite	BMC, BCC, E		S2	CR
Pigeons and Doves					
Zenaida macroura	Mourning dove	BMC		S5	
Cuckoos and Roadrunners					
Coccyzus americaus	Yellow-billed cuckoo	BMC, BCC, T		S4	IM

Table 1.1. Animal species of special concern reported on ORR[a] (continued)

Scientific name	Common name	Status[b]			
		Federal	TN	NatureServe[c]	PIF[d]
Goatsuckers					
Antrostomus carolinensis	Chuck-will's widow	BMC, BCC		S3	IM
Antrostomus vociferus	Eastern whip-poor-will	BMC, BCC		S3	IM
Chordeiles minor	Common nighthawk	BCC		S4	IM
Swifts					
Chaetura pelagica	Chimney swift	BCC		S5	IM
Kingfishers					
Megaceryle alcyon	Belted kingfisher	BCC		S5	MA
Woodpeckers					
Melanerpes erythrocephalus	Red-headed woodpecker	BMC, BCC		S4	PR
Colaptes auratus	Northern flicker	BMC		S5	MA
Tyrant Flycatchers					
Contopus virens	Eastern wood-pewee			S5	MA
Empidonax virescens	Acadian flycatcher			S5	MA
Contopus cooperi	Olive-sided flycatcher	BMC, BCC		S1	PR
Empidonax trailii	Willow flycatcher	BMC, BCC, E		S2	
Swallows					
Progne subis	Purple martin			S5	MA
Hirundo rustica	Barn swallow			S5	MA
Kinglets, Gnatcatchers, and Thrushes					
Hylocichla mustelina	Wood thrush	BMC, BCC		S4	MA
Shrikes					
Lanius ludovicianus	Loggerhead shrike	BMC, BCC, E	NM	S1	
Wood Warblers					
Vermivora chrysoptera	Golden-winged warbler	BMC, BCC	T	S3	IM
Setophaga cerulea	Cerulean warbler	BMC, BCC	NM	S3	IM
Setophaga discolor	Prairie warbler	BMC, BCC		S3	MA
Mniotilta varia	Black-and-white warbler			S4	MA
Protonotaria citrea	Prothonotary warbler	BMC, BCC		S4	MA
Geothlypis formosa	Kentucky warbler	BMC, BCC		S4	MA
Cardellina canadensis	Canada warbler	BMC, BCC		S3	MA
Icteria virens	Yellow-breasted chat	BCC		S4	MA
Tanagers					
Piranga rubra	Summer tanager	BMC		S4	MA
Towhees, Sparrows, and Allies					
Pipilo erythrophthalmus	Eastern towhee			S5	MA
Spizella pusilla	Field sparrow	BMC, BCC		S4	MA
Ammodramus savannarum	Grasshopper sparrow	BMC, BCC		S4	IM

Table 1.1. Animal species of special concern reported on ORR[a] (continued)

Scientific name	Common name	Status[b]			
		Federal	TN	NatureServe[c]	PIF[d]
Ammodramus henslowii	Henslow's sparrow	BMC, BCC	T	S1	IM
MAMMALS					
Myotis grisescens	Gray bat	E	E	S2	
Myotis lucifugus	Little brown bat[f]		T	S3	
Myotis sodalis	Indiana bat[g]	E	E	S1	
Myotis septentrionalis	Northern long-eared bat	E	E	S1	
Myotis leibii	Eastern small-footed bat		NM	S2	
Perimyotis subflavus	Tri-colored bat[f]	PE	T	S2	
Corynorhinus rafinesquii	Rafinesque's big-eared bat		NM	S3	
Sorex dispar	Long-tailed shrew		NM	S2	

[a] *Land and surface waters of the Oak Ridge Reservation (ORR) exclusive of the Clinch River, which borders ORR.*

[b] *Status codes:*

E = endangered (TDEC 2024a, TDEC 2024b, FWS 2021, TWRA 2024)
PE = proposed endangered (TDEC 2024b)
T = threatened (TDEC 2024a, TDEC 2024b, FWS 2021)
S1 = critically imperiled (NatureServe 2024, TDEC 2024b)
S2 = imperiled (NatureServe 2024, TDEC 2024b)
S3 = vulnerable (NatureServe 2024, TDEC 2024b)
S4 = apparently secure (NatureServe 2024, TDEC 2024b)
S5 = secure (NatureServe 2024, TDEC 2024b)
BMC = Birds of management concern (FWS 2011)
BCC = Birds of conservation concern (FWS 2021)
NM = in need of management (TDEC 2024a, TDEC 2024b, TWRA 2024)
OA = overly abundant (FWS 2011)
CR = critical recovery for Bird Conservation Region (BCR) 28 (Appalachian Mountains Bird Conservation Region) (PIF 2024)
IM = immediate management for BCR28 (PIF 2024)
MA = management attention for BCR28 (PIF 2024)
PR = planning and responsibility for BCR28 (PIF 2024)

[c] *NatureServe works with over 60 network organizations and over 1,000 conservation scientists to collect, aggregate, and standardize biodiversity statistics.*

[d] *Partners in Flight (PIF) is an international organization devoted to conserving bird populations in the Western Hemisphere.*

[e] *The bald eagle was federally delisted effective August 9, 2007.*

[f] *Under review for federal listing.*

[g] *A single specimen was captured in a mist net bordering the Clinch River in June 2013.*

Birds recorded on ORR and its boundary waters include 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*) for a total of 236 species. Most of these species are protected under the Migratory Bird Treaty Act (MBTA 1918) and Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds* (EO 2001). 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 along varying numbers of up to 10 routes on ORR provide data for the Partners in Flight Program. Four public nature walks organized by ORNL occurred in 2023 (bird, frog, Reptiles and Amphibians, and Historic Talks at Freels Bend). These walks began in the late winter and carried through mid-summer. They covered topics such as the American woodcock (shown in Figure 1.4), birds of prey, frog calls, inventories of reptiles and amphibians, and the history of ORR. 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 known ORR bird records since 1950 and 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 it is currently listed as a potential breeding bird on the reservation (Roy et al. 2014), because its actual breeding status is still uncertain.

Source: Sarah Darling, ORNL

Figure 1.4. American woodcock fledgling on ORR

The bald eagle (Figure 1.5), 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. At least three bald eagle nests were confirmed on the reservation in 2023, all located along the Clinch River/Melton Hill Lake, between Gallaher Bend and Melton Hill Dam. One nest was first observed in 2011 near the mouth of Walker Branch and has remained active every year since, and another nest near Melton Hill Dam has been documented by an area nature photographer for several years. 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.

Other bird species of interest include the migratory wood thrush and barn swallow, which have been observed nesting on the reservation. The Lincoln's sparrow (*Melospiza lincolnii*) (no listed status) was sighted on ORR in May 2014. Barn owls were documented nesting on the reservation in 2019.

Source: Kelly Roy, ORNL

Figure 1.5. Bald eagle photographed on ORR

Figure 1.6. Purple gallinule caught on a trail surveillance camera at ETTP in 2017

Uncommon birds for ORR recorded in recent years include several species associated with wetland habitats. Due to efforts in the early 2000s to mitigate ETTP's K1007 P-1 pond into a high-quality wildlife habitat, purple martin (*Progne subis*) and willow flycatcher (*Epidonax tralillii*) make their home here every spring and summer. The limpkin (*Aramus guarauna*), which is not usually observed in Tennessee, was seen utilizing the ponds in June 2023. While collaborating on detection methodologies for secretive marsh birds, researchers from ORNL and Charles Sturt University in New South Wales, Australia, photographed a purple gallinule (*Porphyrio martinicus*) on a trail camera at the Heritage Center Greenway Powerhouse Trail in 2017 (Figure 1.6). This was the first documented appearance of a purple gallinule on ORR.

ORNL is continuing monitoring of state-listed four-toed salamanders (*Hemidactylium scutatum*) at the ORR. Although the ORR contains some of the highest densities of this species in eastern Tennessee, they are considered by the state as in need of management. Several of their largest subpopulations on the ORR occur in areas that are slated for development. ORNL has also documented what appear to be state-listed black mountain salamanders (*Desmognathus welteri*, considered by the state as in need of management) on the ORR, just south of the Horizon Center. Two state-listed reptiles have inhabited the ORR: the northern pinesnake (*Pituophis melanoleucus melanoleucus*, state-listed as threatened) and the eastern slender glass lizard (*Ophisaurus attenuatus longicaudus*, state-listed as in need of management). However, there is limited evidence to suggest the number of either species on the reservation.

Several fish species listed and noted for management concern are known to inhabit areas in and around the ORR. 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 the ORR. The tangerine darter (*Percina aurantiaca*), a species listed by the state as in need of management, has also been recorded near the 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 federal listing and were previously listed under the Category 2 candidate designation (Nature Conservancy 1995). FWS now informally refers to these as special concern species.

The state of Tennessee lists 16 plant species occurring on ORR as endangered, threatened, or of special concern; these are included in Table 1.2. An additional 10 threatened, endangered, or special concern species occur in the area and may be present on ORR, although currently unconfirmed. 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 (TDEC 2021, TDEC 2024b).

Table 1.2. Vascular plant species of special concern sighted or reported on or near ORR

Species	Common name	Habitat on ORR	Status/rank code[a,b]
Currently known to be or previously reported on ORR			
Aureolaria patula	Spreading false foxglove	River bluff	S, S3
Berberis canadensis	American barberry	Rocky bluff	S, S2
Bolboschoenus fluviatilis	River bulrush	Wetland	S, S1
Delphinium exaltatum	Tall larkspur	Barrens and woodlands	E, S2
Diervilla lonicera	Northern bush-honeysuckle	Rocky river bluff	T, S2
Draba ramosissima	Branching whitlow-grass	Limestone cliff	S, S2
Elodea nuttallii	Nuttall waterweed	Pond, embayment	S, S2
Eupatorium godfreyanum	Godfrey's thoroughwort	Dry woods edge	S, S1
Fothergilla major	Mountain witch-alder	Woods	T, S2
Helianthus occidentalis	Naked-stem sunflower	Barrens	S, S2
Juglans cinerea	Butternut	Lake shore	T, S3
Juncus brachycephalus	Small-head rush	Open wetland	S, S2
Liparis loeselii	Fen orchid	Forested wetland	T, S1
Panax quinquefolius	American ginseng	Rich woods	S, S3
Platanthera flava var. herbiola	Tuberculed rein-orchid	Forested wetland	T, S2
Spiranthes lucida	Shining ladies'-tresses	Boggy wetland	T, S1
Rare plants that occur near and could be present on ORR			
Agalinis auriculata	Earleaf false foxglove	Calcareous barren	E, S2
Allium burdickii[c]	Narrow-leaf Ramps	Moist woods	T, CE, S1
Allium tricoccum[c]	Ramps	Moist woods	S, CE, S1
Lathyrus palustris	Marsh pea	Moist meadows	S, S1
Liatris cylindracea	Slender blazing star	Calcareous barren	T, S2
Lonicera dioica	Mountain honeysuckle	Rocky river bluff	S, S2
Meehania cordata	Heartleaf meehania	Moist calcareous woods	T, S2
Pedicularis lanceolata	Swamp lousewort	Calcareous wet meadow	S, S1

Table 1.2. Vascular plant species of special concern sighted or reported on or near ORR (continued)

Species	Common name	Habitat on ORR	Status/rank code[a,b]
Pseudognaphalium helleri	Heller's catfoot	Dry woodland edge	S, S2
Pycnanthemum torreyi	Torrey's mountain-mint	Calcareous barren edge	E, S1

[a] State status codes (TDEC 2021):
CE = Status due to commercial exploitation
E = Endangered in Tennessee
S = Special concern in Tennessee
T = Threatened in Tennessee
[b] State conservation status (NatureServe 2024):
S1 = Critically imperiled
S2 = Imperiled
S3 = Vulnerable
[c] 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.
Acronym: *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 of 1966 (NHPA 1966) is maintained in conjunction with the National Environmental Policy Act (NEPA 1969) and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA 1980). 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 several facilities that were eligible for inclusion on the National Register of Historic Places (NHRP), a National Park Service program to identify, evaluate, and protect historic and archeological resources in the United States, as well as numerous facilities that were not eligible for NHRP inclusion. The reservation contains more than 44 known prehistoric sites (primarily archeological evidence of former structures), 254 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 (NDAA 2014), 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 (DOE-DOI 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 a National Historic Landmark since 1966, and it 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.

Occasional public access to Buildings 9731 and 9204-3 at the Y-12 Complex last occurred on November 12, 2015, when DOE facilitated public tours of both buildings to celebrate the establishment of the National Park. By helping to develop the National Park, DOE aims to enhance safe access to these buildings while protecting the agency's mission capabilities.

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 the National Historic Preservation project that developed the K-25 History Center. The K-25 History Center serves to highlight the historic aspects of ETTP and of the communities that were displaced during the construction of the site.

On May 11, 2023, a groundbreaking was held for the K-25 Viewing Platform that will provide an expansive view of the building's original footprint. The facility is being constructed by the US Army Corps of Engineers using contractor Geiger Brothers Inc. to manage construction. The viewing platform will be completed in 2025 and is located just north of the K-25 History Center. It will include 10-foot-tall wraparound glass windows and exhibits that provide quick facts and visuals related to the historic importance of the K-25 Building, as well as view scopes and a scale model of the original facility.

The K-25 History Center and Viewing Platform complement the Manhattan Project National Historic Park established in 2015, which includes the footprint of the former K-25 Building (DOE-DOI 2015). The National Park Service is assisting 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. As part of the activities to establish the park, DOE launched the K-25 Virtual Museum which details the history of the K-25 Gaseous Diffusion Plant through narrative and photographs, which can be viewed **here**.

In addition to the X-10 Graphite Reactor, six additional historic ORR properties are listed individually in the planning for a History Center:

- Freels Bend Cabin
- 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.

ORNL and Y-12 programmatic agreements and memorandums of agreement among DOE, the State of Tennessee, the Advisory Council on Historic Preservation, and consulting parties serve to provide a system of review for projects that may potentially affect historic and archaeological resources on the ORR. The ORNL and Y-12 programmatic agreements are currently being updated to reflect new architectural building surveys and revisions to each site's Historic Preservation Plans. In 2023, work began to develop a new memorandum of agreement to address mitigation activities for the planned demolition of DOE ORNL Office of Science (SC) Buildings 9401-1, 9201-2, 9204-1, 9732-02, 3034, 3036, 3501, 5505, and 2523, and DOE Oak Ridge Office of Environmental Management (OREM) Buildings 3002, 3003, 3018, 3038, 3029, 3030, 3031, 3032, 3033, 3033A, 3118, 3042, 3515, 3542, and 3517. These historic contaminated buildings were determined to pose excessive environmental risks.

1.4. Oak Ridge Sites

ORR includes a number of sites critical to the mission of DOE. Eight of these sites are described in this section: ORNL, the Y-12 Complex, ETTP, EMWMF, the Oak Ridge National Environmental Research Park, ORISE, NNSA OST AOEC, and the TWPC.

United Cleanup Oak Ridge LLC (UCOR) is the lead DOE ORR cleanup contractor, led by Amentum, Jacobs, and Honeywell, and addresses expanded cleanup operations at ORNL and Y-12, in addition to the continuing final soil and groundwater remediation at ETTP.

The scope of UCOR activities includes characterization and cleanup of former production facilities, building pads, and impacted environmental media; management and maintenance of active ORR facilities; long-term management of inactive waste disposal sites; and water quality monitoring. The *2023 Cleanup Progress: Annual Report on Oak Ridge Reservation Cleanup* (UCOR 2023) provides detailed information on UCOR activities at the ORR and is available **here**.

1.4.1. Oak Ridge National Laboratory

ORNL (shown in Figure 1.7) is managed for DOE by UT-Battelle, LLC, a partnership between the University of Tennessee and the 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 Frontier 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 ITER project (formerly the 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 5,800 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.

After completing facility upgrades and in-depth safety planning in 2022, OREM and its contractor, Isotek Systems, LLC (Isotek) conducted significant processing operations on the remaining inventory of ^{233}U stored at ORNL in 2023. The effort to process and dispose of the remaining high-dose ^{233}U is OREM's highest priority at ORNL. The current phase of the project, using hot cells, has enabled Isotek to enhance productivity by processing larger amounts of ^{233}U, as well as allowing employees to extract more medical isotopes. DOE and Isotek have partnered with TerraPower, a private nuclear innovation company, to extract ^{229}Th from the ^{233}U. TerraPower then uses the material to create the ^{225}Ac needed for targeted alpha therapy to treat diseases such as breast, prostate, colon, and neuroendocrine cancers, melanoma, and lymphoma.

UCOR continued to carry out characterization and deactivation of former reactors and isotope production facilities in 2023 and completed demolition and final packaging of the Low Intensity Test Reactor (Building 3005). At a group of buildings called "Isotope Row" that were constructed in the 1950s and early 1960s to process radioisotopes, deactivation was completed in Buildings 3030, 3031, and 3032, and significant progress was made in Buildings 3029, 3118, and 3033. Deactivation also proceeded at the Oak Ridge Graphite Reactor support facility buildings: Building 3003 deactivation was completed and significant decontamination was also completed in the 3002 filter house. This work focuses on asbestos, lead, and universal waste removal to eliminate high-risk contaminated structures and to create space for future research missions at ORNL.

Demonstrating 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. Implementing an environmental management system (EMS) allows environmental impacts to be systematically measured, managed, and controlled. 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.

Examples of environmental performance optimization during fiscal year (FY) 2023 include the following:

- The calculated energy use intensity was 237,514 Btu/gross square foot. This is a cumulative reduction of 34.7 percent since FY 2003 and a reduction of 1.43 percent from the FY 2021 baseline, but it is an increase of 1.41 percent from FY 2022.

Figure 1.7. Aerial view of the Oak Ridge National Laboratory

- The diversion rate for municipal solid waste at ORNL was 65.7 percent in FY 2023. Sustainable Campus Initiative staff plan to work with procurement staff to continue to employ terms and conditions within construction contracts to manage construction waste and recycling.
- UT-Battelle implemented 29 ongoing and new pollution prevention projects at ORNL during 2023, which eliminated more than 11.8 million kg of waste.
- Eighty percent of all ORNL vehicles are alternative fuel vehicles, with 88 percent of all replacements since FY 2020 being alternative fuel or electric vehicles. Ninety-three percent of light-duty vehicles operate on alternative fuels, exceeding DOE fleet management goals.

See Section 5.2.1.4 for additional details on ORNL environmental sustainability performance data for FY 2023.

1.4.2. Y-12 National Security Complex

The Y-12 Complex (shown in Figure 1.8) 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 ^{235}U 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 a leader in materials science and precision manufacturing. As the main storage facility for the nation's supply of enriched uranium, Y-12 serves as the nation's only source of enriched uranium nuclear weapons components and provides enriched uranium for the US Navy. 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 issued the Construction Execution/Management Plan, Outfall 200 Mercury Treatment Facility at the Y-12 National Security Complex, Oak Ridge, Tennessee (UCOR 2017). The Outfall 200 Mercury Treatment Facility is a vital piece of infrastructure that will open the door for demolition of Y-12's large, deteriorated, mercury-contaminated facilities and subsequent soil remediation by providing a mechanism to limit potential mercury releases into Upper East Fork Poplar Creek. The west end Y-12 storm drain system discharges to Upper East Fork Poplar Creek at Outfall 200, and mercury from historic operations is present at Outfall 200 where storm water enters Poplar Creek.

In FY 2023, progress continued with construction of the Outfall 200 Mercury Treatment Facility, DOE Environmental Management research in new remediation technologies to address mercury releases into the environment from past operations, and contracting for the first mercury remediation technology demonstration. In November 2023, OREM tasked UCOR to finish construction of the facility after the contract with APTIM-North Wind Construction expired. At the headworks site, the first lift of concrete walls is complete, and work continues with construction of a 500,000-gallon equalization tank. All underground piping has been installed and tested, and the painting of concrete surfaces and structural steel is progressing. The new facility is slated to be operational in 2025. A new Technology Demonstration Facility is being developed (formerly the Disposal Area Remedial Action, or DARA, facility) to carry out demonstration of proposed mercury treatment technologies.

Deactivation activities continued at three large former uranium processing facilities—Alpha-2, Alpha-4, and Beta-1—throughout FY 2023. At Alpha-2 (Building 9201-02), all deactivation activities were completed in the aboveground floors to prepare for demolition in 2024. Deactivation of the upper floors of Beta-1 (Building 9204-01) is expected to be completed in early FY 2024, and more than 1 million gallons of water have been removed, treated, and discharged. At Alpha-4 (Building 9201-04), workers began preparing the facility for deactivation, which is contaminated with elemental mercury. Workers have been sampling asbestos-containing material, performing utility isolations to bring the building to cold and dark status, and characterizing more than 400 legacy drums.

Y-12's environmental policy reflects a commitment to providing sound environmental stewardship practices through the implementation of its EMS. At the end of FY 2023, the Y-12 Complex had achieved nine of twelve established environmental targets driven by the EMS, and the remaining targets were carried into future years. Highlights of achievements include the following (further details and additional successes are presented in Chapter 4 of this report):

- **Clean air.** Y-12 completed a project to seal the Stack 11 basin and identified its improved mission operations and improvements to air emissions.
- **Energy efficiency.** Y-12 obtained a Utility Energy Savings Contract and funding approval

and also completed chiller plant improvements in three locations.

- **Hazardous materials.** A project to disposition and ship legacy mixed waste according to the site treatment plan continued, and five items were shipped in FY 2023 to meet plan milestones. Unneeded materials and equipment were dispositioned from Building 9998 and two tanker trailers in FY 2023. Y-12 improved waste characterization processes and implemented real-time radiography to improve control and management of low-level radioactive waste. Shipping resumed in February 2023.
- **Land, water, and natural resources.** Y-12 completed upgrading sanitary sewer networks in two areas as part of a project to protect the sanitary sewer lines from infill and infiltration. Y-12 also completed tank assessments on six aboveground inactive tanks and dikes in FY 2023.

Figure 1.8. Aerial view of the Y-12 National Security Complex

Y-12 continues to strive to reduce impacts on the environment through increased use of environmentally friendly products and processes and reductions in waste and emissions. In FY 2023, the Y-12 Complex implemented 105 pollution prevention initiatives that resulted in a reduction of more than 17.8 million lbs of waste and projected cost efficiencies of more than $3.4 million. Also in 2023, Y-12 diverted 56.8 percent of municipal waste (over 4.1 million lbs) and 32 percent of construction and demolition waste (over 13.2 million lbs) from landfill disposal through source reduction, reuse and recycle.

Compared to the FY 2003 baseline year, Y-12 has seen an energy intensity reduction of 50.38 percent as of FY 2023. During FY 2023, energy intensity was 207,645 Btu/gross square foot, a little over a half of a percentage above the prior year’s 205,343 Btu/gross square foot. After the COVID-19 pandemic, rates have been rising slightly, especially compared to pandemic years 2020 and 2021, as the site’s maximum teleworking policy expired and the site's population increased with newly hired employees. Continuing and new construction projects also contribute to the slightly increased energy intensity. Sustainability goals and performance status for the Y-12 Complex are listed in Chapter 4, Table 4.1.

1.4.3. East Tennessee Technology Park

ETTP (see Figure 1.9), 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.

ETTP completed and also made significant progress on several soil remedial actions in 2023 that help protect groundwater. The site is divided into two cleanup regions: Zone 1, a 1,300-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 from 6 to 38 acres.

EU-13 near Poplar Creek once housed many of the gaseous diffusion and uranium hexafluoride enrichment support facilities. Remedial action centered on soil and concrete associated with a radiologically contaminated release from a tie line adjacent to the former K-631 Surge and Waste Facility. Site restoration activities included placing clean fill topped with gravel to stabilize the site.

Remediation continued within EU-21, an area that is located in the middle of the K-25 footprint, which is part of the Manhattan Project National Historical Park. Since July 2021, more than 61,600 yd^3 of contaminated soil was removed and taken to the local disposal facilities. By the end of 2023, crews were excavating the final section of contaminated material.

At EU-16, soil remedial actions were completed at the former K-1064 Salvage Material Yard, the K-1064-H area, and a radiologically contaminated hot spot. Site restoration activities included placing soil fill and hydroseeding the area to stabilize the site. Crews also completed a remedial action to remove historical waste materials and contaminated soil at the former K-1064 North Trash Slope located along the bank of Poplar Creek. Site restoration activities included placing large stone (riprap) fill to stabilize the site.

At EU-17, a remedial action was completed to remove exposed transite pieces (material made using asbestos) that were historically disposed and located along the banks of Poplar Creek. Site restoration activities included placing large stone fill to stabilize the site.

A soil remedial action was completed in EU-38 at the former K-1417-B Drum Storage Yard. Site restoration activities included placing clean fill topped with gravel to stabilize the site. Crews also started a remedial action to remove sediment from sumps at the K-1417-A Concrete Block Casting Facility.

A remedial action was started at EU-39 to remove contaminated soil from the footprint of the K-1420 Equipment Decontamination Facilities.

In February 2023, UCOR completed a Time-Critical Removal Action of contaminated soils at the EU-19 mudflat. The mudflat was located at the end of a ditch that empties into Poplar Creek and had been impacted by past site operations. Sevenson Environmental Services teamed with UCOR to remove 8,000 yd^3 from a floating work platform positioned in the creek. An onshore 125-ton crane was used to move the containers of excavated soil from the work platform for characterization and disposal.

The UCOR EMS environmental sustainability principles incorporate the procurement of environmentally preferable products, recycling, and pollution prevention and waste minimization practices in work processes and activities at ETTP. UCOR recycles much of its universal waste, municipal solid waste, and scrap metal; reuses large amounts of construction and demolition debris; and encourages the reduction of waste wherever possible. In 2023, the Sustainability Leadership Award-winning projects saved more than 1,325 MTs of greenhouse gas emissions, 772,700 lbs of waste from landfills, and treated 16,029,000 gallons of wastewater. In addition to lessening the impact on the environment, these pollution prevention measures also saved approximately $7.8 million. UCOR's pollution prevention and waste minimization practices at ETTP are detailed further in Section 3.2.1.

OREM continued to see significant momentum in the Reindustrialization Program at ETTP. The former government-owned uranium enrichment complex is being turned into a multiuse industrial park that includes national historic preservation and conservation and greenspace areas. Accounting for committed land transfers to date, only a few hundred acres of the approximately 2,200 original acres remain for final transfer.

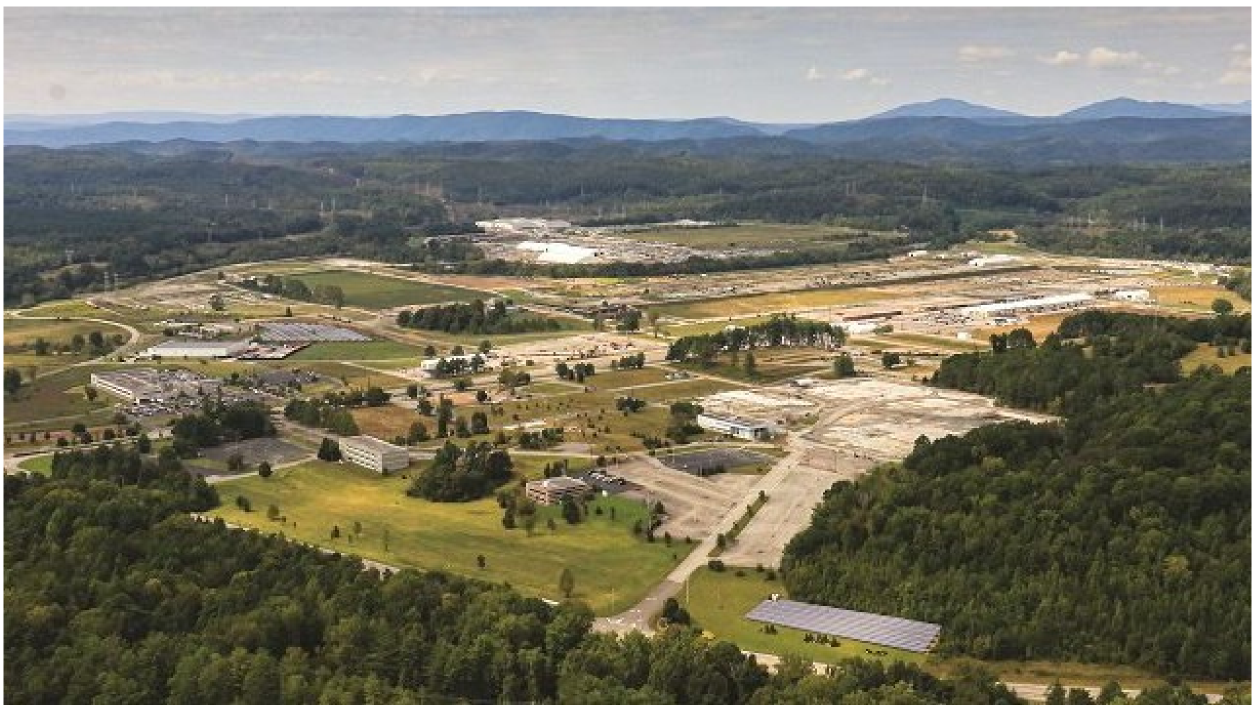


Figure 1.9. Aerial view of East Tennessee Technology Park

During 2023, the Reindustrialization team advanced the regulatory review of almost 500 acres of remediated land in transfer packages. This land includes the former K-1037 Steam Plant and Toxic Substances Control Act Incinerator package, the former Powerhouse Area, the former K-732 Switchyard, and multiple parcels intended for development of a new municipal airport. Upon regulatory approval, transfer packages are submitted for department and congressional approvals, which finalizes the process. Clean energy and new nuclear businesses currently developing in these areas and the Oak Ridge Community include TRISO-X, Ultra Safe Nuclear Corporation, Kairos Power, and the Tennessee Valley Authority.

1.4.4. Environmental Management Waste Management Facility

The EMWMF (shown in Figure 1.10) is located in eastern Bear Creek Valley near the Y-12 Complex and is managed by UCOR. The 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.

The 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, the EMWMF operates a leachate collection system. In 2023, the facility collected, analyzed, and disposed of approximately 3.53 million gallons of leachate. The leachate is treated at the ORNL Liquids and Gaseous treatment facility, which is also operated by UCOR (UCOR 2023).

Figure 1.10. Aerial view of the Environmental Management Waste Management Facility

In FY 2023, EMWMF received 5,211 waste shipments from cleanup projects at ETTP, ORNL, and Y-12, plus 84 clean fill shipments for the enhanced operational cover expansion and constructing access roads and dump ramps. The EMWMF landfill has a design capacity of 2.331 million yd^3 and is now over 85 percent filled. Planning continued in FY 2023 for another disposal facility, the Environmental Management Disposal Facility (EMDF), to provide the capacity required to complete Oak Ridge's cleanup mission.

A groundbreaking ceremony for the EMDF was held on August 2, 2023. OREM continues to work with EPA and TDEC on regulatory documents for the EMDF landfill. The Early Site Preparation Remedial Design Report/Remedial Action Work Plan was approved in June 2023, and the Groundwater Field Demonstration Remedial Design Work Plan/Remedial Action Work Plan was prepared and reviewed in 2023 with approval in October 2023 (DOE 2023b, DOE 2023c).

1.4.5. Oak Ridge Environmental Research Park

DOE established the Oak Ridge National Environmental Research Park (see Figure 1.11) 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 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.

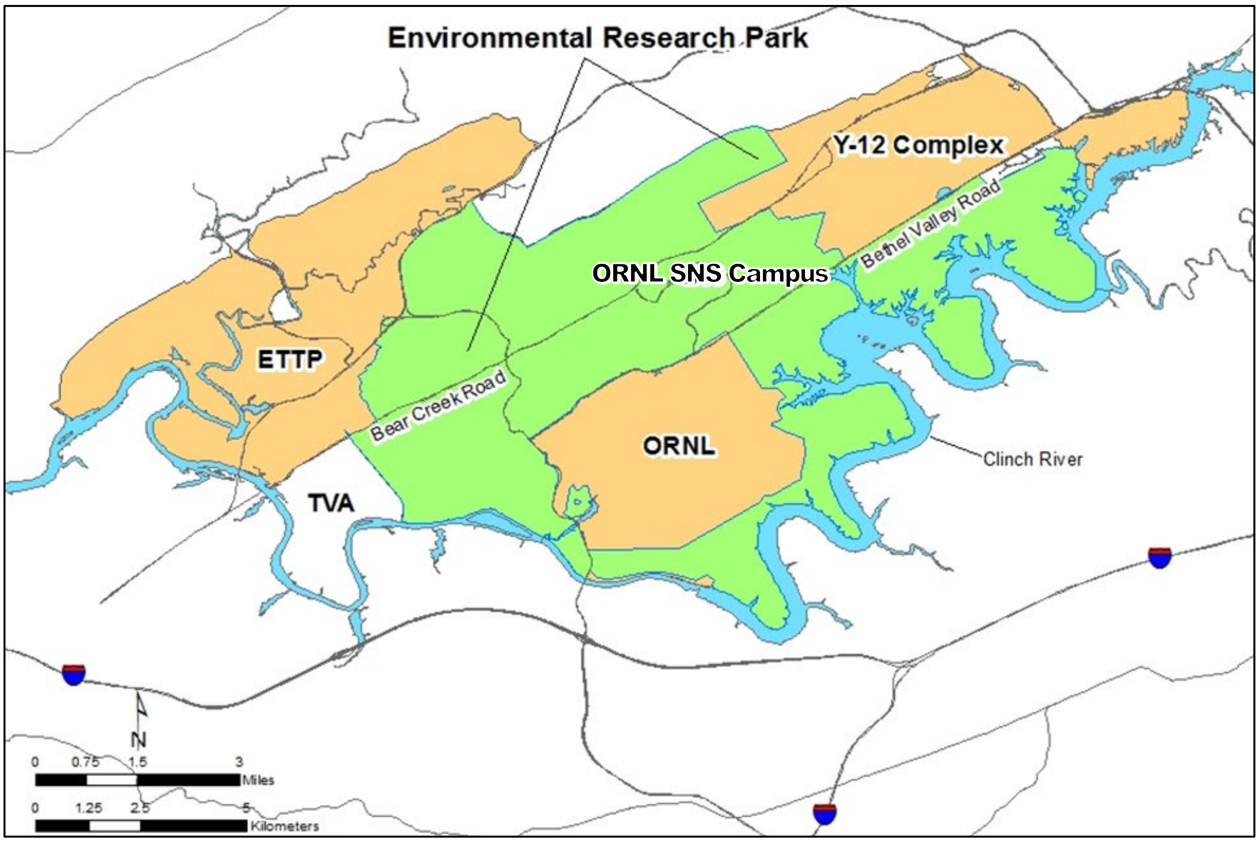


Figure 1.11. Location of the Oak Ridge National Environmental Research Park

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 measure environmental factors precisely and accurately for extended periods. Because the park is under the jurisdiction of the federal government, public access is restricted, and therefore experimental sites and associated equipment are not disturbed. 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

The Oak Ridge Institute for Science and Education (ORISE) is managed for DOE by Oak Ridge Associated Universities and is located 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. 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 United States 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.

In 2023, ORISE's Radiation Emergency Assistance Center/Training Site (REAC/TS) coordinated with the North Atlantic Treaty Organization (NATO) to host radiation emergency training events in Oak Ridge. ORISE also hosted its first annual ORISE Postdoctoral Mini Symposium open to members of the ORISE STEM Workforce Development community, which attracted 487 attendees over five separate professional development sessions (ORAU 2024).

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, or OST.

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

1.4.8. Transuranic Waste Processing Center

The TWPC is located on an approximately 10.5-hectare (26-acre) tract of land in the Melton Valley area of ORNL about 120 feet west of the existing Melton Valley Storage Tanks, and it is managed by UCOR. The TWPC's mission is to receive transuranic waste for processing, treatment, repackaging, and shipment to designated facilities for final disposal.

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. As of 2023, the TWPC has processed approximately 99 percent of the contact-handled transuranic waste and 98 percent of the remote-handled transuranic waste, and it has also completed regulatory milestones in the *Site Treatment Plan for Mixed Wastes on the US Department of Energy Oak Ridge Reservation* (TDEC 2020) on schedule.

Figure 1.12. Transuranic Waste Processing Center

Key progress for the project during 2023 included the following actions (UCOR 2023):

- TWPC completed critical actions associated with readiness preparation to commission new waste processing capabilities at TWPC for high-activity oxide wastes and wastes requiring special treatment to meet Waste Isolation Pilot Plant acceptance criteria. TWPC continued processing the legacy Nuclear Fuel Services waste (1.9 m^3) and by-product wastes from transuranic waste processing (12.8 m^3).
- TWPC continued certification and shipment of 159 m^3 of transuranic waste to the Waste Isolation Pilot Plant, 72.5 m^3 of mixed low-level waste to treatment and disposal, and 1.8 m^3 of hazardous waste to treatment and disposal, eliminating 855 containers of the stored inventory.

1.5. References

Birdwell 2011. Birdwell, Kevin Ray, "Wind Regimes in Complex Terrain of the Great Valley of Eastern Tennessee." PhD dissertation, University of Tennessee, May.

Broad 2007. Broad, William J, *Why They Called It the Manhattan Project*. New York Times, October 30, 2007. Retrieved May 25, 2024, from https://www.nytimes.com/2007/10/30/science/30manh.html.

Census Bureau 2024a. *Metropolitan and Micropolitan Statistical Areas Population. Totals: 2020-2023*. US Census Bureau, Washington, DC. Retrieved July 20, 2024, from https://www.census.gov/data/tables/time-series/demo/popest/2020s-total-metro-and-micro-statistical-areas.html.

Census Bureau 2024b. *County Population Totals and Components of Change: 2020-2023*. US Census Bureau, Washington, DC. Retrieved July 20, 2024, from https://www.census.gov/data/tables/time-series/demo/popest/2020s-counties-total.html.

Census Bureau 2024c. *City and Town Population Totals: 2020-2023*. US Census Bureau, Washington, DC. Retrieved July 20, 2024, from https://www.census.gov/data/tables/time-series/demo/popest/2020s-total-cities-and-towns.html.

CERCLA 1980. *Comprehensive Environmental Response, Compensation, and Liability Act*. Title 42 US Code Chapter 103.

CWA 1972. *Clean Water Act.* Title 33 US Code §1251 et seq.

DOE 2001. *Cultural Resource Management Plan, DOE Oak Ridge Reservation, Anderson and Roane Counties, Tennessee*. DOE/ORO-2085, US Department of Energy Oak Ridge Operations Office, Oak Ridge, Tennessee, July.

DOE 2012. *Environment, Safety, and Health Reporting.* DOE Order 231.1B, June 27, 2011, US Department of Energy, Washington, DC.

DOE-DOI 2015. "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". Washington, DC, November 10, 2015.

DOE-FWS 2013. "Memorandum of Understanding between the United States Department of Energy and the United States Fish and Wildlife Service Regarding Implementation of Executive Order 13186, 'Responsibilities of Federal Agencies to Protect Migratory Birds'." US Department of Energy and US Fish and Wildlife Service, Washington, DC. Retrieved May 25, 2024, from https://www.energy.gov/sites/prod/files/2013/10/f3/Final%20DOE-FWS%20Migratory%20Bird%20MOU.pdf.

DOE 2023a. *2023 Remediation Effectiveness Report for the US Department of Energy Oak Ridge Site, Oak Ridge, Tennessee, Data and Evaluations*. DOE/OR/01-2938&ID1, March 2023, US Department of Energy, Oak Ridge Office, Oak Ridge, Tennessee.

DOE 2023b. *Remedial Design Report/Remedial Action Work Plan for the Environmental Management Disposal Facility, Oak Ridge, Tennessee: Early Site Preparation Activities*. DOE/OR/01-2934&D2, March 2023, US Department of Energy, Oak Ridge Office, Oak Ridge, Tennessee

DOE 2023c. *Remedial Design Work Plan/Remedial Action Work Plan for the Groundwater Field Demonstration at the Environmental Management Disposal Facility, Oak Ridge, Tennessee*. DOE/OR/01-2948&D1, October 2023, US Department of Energy, Oak Ridge Office, Oak Ridge, Tennessee.

East Tennessee Economic Council. *US Department of Energy FY 2020 Economic Impact in Tennessee.* Oak Ridge, Tennessee.

EO 2001. *Responsibilities of Federal Agencies to Protect Migratory Birds*. Issued January 10, 2001.

EPA 2023. *Tennessee Nonattainment/ Maintenance Status for Each County by Year for All Criteria Pollutants.* April 30, 2024. Retrieved May 25, 2024, from https://www3.epa.gov/airquality/greenbook/anayo_tn.html.

ESA 1973. *Endangered Species Act*. Title 16 US Code Chapter 35 §1531 et seq.

FWS 2011. *Birds of Management Concern and Focal Species*. US Department of the Interior, US Fish and Wildlife Service, Migratory Bird Program, Falls Church, Virginia. Retrieved May 25, 2024, from https://www.fws.gov/sites/default/files/documents/Birds-of-Management-Concern-and-Focal-Species.2011_2.pdf.

FWS 2021. *Birds of Conservation Concern 2021*. US Department of the Interior, US Fish and Wildlife Service, Migratory Birds, Falls Church, Virginia. Retrieved May 25, 2024, from https://www.fws.gov/sites/default/files/documents/birds-of-conservation-concern-2021.pdf.

Hogan 2021. Hogan, Colbi W, "Displaced to Save the World: Strategies for Using Historic Preservation and Education to Interpret Pre-1942 Communities in Oak Ridge, Tennessee." PhD dissertation, Middle Tennessee State University, August.

Johnson 2018. Johnson, Charles W. (March 1, 2018). *Oak Ridge*. The Tennessee Historical Society. Retrieved May 26, 2024, from https://tennesseeencyclopedia.net/entries/oak-ridge.

MBTA 1918. *Migratory Bird Treaty Act.* Title 16 US Code §§703–712.

McCracken et al. 2015. McCracken, M.K., N.R. Giffen, A.M. Haines, and J.W. Evans, *Bat Species Distribution on the Oak Ridge Reservation.* ORNL/TM-2015/248, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Nature Conservancy 1995. *The Oak Ridge Reservation, Biodiversity, and the Common Ground Process Final Report*. Prepared for DOE under contract DE-AC05-840R21400, October. Retrieved May 26, 2024, from https://www.nerp.ornl.gov/wp-content/uploads/2018/07/orr_tnc_1995.pdf.

NatureServe 2024. NatureServe Network Biodiversity Location Data accessed through NatureServe Explorer [web application]. NatureServe, Arlington, Virginia. Retrieved May 25, 2024, from https://explorer.natureserve.org/.

NDAA 2014. National Defense Authorization Act of 2015. HR 3979, SEC. 3039.

NEPA 1969. *National Environmental Policy*. Title 42, US Code Chapter 55.

NHPA 1966. *National Historic Preservation Act*. Public Law 89-665; Title 54, US Code 300101 et seq.

Olwell 1999. *Help Wanted for Secret City: Recruiting Workers for the Manhattan Project at Oak Ridge, Tennessee, 1942–1946*. Tennessee Historical Quarterly, Spring 1999, 58(1): 52–69.

ORAU 2024. *ORAU Story 2023.* 2023 Annual Report for Oak Ridge Associated Universities, 100 ORAU Way, Oak Ridge, Tennessee 37830. Retrieved July 13, 2024, from https://www.orau.org/news/annual-report.html.

Parr and Hughes 2006. Parr, P.D. and J.F. Hughes, *Oak Ridge Reservation Physical Characteristics and Natural Resources.* ORNL/TM-2006/110, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

PIF 2024. Avian Conservation Assessment Database Scores. Bird Conservancy of the Rockies. Database updated Spring 2024. Retrieved May 25, 2024, from https://pif.birdconservancy.org/avian-conservation-assessment-database-scores/.

Reed 2014. Reed, Bruce Cameron. *The History and Science of the Manhattan Project, Second Edition*. Springer-Verlag, New York.

Rosensteel 1996. Rosensteel, Barbara A., *Wetland Survey of the X-10 Bethel Valley and Melton Valley Groundwater Operable Units at Oak Ridge National Laboratory, Oak Ridge, Tennessee*. ORNL/ER 350, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Rosensteel 1997. Rosensteel, Barbara A., *Wetland Survey of Selected Areas in the Oak Ridge Y-12 Plant Area of Responsibility, Oak Ridge, Tennessee*. Y/ER-279, Y-12 National Security Complex, Oak Ridge, Tennessee.

Rosensteel and Trettin 1993. Rosensteel, Barbara A. and Carl C. Trettin, *Identification and Characterization of Wetlands in the Bear Creek Watershed.* Y/TS-1016, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Roy et al. 2014. Roy, W.K., N.R. Giffen, M.C. Wade, A.M. Haines, J.W. Evans, and R.T. Jett, *Oak Ridge Reservation Bird Records and Population Trends*. ORNL/TM-2014/109, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Souza 2001. Souza, Peter A., *Cultural Resource Management Plan: Department of Energy Oak Ridge Operations Office, Anderson and Roane Counties, Tennessee*. DOE/ORO 2085, US Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tennessee, July 2001.

TDEC 2020. *Site Treatment Plan for Mixed Wastes on the US Department of Energy Oak Ridge Reservation*. TDEC-VER.24.2, Tennessee Department of Environment and Conservation, Nashville, Tennessee, May 13.

TDEC 2021. *Tennessee Natural Heritage Program Rare Plant List*. Tennessee Department of Environment and Conservation, Division of Natural Areas, Nashville, Tennessee.

TDEC 2024a. *Rules and Regulations for In Need Management, Threatened, and Endangered Species.* Chapter 1660-01-32, Rules of the Tennessee Wildlife Resources Agency, Biodiversity, Tennessee Department of Environment and Conservation, Nashville, Tennessee, May 14, 2024. Retrieved May 25, 2024, from https://casetext.com/regulation/tennessee-administrative-code/title-1660-tennessee-wildlife-resource-agency/subtitle-1660-01-wildlife-resources/chapter-1660-01-32-rules-and-regulations-for-in-need-of-management-threatened-and-endangered-species/.

TDEC 2024b. *Rare Species Dataviewer*. Tennessee Department of Environment and Conservation, Nashville, Tennessee. Retrieved May 25, 2024, from https://dataviewers.tdec.tn.gov/dataviewers/f?p=9014:3:118904174220701.

TVA 2024. Tennessee Valley Authority "2023 was the first year since 2016 the 41,000 sq-mile Tennessee River basin received below-normal rainfall and only the second year since 2012." *Linkedin*. January 5, 2024. Retrieved May 18, 2024, from https://www.linkedin.com/posts/tva_2023-was-the-first-year-since-2016-the-41000-activity-7149058276331028481-YxJ5.

TWRA 2024. Tennessee Wildlife Resources Agency. Retrieved May 26, 2024, from http://www.tn.gov/twra.

UCOR 2017. *Construction Execution/Management Plan, Outfall 200 Mercury Treatment Facility at the Y-12 National Security Complex, Oak Ridge, Tennessee*. UCOR-4972/R3, UCOR, Oak Ridge, Tennessee, October 15.

UCOR 2023. *2023 Cleanup Progress: Annual Report to the Oak Ridge Regional Community, Oak Ridge, Tennessee*. OREM- 23-7637, UCOR, Oak Ridge, Tennessee.

Zurawski 1978. Zurawski, A., "Summary Appraisals of the Nation's Ground-Water Resources–Tennessee Region." US Geological Survey Professional Paper 813-L.

Migratory birds known to nest on the Oak Ridge Reservation, such as this summer tanager, are covered by the Migratory Bird Treaty Act. DOE and its partners follow a wildlife management plan to protect migratory birds and their habitats.

2

Compliance Summary and Community Involvement

Activities conducted on ORR must conform to environmental standards established by federal and state statutes and regulations, DOE orders, contract-based standards, and compliance and settlement agreements where applicable. 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 enforce compliance with applicable regulations.

The following sections summarize the major environmental statutes and their 2023 status for DOE operations on ORR. Note that the DOE Reindustrialization Program, typically in coordination with the Community Reuse Organization of East Tennessee, has leased several facilities at ETTP and the Oak Ridge Science and Technology Park at ORNL to private entities over the past several years. This report does not discuss the compliance status of these lessee operations.

2.1. Laws and Regulations

Table 2.1 is a summary of the principal environmental standards applicable to DOE activities on ORR, their 2023 status, and the sections in this report that provide more detailed information.

2.2. External Oversight and Assessments

Table 2.2 lists the inspections of ORR environmental activities conducted by regulatory agencies for each of the major ORR sites (ETTP, Y-12, and ORNL) during 2023. This table does not include internal DOE or DOE contractor assessments, audits, or evaluations.

2.3. Reporting of Oak Ridge Reservation Spills and Releases

Substances defined as hazardous under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) are considered harmful to human health and the environment. Because 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. Neither ETTP, Y-12, nor ORNL had any spills exceeding CERCLA reportable quantity limits.

Certain releases 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]). Neither ETTP, Y-12, nor ORNL had any reportable releases of oil to area waterways.

Neither ETTP, Y-12, nor ORNL had any reportable releases of extremely hazardous substances, as defined by the Emergency Planning and Community Right-to-Know Act, in 2023. See Sections 3.3.12, 4.3.10, and 5.3.10 of this report for more information.

2.4. Notices of Violations and Penalties

ETTP had no notices of environmental violations or penalties in 2023.

In 2023, compliance with the Y-12 National Pollutant Discharge Elimination System (NPDES) water discharge permit limits was nearly 100 percent; there were no Clean Air Act violations or exceedances. Personnel from the TDEC Division of Solid Waste Management performed an unannounced Resource Conservation and Recovery Act hazardous waste compliance inspection of Y-12 from March 6–7, 2023. The inspections covered waste storage areas and records reviews. Two issues were identified: storage of three bags of spent aerosol cans for more than one year and one aerosol can puncturing device that was not closed securely. Immediate corrective actions were taken where possible. The issues and their causes are being reviewed to prevent recurrence.

There were no notices of environmental violations or penalties received by UT-Battelle, LLC (the ORNL managing contractor) or by other contractors (Isotek and UCOR) who conducted activities at ORNL in 2023. ORNL wastewater treatment facilities achieved a numeric permit compliance rate of 99.9 percent in 2023. One *Escherichia coliform* exceedance occurred in June 2023 at X01 (Sewage Treatment Plant) due to an operational issue with the disinfection system ozone diffuser. The diffuser has since been fixed.

2.5. Community Involvement and Resources

DOE and its contractors provided or supported numerous community involvement activities in 2023 that addressed a range of subjects. These included American Museum of Science and Energy (AMSE) community meetings hosted by the City of Oak Ridge, ETTP airport public meetings, AMSE public bus tours of ORR, and public comment periods for environmental permitting and groundwater cleanup.

During 2023, DOE and its contractors continued long-term partnerships with organizations such as East Tennessee Children's Hospital, Foothills Land Conservancy, Second Harvest, Emory Valley Center, Legacy Parks, Methodist Medical Center, Junior Achievement, Roane County NAACP Freedom Fund, Boys and Girls Clubs, Centro Hispano, YWCA of East Tennessee, multiple Tennessee First Robotics Teams, the University of Tennessee Nuclear Engineering Department, and Roane State Community College. DOE contractors and employees donated over $1.5 million to these and many other charities and programs in fiscal year (FY) 2023 (UCOR 2023, Y-12 2023, Philanthropy News Digest 2024).

2.5.1. Environmental Justice

As part of ORR's evolving mission, DOE and its contractors integrate environmental justice elements contained in executive orders and other guidance into all programs and activities through a variety of initiatives. Sites promote career awareness and development to attract a diverse workforce as an investment in the future of ORR's mission and activities. Outreach to underserved communities through ORR partnerships, programs, and activities ensures they have equal representation in environmental decision-making.

2.5.2. 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 on environmental policy and DOE's commitment to providing sound environmental stewardship practices and keeping the public informed is available to the public through sponsored forums and public documents such as this report. Public comments solicited in 2023 included the proposed plan for an interim Record of Decision for groundwater in the Main Plant Area at ETTP and the Hazardous Waste Management Corrective Action Permit reissued to the Y-12 National Security Complex.

2.5.3. 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. ORSSAB resumed in-person/virtual hybrid meetings in 2023 after conducting meetings virtually only during 2020–2022 due to COVID-19. 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 https://www.energy.gov/orem/oak-ridge-site-specific-advisory-board. 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. (For more information, call 865-241-4583 or 865-241-4584.)

2.5.4. 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 45,000 documents describing environmental activities in Oak Ridge.

The center is open Monday through Friday from 8 a.m. to 5 p.m. and can be reached by phone at 865-241-4780, or toll-free at 1-800-382-6938 (option 6). 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.

2.5.5. Other Resources

- Agency for Toxic Substances and Disease Registry: 1-800-232-4636, https://www.atsdr.cdc.gov
- DOE main website: https://www.energy.gov
- DOE Oak Ridge Public Affairs Office: 865-576-0885
- EPA Region 4: 1-800-241-1754, https://www.epa.gov/aboutepa/about-epa-region-4-southeast
- TDEC, DOE Oversight Division: 865-481-0995, https://www.tn.gov/environment/program-areas/rem-remediation/orr.html
- ETTP: https://www.energy.gov/orem/cleanup-sites/east-tennessee-technology-park
- Y-12 National Security Complex: https://www.y12.doe.gov/
- ORNL: https://www.ornl.gov/

Table 2.1. Applicable environmental laws and regulations and 2023 status

Regulatory program description	2023 status	Report sections
The Clean Air Act and State of Tennessee rules regulate the release of air pollutants through permits and quality limits. Emissions of radionuclides are regulated by EPA via National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities. Greenhouse gas (GHG) emissions inventory tracking and reporting are regulated by EPA and by DOE.	In 2023 all activities on ORR were conducted in accordance with Clean Air Act requirements.	3.3.4 4.3.4 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 CERCLA notices of violations were issued for ORR actions during 2023.	3.3.9 4.3.8, 4.3.12 5.3.8
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. In 2023, ETTP achieved a compliance rate of 100% with NPDES permit limits. The percentage of compliance with permit discharge limits for 2023 at Y-12 was nearly 100 percent. ORNL wastewater treatment facilities achieved a numeric permit compliance rate of 99.9 percent in 2023. One *Escherichia coliform* exceedance occurred at ORNL in June 2023 at X01 (Sewage Treatment Plant) due to an operational issue with the disinfection system ozone diffuser. The diffuser has since been fixed. See Appendix D.	3.3.5 4.3.5 5.3.4
The Energy Independence and Security Act (EISA) Section 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 (SSPs) and associated reporting provide data on sustainability projects and support EISA Section 438 compliance.	4.2.6 5.2.1.4, 5.2.1.5

Table 2.1. Applicable environmental laws and regulations and 2023 status (continued)

Regulatory program description	2023 status	Report sections
The Emergency Planning and Community Right-to-Know Act (EPCRA), also referred to as the Superfund Amendments and Reauthorization Act Title III, requires reporting of emergency planning information, hazardous chemical inventories, and environmental releases of certain toxic chemicals to federal, state, and local authorities.	In 2023, DOE facilities on ORR operated in accordance with emergency planning and reporting requirements as defined by EPCRA. ETTP had no reportable releases of hazardous or extremely hazardous substances. Y-12 and ORNL had no reportable releases of extremely hazardous substances. In 2023, Y-12 reported 43 chemicals that were over Section 312 inventory thresholds. ORNL exceeded the Section 3.13 reporting threshold and reported on the manufacture of nitrate compounds as by-products of on-site sewage treatment.	3.3.12 4.3.10 5.3.10
The National Environmental Policy 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 certain NEPA documents.	During 2023, 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. In 2023, 50 NEPA reviews were conducted at Y-12, with 10 of those being federal CX documents requiring approval by the NNSA NEPA Compliance Officer. UT-Battelle, LLC at ORNL conducted 65 reviews of activities that were approved under general actions or generic CX determinations.	3.3.2 4.3.2 5.3.2
The National Historic Preservation Act (NHPA) 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 identify methods to avoid, mitigate, or minimize adverse effects or harm. During 2023, activities on ORR were conducted in compliance with NHPA requirements.	3.3.3 4.3.3 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 to facilitate compliance with TDEC and US Army Corps of Engineers requirements. Wetland protection on ORR is conducted according to 10 *Code of Federal Regulations* 1022 and Executive Order (EO) 11990, *Protection of Wetlands*. No new wetlands were delineated at ETTP or Y-12 in 2023. At ORNL, four wetlands were delineated in 2023.	1.3.6.1 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. No notices of violation were issued for ETTP or ORNL in 2023. At Y-12, two issues were identified: storage of three bags of spent aerosol cans for more than one year and one aerosol can puncturing device that was not closed securely. Immediate corrective actions were taken where possible. The issues and their causes are being reviewed to prevent recurrence.	3.3.8 4.3.7, 4.3.13 5.3.6, 5.3.7

Table 2.1. Applicable environmental laws and regulations and 2023 status (continued)

Regulatory program description	2023 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 2023 for residual chlorine levels, bacterial constituents, and disinfectant by-products in ORR's water system were all within acceptable limits.	3.3.7 4.3.6 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 one PCB waste storage area in 2023 for nonradioactive PCB waste (primarily ballasts). In 2023, UT-Battelle, LLC operated five PCB storage areas. Four were located at ORNL, and one was located at the Y-12 Complex. There were no other PCB storage areas at 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.	3.3.11 4.3.9 5.3.9
The Bald and Golden Eagle Protection Act protects bald and golden eagles by prohibiting, except under 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. Three active bald eagle nests on ORR are protected in accordance with this act. Eaglets have been successfully fledged from the 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, 1.3.6.3
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 2023 status (continued)

Regulatory program description	2023 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 *2023 Oak Ridge Reservation Annual Site Environmental Report* summarizes ORR environmental activities during 2023 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.	4.3.14, 4.7 4.8.2 5.3.13
DOE Order 436.1A, *Department Sustainability* (April 2023), replaced DOE Order 436.1 (May 2011) and 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 436.1A includes a seven-page contractor requirements document (CRD) that is significantly more detailed that the one-page CRD associated with DOE Order 436.1.	DOE contractors on ORR have developed SSPs 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 5.2.1.4
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 2023, 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 was 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. The assessment estimated the maximum 2023 dose to a hypothetically exposed member of the public from all ORR potential exposure pathways combined would be about 3 mrem. Therefore, the 2023 maximum effective dose was about 3% of the 100 mrem annual 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 2023. No limits were exceeded in 2023.	3.2.6 4.3.4, 4.3.14 5.3.13, 5.5, 5.6.2 Chapter 6 Chapter 7

Table 2.1. Applicable environmental laws and regulations and 2023 status (continued)

Regulatory program description	2023 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 2023 dose to a hypothetical exposed member of the public from all ORR potential exposure pathways combined would be about 3 mrem.	Chapter 7
DOE Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, focuses federal attention on the environmental and human health effects of federal actions on minority and low-income populations with the goal of achieving environmental protection for all communities.	In keeping with a presidential memorandum accompanying EO 12898, NEPA evaluations for proposed actions across ORR include an analysis of environmental effects, including human health-related, economic, and social effects on minority and low-income communities.	5.2.1.4
Executive Order 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
Executive Order 13834, *Efficient Federal Operations*, directs federal agencies to manage their buildings, vehicles, and overall operations to optimize energy and environmental performance, reduce waste, and cut costs.	EO 13834 superseded EO 13693. Progress toward meeting the requirements of the EO and achieving DOE sustainability goals is summarized in this report. ORNL, Y-12, and ETTP all have sustainability processes and management systems to comply with the EO and subsequent federal instructions for implementing the EO.	3.2.1 4.2.6.3 5.2.1.4
Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad,* requires agencies to develop action plans for climate change adaptation and increasing resilience at facilities and operations, and has provisions for sustainably rebuilding infrastructure, advancing conservation, encouraging sustainable agriculture and promoting reforestation.	EO 14008 is incorporated into DOE O 436.1A along with EO 14057 and EO 14072, described below. This EO has provisions for achieving environmental justice through investment in marginalized communities through workforce development programs. UCOR aspires to attract and maintain a diverse workforce by implementing programs to increase awareness and access to environmental management careers in minority and underserved communities. ORNL has incorporated elements of EO 14008 in its SSP, updating its vulnerability assessment and resilience plan including actionable resiliency solutions in 2023.	3.2.1.1, 3.3.12.3 4.2.4.3 5.2.1.4

Table 2.1. Applicable environmental laws and regulations and 2023 status (continued)

Regulatory program description	2023 status	Report sections
Executive Order 14057, *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability*, includes setting Federal goals for use of carbon pollution-free electricity (CFE), zero-emission vehicle acquisitions, GHG reduction, and training a climate- and sustainability-focused Federal workforce.	EO 14057 identifies current federal-level sustainability goals including achieving a CFE sector by 2035 and a net-zero emissions economy no later than 2050. UCOR's Zero-Waste program in support of UCOR's sustainability programs provides end-use avenues for products that are no longer useful to the current user. ORNL's SSP incorporates EO 14057 to reduce GHG emissions significantly by 2030.	3.2.1.1 4.2.6.4 5.2.1.4
Executive Order 14072, *Strengthening the Nation's Forests, Communities and Local Economies*, calls on agencies to deploy nature-based solutions to tackle climate change and enhance resilience.	EO 14072, incorporated into DOE O 436.1A, promotes management actions to include pursuit of science-based, sustainable forest and land management and conservation of America's mature and old-growth forests on federal lands to advance nature-based solutions addressing climate change. In 2023, ORNL completed an impact assessment on DOE Order 436.1A and developed an implementation plan for contractor compliance that includes action items for various organizations throughout the lab.	5.2.1.4

Acronyms:

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CFE = carbon pollution-free electricity
CX = categorical exclusion
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
EPCRA = Emergency Planning and Community Right-to-Know Act
ETTP = East Tennessee Technology Park
GHG = greenhouse gas
mrem = millirem
NEPA = National Environmental Policy Act
NHPA = National Historical Preservation 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
SSP = Site Sustainability Plan
TDEC = Tennessee Department of Environment and Conservation
UCOR = United Cleanup Oak Ridge LLC
Y-12 or Y-12 Complex = Y-12 National Security Complex

Table 2.2. Summary of external regulatory environmental audits, inspections, and assessments at ORR, 2023

Date	Reviewer	Subject	Issues
		East Tennessee Technology Park	
July 18	TDEC/EPA	TDEC/EPA RCRA CEI	0
November 9	EPA	ETTP Site Tour	0
		Y-12 National Security Complex	
February 23	TDEC	Quarterly ORR Landfill Inspection ILF-V and CDL-VII	0
February 23	TDEC	Quarterly ORR Landfill Inspection ILF-IV	0
March 7	TDEC	Annual RCRA Hazardous Waste Compliance Inspection (ORR Landfill)	2
March 24	TDEC	Air Quality Inspection	0
May 11	TDEC	ILF-V Area 5 Construction Inspection	0
May 30	TDEC	ILF-V Area 5 Construction Inspection	0
May 31	TDEC	Quarterly ORR Landfill Inspection ILF-II, ILF-V, and CDL-VII	0
June 29	TDEC	Quarterly ORR Landfill Inspection ILF-IV	0
July 10	TDEC	ILF-V Area 5 Construction Inspection	0
August 21	TDEC	ILF-V Area 5 Construction Inspection	0
August 29	TDEC	ILF-V Area 5 Construction Inspection	0
August 31	TDEC	Quarterly ORR Landfill Inspection of ILF-V and CDL-VII and Second Semi-Annual Inspection of Closed ILF-II	0
September 6	TDEC	NPDES Compliance Evaluation Inspection	0
September 7	TDEC	Quarterly ORR Landfill Inspection ILF-IV	0
September 5	TDEC	ILF-V Area 5 Construction Inspection	0
November 22	TDEC	Quarterly ORR Landfill Inspection of ILF-IV, V, and CDL-VII	0
		Oak Ridge National Laboratory *(including UT-Battelle, LLC; UCOR; and Isotek Systems, LLC activities)*	
March 8–9	TDEC	Hazardous Waste Compliance Evaluation Inspection (including UT-Battelle, Transuranic Waste Processing Center, and UCOR)	0
March 9	City of Oak Ridge	CFTF Wastewater Pretreatment Permit Inspection	0
June 7	KCDAQM	Hardin Valley Campus Clean Air Act Inspection	0
June 21–23	TDEC	Biennial NPDES Permit Inspection	0
July 27	City of Oak Ridge	CFTF Wastewater Pretreatment Permit Inspection	0
August 9	TDEC	TWPC Clean Air Act Inspection	0
August 10	TDEC	CFTF Clean Air Act Inspection	0

Acronyms:

CDL = Construction/Demolition Landfill
CEI = Compliance Evaluation Inspection
CFTF = Carbon Fiber Technology Facility
CWA = Clean Water Act
EPA = US Environmental Protection Agency
ETTP = East Tennessee Technology Park
ILF = Industrial Landfill
KCDAQM = Knox County Department of Air Quality Management
NPDES = National Pollutant Discharge Elimination System
ORR = Oak Ridge Reservation
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation
TWPC = Transuranic Waste Processing Center
UCOR = United Cleanup Oak Ridge LLC

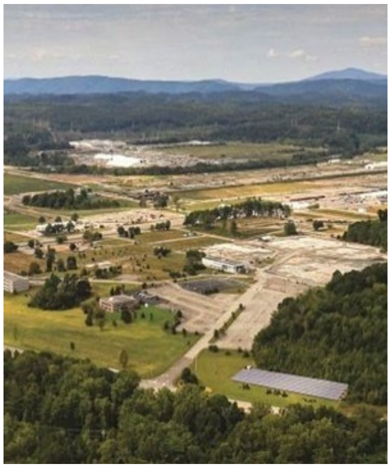
2.6. References

DOE 2023. *2023 Remediation Effectiveness Report for the US Department of Energy Oak Ridge Reservation, Oak Ridge, Tennessee, Data and Evaluations.* DOE/OR/01-2938&D1, US Department of Energy, Oak Ridge, Tennessee, March.

Philanthropy News Digest 2024. "Employee-led giving at ORNL nets $967,871 for area nonprofits." January 21, 2024. Retrieved May 25, 2024, from https://philanthropynewsdigest.org/news/other-sources/article/?id=14586057&title=Employee-led-giving-at-ORNL-nets-$967,871-for-area-nonprofits.

UCOR 2023. "UCOR named 2023 Outstanding Corporate Philanthropist." UCOR NR 2023-19, November 6, 2023. Retrieved May 25, 2024, from https://ucor.com/wp-content/uploads/2023/11/UCOR_NR_2023-19.pdf.

Y-12 2023. "CNS awards $180,000 in grants to community nonprofits." November 8, 2023. Retrieved May 25, 2024, from https://www.y12.doe.gov/news/press-releases/cns-awards-180000-grants-community-nonprofits.



The East Tennessee Technology Park has changed greatly in recent years as remediation projects have been completed.

3

East Tennessee Technology Park

East Tennessee Technology Park (ETTP) was 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 changed to include the enrichment of uranium for nuclear reactor fuel elements and recycling of uranium recovered from spent fuel, and the name changed to the "Oak Ridge Gaseous Diffusion Plant" (ORGDP). In the 1980s, a reduction in demand for nuclear fuel resulted in the shutdown of the enrichment process and production. The emphasis of the mission then changed to environmental management and remediation operations. In 1996, the name changed to the "East Tennessee Technology Park," but today it is also referred to as "the Heritage Center site at ETTP" to reflect the transformation of this site into a multi-use industrial park.

Environmental management and remediation consist of waste management, the cleanup of outdoor storage and disposal areas, the demolition and cleanup of facilities, land restoration, environmental monitoring, and the proper disposal of waste generated from production operations. Beginning in the 1990s, reindustrialization (the conversion of underused government facilities for use by the private sector) became part of ETTP's mission. State and federally mandated effluent monitoring and environmental surveillance involve the collection and analysis of air, water, soil, sediment, and biota samples from ETTP and surrounding areas. Monitoring results are used to assess exposures to the public and the environment, evaluate the performance of treatment systems, and identify concerns within permitted standards for emissions and discharges. On November 10, 2015, DOE and the US Department of the Interior signed a memorandum of agreement (MOA) establishing the Manhattan Project National Historical Park (DOE 2015). The MOA defines agency roles and responsibilities in park administration and provisions for enhanced public access, management, interpretation, and historic preservation. The ORGDP footprint is included within the Manhattan Project National Historical Park. Details are available on the Manhattan Project National Historical Park page of the National Park Service website, **here**, and the K-25 Virtual Museum website details its history through narrative, interviews, and photographs, found **here**.

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 one 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 ORGDP.

After military production of highly enriched uranium was concluded in 1964, the two original process buildings, K-25 and K-27, were shut down. For the next 20 years, the plant's primary mission was 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.

By 1985, the demand for enriched uranium 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 3.3 shows the ETTP property transfer status through 2023. The ETTP mission is to reindustrialize and reuse site assets through leasing and/or transferring excess or underused land and facilities and by 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. 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 businesses 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, 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 in addition to a national park and conservation area. Unless otherwise noted, information about non-DOE entities located on the ETTP site is not provided in this document.

3.2. Environmental Management System

The UCOR Environmental Management System (EMS) is integrated with the UCOR Integrated Safety Management System. UCOR's EMS reflects the elements and framework contained in International Organization for Standardization (ISO) Standard 14001:2004, *Environmental management systems—Requirements with guidance for use* (ISO 2004). UCOR is committed to incorporating sound environmental management, protection, sustainability, and justice considerations in all business decisions,

Figure 3.1. The K-25 Site in 1946

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

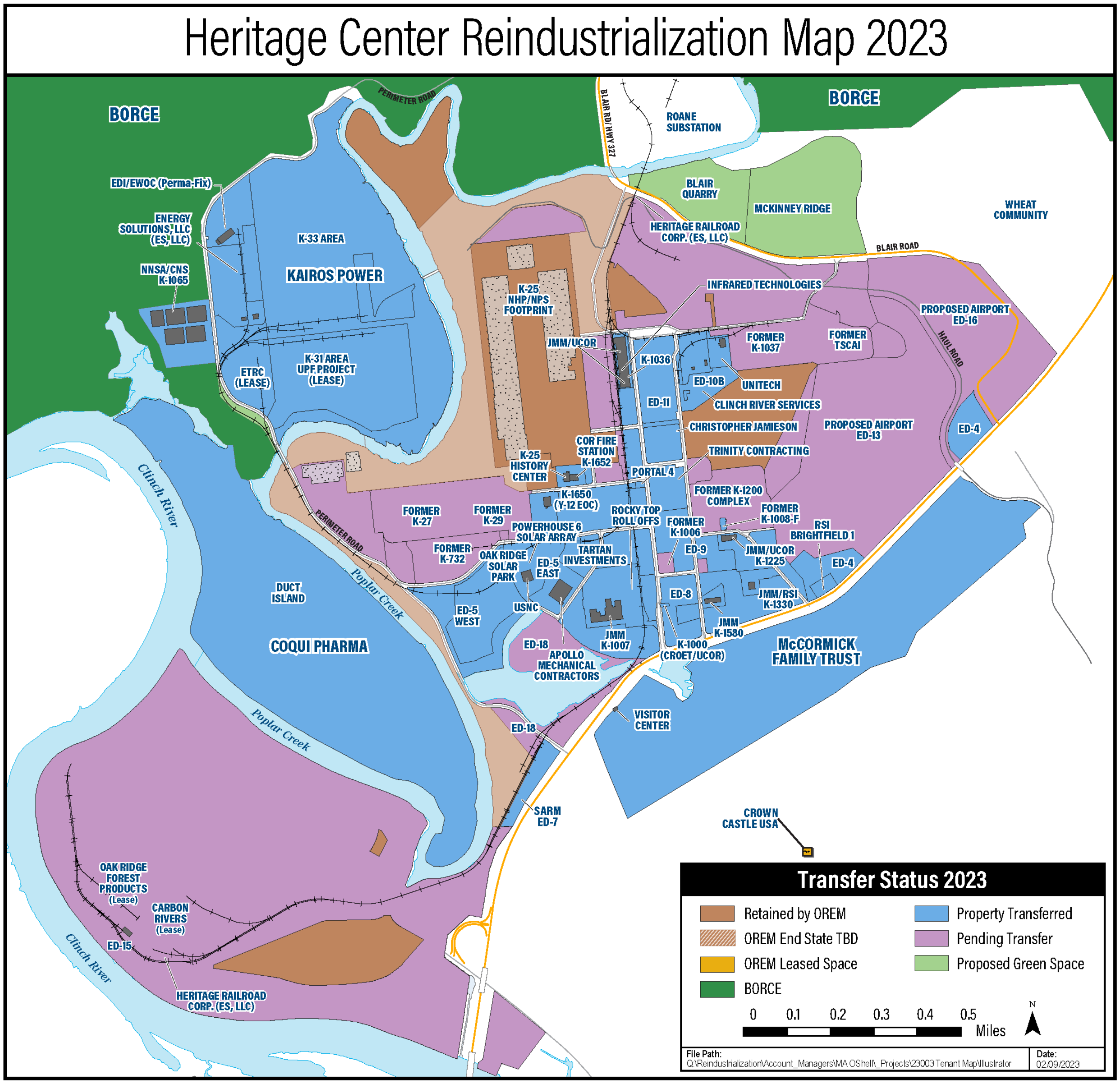


Figure 3.3. East Tennessee Technology Park in 2023, showing progress in reindustrialization

work processes and activities that are part of the DOE Environmental Management (EM) program in Oak Ridge, Tennessee. UCOR's environmental policy also includes a commitment to continually improve the environmental performance of our operations, to protect and sustain human, natural, and cultural resources and 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, in part:

- **Leadership Commitment**— Integrate responsible environmental practices into project operations
- **Environmental Compliance**— 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

- **Partnerships/Stakeholder Involvement—** Maintain partnerships through effective two-way communications with our customer and stakeholders

3.2.1. Sustainable Environmental Stewardship

UCOR received two prestigious DOE complex-wide Sustainability Awards in FY 2023. In the Innovative Approach category, UCOR was honored for its unique and innovative water management practices at the Environmental Management Waste Management Facility (EMWMF). In the Strategic Partnerships category, UCOR's was recognized for its environmental justice work with the predominantly minority Scarboro Community in Oak Ridge by hosting the Community Workforce Workshop with several UCOR staff augmentation companies to offer the opportunity to train and employ community members.

Through a new UCOR Go Zero initiative designed to promote emission reductions and climate resilience, sustainability measures are being incorporated throughout UCOR's processes and activities via UCOR's EMS. The Go Zero initiative focuses on three primary goals: net zero greenhouse gas (GHG) emissions; climate-ready operations and infrastructure; and education and partnerships to accelerate sustainability awareness and operational resilience.

3.2.1.1. Greenhouse Gas Emissions Reduction

UCOR is moving toward a net zero GHG emissions goal primarily through:

- Acquisition of electric vehicles
- Adoption of sustainable resilient remediation best management practices
- Inclusion of renewable and carbon-free energy
- Procurements that reduce Scope 3 GHG emissions
- Acquisitions that are increasingly sustainable through both systems and subcontract improvements
- A zero-waste goal for UCOR's occupied facilities and installations

In the area of renewable energy, Restoration Services, Inc. (RSI), in concert with UCOR, continued operations of ETTP's solar parks (Figure 3.4). 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 3.4. Oak Ridge Powerhouse Six Solar Farm

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) 2023, Brightfield 1 produced 245,700 kWh of energy.

In addition, through the cooperative efforts of DOE, UCOR, RSI, Vis Solis, Inc., CROET, and City of Oak Ridge, a second solar farm—the Powerhouse Six Solar Farm—was constructed on the west end of the park. It is a 1-MW solar farm that became operational in April 2015 and provides renewable energy, long-term lease income to CROET, and bolsters development at ETTP. This project continues to provide numerous benefits to the environment and the community at large, which include 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 City of Oak Ridge renewable energy goals
- Supports TVA renewable energy initiatives
- Offers community economic development jobs and property tax income to City of Oak Ridge
- Demonstrates benefits of ETTP reindustrialization
- Supports DOE renewable energy goals
- Demonstrates collaborative success between DOE and a public utility for renewable energy development

UCOR is in the planning phase for collaboration with Y-12 and the TVA (regional electrical power provider) for constructing a solar array on a former Sanitary Landfill 1 adjacent to the EMWMF at Y-12. Additionally, UCOR, RSI Entech, and the American Museum of Science and Energy (AMSE) in Oak Ridge are working on an agreement to develop a new solar energy exhibit.

To steer the focus on the management of UCOR's upstream Scope 3 GHG emissions, UCOR issued the Sustainable Supply Chain Council (SSCC) Charter (CHT-UCOR-246) in fiscal year (FY) 2023. Through field-level testing of environmentally preferable product alternatives, sustainable procurement training and tools, expanded contract clauses, and other approaches, UCOR is incorporating sustainability and climate management into every aspect of its business and strengthening its resilience.

UCOR continues to emphasize the use of environmentally sustainable products. Large quantity purchases are evaluated for less toxic alternatives. Other product purchases are first reviewed to determine if recycled content material or biobased content alternatives are commercially available, and those alternatives are prioritized for purchase when feasible. To ease the search for environmentally preferable products, Environmentally Preferable Purchasing (EPP) Catalogs were created that are filled with products from categories including Office Supplies, Catering Supplies, Toiletries and Custodial Supplies, Appliances, and Miscellaneous products. The improvement of EPP is one of the values established in the SSCC to improve sustainable acquisition and procurement decisions, processes, and practices throughout the company to reduce UCOR's carbon footprint.

UCOR's exceptional electronics stewardship earned it an award in 2023 from the Global Electronics Council for its use of Electronic Product Environmental Assessment Tool™ methods and leadership in sustainable electronics procurement. This is the ninth consecutive year that UCOR has won an EPEAT™ award.

UCOR also received the Bronze-level GreenBuy Award in FY 2023 for sustainability excellence in purchasing servers, desktop computers, monitors, and signage displays.

UCOR incorporates elements of Executive Orders (EOs) 14057 and 14008, climate science, source reduction, circularity, recycling, and pollution prevention (P2) and waste minimization practices in its work processes and activities. As an example, Figure 3.5 presents a selection of information on UCOR's 2023 P2 recycling activities related to solid waste reduction at ETTP. UCOR recycles much of its universal waste, municipal solid waste and scrap metal, reuses large amounts of construction and demolition debris, and encourages the reduction of waste wherever possible. UCOR's Zero-Waste program in support of UCOR's sustainability programs provides end-use avenues for products that are no longer useful to the current user, leading to a more circular economy. Products are reused or repurposed after use when possible. Products that cannot be reused or repurposed are recycled. The UCOR Free Store, a virtual exchange listing of excess materials stored by workers and transferred upon request, was established to provide another avenue for products to be transferred from project to project, allowing the continuation of the product before disposal. Products that cannot be reused or repurposed are recycled where practical. Note the ‘0’ value in Figure 3.5 represents electronics from FY 2023 sent for reuse/recycling in FY 2024.

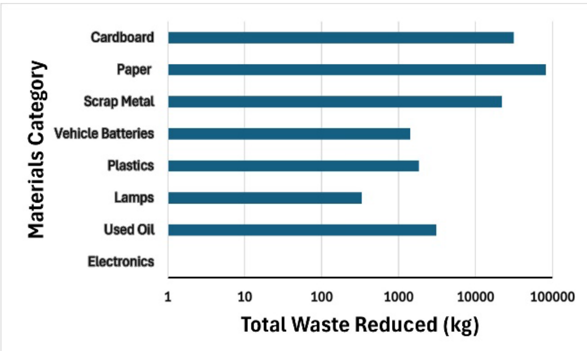


Figure 3.5. Pollution prevention recycling activities related to solid waste reduction at ETTP in FY 2023

In 2016, a significant improvement in the diversion of scrap metal was made, by petitioning and receiving agreement from the EPA and the Tennessee Department of Environment and Conservation (TDEC) to apply an unprecedented CERCLA screening process that allows noncontaminated scrap metal from CERCLA areas, previously excluded from commercial recycling services, to be safely 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 agreement continues to be successfully employed, allowing approximately 48,900 lb of scrap metal to be recycled in FY 2023 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. Since FY 2016, 4,241,122 lb of scrap-metal recycled as a result of the screening process, diverting a valuable material from the landfill for reclamation, while saving 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, ORNL, and Y-12.

3.2.1.2. Climate-ready Operations and Infrastructure

UCOR protects the DOE Oak Ridge Office of Environmental Management’s (OREM) mission-critical assets by building climate-ready operations and infrastructure. UCOR participated in the inaugural voluntary DOE Sustainable Climate-Ready Sites (SCRS) program in FY 2023 and received the ‘Top Site Score’ recognition based on performance in 15 categories (e.g., Air Quality, Cultural Resource Protection, Fleet, Habitat Quality, Pollution Prevention, Water Management).

The UCOR Vulnerability Assessment & Resilience Plan (VARP) formally issued in FY 2023 was developed to identify site-level risks to mission-critical assets and infrastructure posed by climate change. Current and projected climate hazards and trends were characterized using science-based resources. A risk matrix was prepared to help prioritize areas for focus for resilience solutions development and funding. One VARP solution instituted was an award-winning resilience solution for Real Time Physiological Monitoring to Provide Early Detection and Prevention of Heat Stress. This solution provides advance capabilities to ensure work continues to be performed safely with maximized efficiencies during higher temperatures attributed to climate change.

UCOR is more closely monitoring the impacts of weather events including performing post-weather event analyses to assess and trend the impacts to OREM's mission.

Sustainable resilient remediation best management practices are also being implemented to limit negative environmental impacts, maximize social and economic benefits, create resilience against increasing climate threats, and improve long-term risk management. UCOR is one of the DOE contractors having responsibilities for land management of portions of the ORR. The Natural Resources Management Team for ORR, centered at ORNL and partially funded by UCOR, is responsible for the creation and implementation of an Invasive Plant Management Plan. At ETTP, these efforts have included:

- Exposure Unit (EU)-29 demonstration field invasive plant control
- Powerhouse Trail privet control
- Wheat Church Vista invasive plant control
- Black Oak Ridge Conservation Easement kudzu and invasive plant control

For additional information, please see Chapter 6.

3.2.1.3. Education and Partnerships

Research has shown that the most sustainable outcomes originate from a climate-aware workforce and community and collaboration between stakeholders with mutual goals. UCOR is investing in specialized awareness and education efforts designed to develop a climate- and sustainability- focused workforce. Engaging activities featuring sustainability and climate management lessons are brought to the workers in the field. These efforts are fostering a culture of sustainability and climate action throughout the workforce and developing resources to effectively implement OREM's sustainability goals.

In addition to building awareness and competency, UCOR is also leveraging partnerships to achieve its ambitious sustainability goals. These partnerships include other communities:

- Historic, predominantly minority Scarboro Community, focused on environmental justice and workforce development
- Historically Black Colleges and Universities (HBCUs) and Minority Serving Institutions to increase awareness and access to environmental management careers
- Labor organizations to promote diversity in the workforce

Additional collaborations have been established with public and private sectors, including:

- TVA for assistance in UCOR's renewable energy and electric vehicle transitions
- University of Tennessee for educational and opportunity awareness
- Other ORR contractors to develop the most efficient and collaborative approaches to accomplishing sustainability goals and climate resilience
- Suppliers to encourage efforts to reduce GHG emissions

UCOR reinforces good environmental stewardship and sustainability practices throughout the workforce with its Sustainability Leadership Awards, a competitive internal recognition program. Fourteen categories for nominations include topics such as energy management, acquisition and procurement, travel and commuting, and waste management. The program was expanded in 2023 to include a category for Diversity, Equity, and Inclusion, and in 2024 will include Natural Resource Management as a significant component of sustainability in order to encourage further development of these UCOR values. Four UCOR projects were recognized in 2023, as summarized below:

- The Achieving Sustainability through Virtual Information Sharing project was recognized for the implementation of Diligent Boards which is a secure profile for users to share files, meeting minutes, and feedback. The transition from providing and shipping binders filled with information, data analysis, and discussion points, has accumulated a savings of $17,300 (e.g., binder shipping costs, purchase of binder materials), 13 MT of carbon dioxide (CO_2), and 1150 lb (i.e., weight of binder materials).

- The EU-21 Intermodal Shipping Campaign was recognized for the management of 3,000 yd^3 of Resource Conservation and Recovery Act F-listed soil used at Heritage Center. Originally, it was planned to use a trucking method, but the team elected to partner with Perma-Fix Environmental Services Inc. to complete rail bulk disposal. Using a lined intermodal container to package the soil, the bags were craned into the railcars and packed 100 yd^3 per railcar. The use of the shipping campaign resulted in savings of $4,365,000, 771,550 lb (i.e., 1187 steel B-25 boxes [650 lb each]), and 1268 MT of CO_2.
- The Innovative Management of EMWMF Landfill Wastewater was recognized for the installation and expansion of the enhanced operational cover at the EMWMF Landfill consisting of a 1-foot layer of compacted clay covered by a protective layer that sheds clean stormwater runoff from the landfill. The EMWMF environmental stewardship and exceptional water management conservation actions are highlighted by preserving water quality for 64 million gal of stormwater that were released to the local watershed for ecological benefit while eliminating 175 MT of greenhouse gases and saving $3,460,000.
- The Environmental Management Disposal Facility (EMDF) Salamander and Rein Orchid Relocation was recognized for the partnership between the EMDF project and the ORNL Natural Resources Management Team to relocate approximately 300 Four-Toed Salamanders (a species of Special Concern in Tennessee) and Tubercled Rein Orchids (a Tennessee threatened species) to protect them from the impact of the EMDF Landfill.

Together, the projects represented sustainability accomplishments in resource conservation, waste diversion, waste reduction, and P2. These accomplishments were the result of teamwork, assessing solutions and implementing those with the most environmental benefits, reducing the use of virgin materials, and mitigating hazards to the environment, wildlife, and workers.

In 2023, the Sustainability Leadership Award winning projects saved more than 1,325 MT of GHG emissions, 772,700 lb. of waste from landfills, and treated 16,029,000 gal of wastewater. In addition to lessening the impact on the environment, these P2 measures also saved approximately $7.8 million.

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, assessments conducted by functional or project organizations, and routine field walkdowns conducted by a variety of functional and project personnel such as Pollution Prevention Opportunity Assessments (PPOAs). PPOAs evaluate the disposition of trash receptables, recyclables, and determine ways to improve pollution prevention in the area. Assessments are prioritized and scheduled based on risk management principles and performed in accordance with procedures. 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). For additional information, see Section 3.4.

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 environmental, safety, and health (ES&H) goals.

UCOR works continuously to improve its 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: h(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 company-level EMS objectives that remain fairly consistent 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 436.1, *Departmental Sustainability* (DOE 2011a), and include the following:

- Comply with all applicable environmental regulations, permits, regulatory agreements, and DOE orders.
- Reduce or eliminate the acquisition, use, storage, generation, and/or release of toxic, hazardous, and radioactive materials; waste; and GHG through acquisition of environmentally preferable products, conduct of operations, removal and safe disposition, waste minimization, 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, community engagement, 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.

The EMS objectives and targets reduce the environmental impact of UCOR activities and accomplish the DOE sustainability goals. Each year, ETTP reports its performance in the DOE Sustainability Dashboard, which collects data such as energy and water usage, GHG generation, sustainable buildings, facility metering, waste diversion, renewable energy, sustainable acquisitions, and electronic stewardship.

The Office of Management and Budget's Environmental Stewardship Scorecard is used to track and measure site-level EMS performance. During FY 2023, UCOR received a "green" for EMS performance, indicating full implementation of EMS requirements.

3.2.5. Implementation and Operation

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 the Integrated Safety Management System. UCOR has embodied its program for environmental compliance and the protection of natural resources in a companywide environmental management and protection policy. The policy is UCOR's fundamental commitment to incorporating sound environmental management practices in all business decisions, work processes, and activities.

3.2.6. Pollution Prevention/Waste Minimization/Release of Property

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 and other generated wastes 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, and Sustainability Leadership Awards. Each year, the projects that are recognized in the Sustainability Leadership Awards are often the source of UCOR's national-level awards nominations (e.g., DOE Headquarters annual award program).

DOE Order 458.1, *Radiation Protection of the Public and Environment* (DOE 2011b), requires that a process be in place to ensure that radiologically contaminated materials are not released to the public or the environment, except in compliance with permit effluent requirements or other agreements with regulatory agencies.

Materials and equipment may be released to the public through an approved pollution prevention/recycling program or through property sales (procedure PROC-PR-2032, *Disposition of Personal Property* [UCOR 2020a], governs the process of releasing personal property), and real property may be transferred to the public through CROET.

Materials and equipment that are to be recycled or reused may follow one of two paths. If process knowledge is sufficient to establish that the materials and equipment have never been in contaminated areas (for example, empty beverage cans from a specified break area or an office building), then the materials may be released for recycling or reuse. Materials and equipment that have been in radiologic areas must be examined by trained radiologic control technicians and the results documented before the materials and equipment may be released. Materials and equipment that fail to meet the free release criteria are either decontaminated to the point that they meet the free release criteria or are properly disposed of at an appropriate disposal facility. The release of property from radiologic areas is governed by procedure PROC-RP-4516, *Radioactive Contamination Control and Monitoring* (Table 3.1). In addition to the types and quantities of recycled materials and equipment shown above in Figure 3.5, 78,460 lb of office furniture, office supplies, and safety wear were released to the public through property sales.

Real property to be transferred must meet the release criteria established by DOE Order 458.1 (DOE 2011b) and the appropriate record of decision (ROD). DOE ensures that these requirements are met through independent verification by a third party. Currently, this verification is performed by Oak Ridge Associated Universities (ORAU) through a direct contract with DOE. The direct contract with DOE ensures that the evaluation is conducted independently of UCOR, DOE's cleanup contractor. ORAU reviews historic data, facility use history, verification strategies, methodologies, techniques, and equipment. When ORAU deems it appropriate, additional sampling and/or radiological surveys are undertaken. Results of the evaluation and verification are summarized in a report to DOE that is then submitted to DOE Headquarters for approval as part of the transfer package.

Table 3.1. Surface contamination values and DOE Order 458.1 authorized limits for surface activity

Radionuclide	Removable	Total (fixed + removable)
Natural Uranium, ^{235}U, ^{238}U, and associated decay products	1,000	5,000
Transuranic, ^{226}Ra,^{228}Ra,^{230}Th,^{228}Th,^{231}Pa,^{227}Ac,^{125}I,^{129}I	20	100/500
Natural Th, ^{232}Th,^{90}Sr,^{223}Ra,^{224}Ra,^{232}U,^{126}I,^{131}I,^{133}I	200	1,000
Beta-gamma emitters except ^{90}Sr and others noted above	1,000	5,000
Tritium and Special Tritium Compounds	10,000	
Hard to Detect: Pu-241, C-14, Fe-55, Ni-59, and Ni-63	10,000	50,000

Note: *Limits are shown in dpm/100 cm^2.*

3.2.7. Competence, Training, and Awareness

The UCOR training program and qualification process ensures that needed skills for the workforce are identified and developed and documents knowledge, experience, abilities, and competencies of the workforce for key positions requiring qualification. 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, found **here**, which includes a link to its environmental policy statement in *Environmental Management and Protection*, POL-UCOR-007 (UCOR 2020b), 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 *Oak Ridge Annual Site Environmental Report* [ASER], DOE 2023a, DOE-SC-OSO/RM-2023-01] and the annual cleanup progress report [UCOR 2024, *2023 Cleanup Progress—Annual Report to the Oak Ridge Regional Community*, OREM-23-7637]).

UCOR participates in a number of public meetings related to environmental activities at the site (e.g., Oak Ridge Site Specific Advisory Board 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 Plan-Do-Act-Check, it provides a framework by which work incorporates mitigation of 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 environmental 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 2023a, UCOR-4127/R11). The EMS program is audited by a third party triennially for conformance to the ISO 14001:2004 standard (ISO 2004) as was required by DOE Order 436.1, *Departmental Sustainability, Attachment 1 Contractor Requirements Document* (DOE 2011a), with the most recent having been conducted in 2021. The results of the audit were zero findings, two observations, and three proficiencies. The two observations were analyzed, actions were implemented to improve the EMS records and document controls, and the issues were closed.

3.2.10. Management Review

A formal review/presentation with UCOR senior management is conducted once per year that addresses the ISO 14001:2004 (ISO 2004) required elements, including focus areas for the upcoming year. At least two of the senior managers are present for management reviews. The environmental policy is also reviewed during the annual EMS management review and revised, as necessary. Also, periodic reports are submitted to senior management on the status of EMS calendar year company-level objectives and targets.

3.3. Compliance Programs and Status

During 2023, ETTP operations were conducted in compliance with contractual and regulatory environmental requirements. There were no National Pollutant Discharge Elimination System (NPDES) noncompliances, nor did ETTP receive any Notices of Violation in 2023. Figure 3.6 shows the trend of NPDES compliance at ETTP since 2013. The following sections provide more detail on each compliance program and the environmental remediation-related activities in 2023.

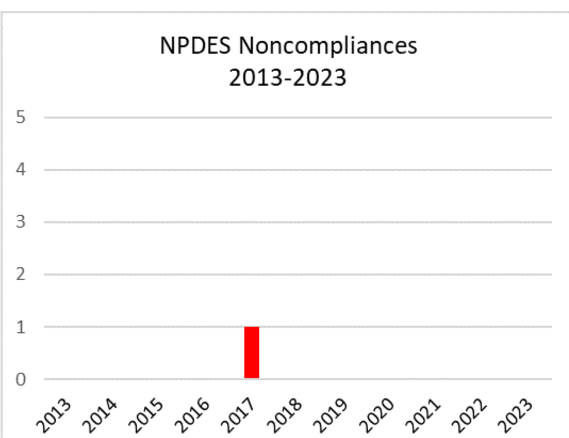


Figure 3.6. ETTP NPDES permit noncompliances since 2013

In addition, ETTP is tracked on EPA's Enforcement and Compliance History Online database (FRS ID 110002471094).

3.3.1. Environmental Permits Compliance Status

Table 3.2 contains a list of environmental permits that were in effect at ETTP in 2023. ETTP received no notices of environmental violations or penalties in 2023.

Table 3.3 presents a summary of environmental audits and oversight visits conducted at ETTP in 2023.

3.3.2. National Environmental Policy 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.

For many of the current operations at ETTP conducted under CERCLA, NEPA reviews are conducted concurrently with the CERCLA planning process to ensure that NEPA values are incorporated into CERCLA projects and documentation. These NEPA values include analysis of cumulative, off-site, ecological, and socioeconomic impacts. Opportunities for early public involvement are also provided early in the CERCLA process which meet the requirements of NEPA.

For non-CERCLA activities, a checklist incorporating NEPA and EMS requirements has been developed as an aid for project planners which document the potential for impacts on the environment. This checklist is used to collect necessary information to conduct a NEPA review.

Table 3.2. East Tennessee Technology Park environmental permits, 2023

Regulatory driver	Permit title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
CWA	NPDES permit for groundwater and storm water discharges	TN0002950	02-04-2022	03-31-2027	DOE	UCOR	UCOR
CWA	SOP—waste transportation project; Blair Road and Portal 6 sewage pump and haul permit	SOP-05068	09-22-2022	02-28-2028	TTS	TTS	TTS
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:

DOE = US Department of Energy
ID = identification (number)
NOA = Notice of Authorization
NPDES = National Pollutant Discharge Elimination System
ORR = Oak Ridge Reservation
PBR = Permit-by-Rule
RCRA = Resource Conservation and Recovery Act
SOP = state operating permit
TDEC = Tennessee Department of Environment and Conservation
TTS = Turnkey Technical Services, LLC.
UCOR = UCOR, an Amentum-led partnership with Jacobs

Table 3.3. Regulatory oversight, assessments, inspections, and site visits at East Tennessee Technology Park, 2023

Date	Reviewer	Subject	Issues
July 18	TDEC/EPA	TDEC/EPA RCRA CEI	0
November 9	EPA	ETTP Site Tour	0

Acronyms:

CEI = Compliance Evaluation Inspection
COR = City of Oak Ridge
EPA = US Environmental Protection Agency
ETTP = East Tennessee Technology Park
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation

To streamline the NEPA review and documentation process of non-CERCLA work, the DOE Oak Ridge Office has approved generic categorical exclusion (CX) determinations that cover certain proposed activities (i.e., maintenance activities, facility upgrades, personnel safety enhancements). A CX is 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. For activities that are not covered by a CX and have the potential for environmental impact, NEPA Review Reports identify new or changing environmental aspects associated with proposed activities and the ways that mitigation measures form integral components of a proposed project's design rendering impacts not significant. During 2023, there were no NEPA review reports generated to document UCOR activities at ETTP.

3.3.3. National Historic Preservation Act (NHPA) Compliance at ETTP

There were 135 facilities at ETTP eligible for inclusion on the National Register of Historic Places, a US National Park Service program to identify, evaluate, and protect historic and archeological resources in the United States, and numerous other facilities that were not eligible for inclusion on the National Register of Historic Places. More than 800 facilities were demolished at ETTP.

To commemorate the historic contributions of the ETTP K-25 gaseous diffusion plant, the first such uranium processing plant in the world, a final mitigation plan was developed by DOE in 2012 in exchange for the demolition of the facility. The mitigation plan called for the designation of a commemorative area around the building's perimeter from which future surface development would largely be restricted; the demarcation of the building's footprint; the construction of a viewing platform; an online virtual museum; and the development of a history center within the ETTP Fire Station #4. The final MOA was signed in August 2012 between DOE, the State Office of Historic Preservation, the Federal Advisory Council on Historic Preservation, the City of Oak Ridge, and the East Tennessee Preservation Alliance (DOE 2012). In 2015 the Manhattan Project National Historical Park (MPNHP) was established to incorporate the K-25 footprint, and on February 27, 2020, the K-25 History Center opened to the public (DOI 2015).

Construction of the viewing platform began on May 11, 2023, which will enable visitors to see across the entire footprint of the former K-25 Building, and so gain a sense of the size of the former building (Figure 3.7). The facility is being constructed by the U.S. Army Corps of Engineers using contractor Geiger Brothers Inc. to manage construction and UCOR to provide engineering support. The viewing platform will be completed in 2025 and is located just north of the K-25 History Center. It will include 10-foot-tall wraparound glass windows and exhibits that provide quick facts and visuals related to the historic importance of the K-25 Building, as well as view scopes and a scale model of the original facility.

Figure 3.7. Artists' rendering of future K-25 Viewing Platform

NHPA Compliance Throughout the ORR on UCOR D&D Projects

In accordance with Section 106 of the NHPA, UCOR works with OREM to provide a system of review for UCOR D&D projects throughout the ORR that have the potential to affect historic and archaeological resources on the ORR. The review process is guided by ORNL and Y-12 Programmatic Agreements, which follow the approach outlined in each site's Historic Preservation Plan, and also MOAs between DOE, the state of Tennessee, the Advisory Council on Historic Preservation, and consulting parties.

Undertakings by UCOR that affect facilities identified as historical and cultural resources in the Historic Preservation Plans undergo a three-tier system of review: (1) Level One—programmatic exclusions (no adverse effect on historic properties); (2) Level Two—internal review by the UCOR NHPA coordinator and/or OREM and/or the OREM Cultural Resources Management Coordinator; and (3) Level Three—review by the Tennessee State Historic Preservation Officer. DOE activities involving ORR artifacts of historical and/or cultural significance are identified before demolition and are catalogued in a database to aid in historic interpretation. In 2023, 13 Level One and 3 Level Two reviews were conducted for UCOR D&D activities.

3.3.4. 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 establishes comprehensive federal and state regulations to limit air emissions and includes five major regulatory programs: the National Ambient Air Quality Standards, State Implementation Plans, New Source Performance Standards, 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 2023. The ETTP ambient air-monitoring program permitted source operations tracking and record keeping, which provided documentation fully supporting a 100-percent compliance rate.

3.3.5. 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 the CWA was EPA's establishment of limits on specific pollutants allowed to be discharged in US waters by municipal sewage treatment plants 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 2023, ETTP discharged storm water and groundwater to the waters of the state of Tennessee under the individual NPDES permit TN0002950, which regulates storm water discharges. Sewage discharges from routine breakrooms, restrooms, and change house showers were discharged to the City of Oak Ridge Rarity Ridge Wastewater Treatment Plant collection network.

3.3.6. National Pollutant Discharge Elimination System Permit Noncompliances

In 2023, compliance with ETTP NPDES storm water permit TN0002950 was determined by more than 95 laboratory analyses, field measurements, and flow estimates. The NPDES permit compliance rate for all discharge points for 2023 was 100 percent.

3.3.7. Safe Drinking Water Act Compliance Status

Since October 1, 2014, all water at the ETTP site has been supplied by the City of Oak Ridge drinking water plant, located north of the Y-12 Complex in Oak Ridge, Tennessee. ETTP operations are in full compliance with this act.

3.3.8. 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. At the end of 2023, ETTP had two hazardous waste Central Accumulation Areas, managed and operated by personnel of the Uranium Processing Facility, a Consolidated Nuclear Security, LLC owned project.

TNHW-164 is the hazardous waste corrective action document, which covers ORR areas of concern and solid waste management units.

In CY 2023, ETTP prepared and submitted to the TDEC Division of Solid Waste Management the CY 2022 annual report of hazardous waste activities. This report identifies the type and amount of hazardous waste that was generated, shipped off site, or is staged for shipment. In 2023, ETTP was in full compliance with this act.

3.3.9. 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. Under CERCLA, a site is investigated and remediated if it poses significant risk to health or the environment. The EPA National Priorities List 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 National Priorities List and numerous CERCLA decision documents are approved for ETTP site cleanup actions for both facility demolitions and soil remediation. In 2023, ETTP was in full compliance with this act.

3.3.10. East Tennessee Technology Park RCRA-CERCLA Coordination

The *Federal Facility Agreement for the Oak Ridge Reservation* (DOE 1992, FFA-PM/18-011, DOE/OR-1014) is intended to coordinate the corrective action processes of Resource Conservation and Recovery Act (RCRA) required under the *Hazardous and Solid Waste Amendments* permit with CERCLA response actions.

3.3.11. Toxic Substances Control Act (TSCA) Compliance Status—Polychlorinated Biphenyls

On April 3, 1990, DOE notified EPA Headquarters (as required by 40 CFR Part 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 PCB wastes.

At this time, no PCB-contaminated electrical equipment is in service at ETTP.

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 Oak Ridge Office and EPA

Region 4 consummated a major compliance agreement known as the *Oak Ridge Reservation Polychlorinated Biphenyl Federal Facilities Compliance Agreement* (DOE 2018, ORR-PCB-FFCA), which became effective December 16, 1996, and was last revised on October 8, 2018, to Revision 6. The facilities that were included on the ORR-PCB-FFCA have been demolished and disposed.

ORR-PCB-FFCA 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) per 40 CFR Part 761.180(a) (EPA 1979). The written PCBADL is prepared by July 1 of each year and covers the previous calendar year. 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 three years. In 2023, ETTP was in full compliance with this act.

3.3.12. Emergency Planning and Community Right-to-Know Act Compliance Status

The Emergency Planning and Community Right-to-Know Act (EPCRA), which is also identified as Title III of the Superfund Amendments and Reauthorization Act, requires that facilities report inventory 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 2023 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 2023.

3.3.12.1. 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 2023, six chemicals were located at ETTP. These chemicals were diesel fuel, unleaded gasoline, sulfuric acid (including large, lead-acid batteries), Chemical Specialties, Inc. Ultrapoles, CETCO Quik-Solid, and various lubricating oils. As part of operations at ETTP subsiding, there has been a steady decrease in the number of chemicals that are required to be reported under Section 312.

3.3.12.2. 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 2023, there were no chemicals that met the reporting requirements.

3.3.12.3. Environmental Justice

UCOR strives to increase environmental justice efforts by advocating for and facilitating underserved and marginalized communities' involvement in environmental decision making. UCOR incorporates elements of EO 14008, Justice40 Initiative, and environmental justice initiatives into its community investment and commitment and workforce development programs. UCOR aspires to attract and maintain a diverse workforce that will promote the next generation of cleanup. This goal is achieved by increasing awareness and access to environmental management careers in minority and underserved communities; collaborating with labor organizations to promote diversity in the labor workforce; partnering with HBCUs and Minority Serving Institutions; and maintaining a culture of inclusion and accountability.

UCOR aims to create innovative tactics to bridge the gap between our work and the community. UCOR and DOE have partnered with the historic, predominantly minority Scarboro Community throughout its contract. The UCOR senior leadership team meets with Scarboro Community leaders often to provide updates on environmental cleanup projects. These relationships were established with Scarboro Community members to best understand how benefits can be shared with the community. During these meetings, community leaders have said they want to receive on-going information about economic benefits and opportunities for employment to help socio-economic growth in their area. In response, UCOR co-sponsored the National Association for the Advancement of Colored People (NAACP) Oak Ridge Job Fair at the Scarboro Community Center, where information was presented on apprenticeships, careers at UCOR, and small business opportunities. This is a part of ongoing outreach efforts to increase UCOR's environmental justice initiatives, identify barriers to employment, and build and maintain a skilled and diverse workforce. UCOR partnered with the NAACP and the City of Oak Ridge, who provided valuable information to community members about specific employment opportunities tailored to their interests.

UCOR maintains communication with the Scarboro Community through the Environmental Justice E-mail Blast. The email updates the community on available job opportunities and events at UCOR. This informal medium provides a direct pipeline of information and reaches 80-plus key stakeholders in and around the Scarboro Community.

UCOR engages with an environmental non-profit organization, Socially Equal Energy Efficient Development (SEEED), which provides pathways out of poverty for young adults through career readiness training, environmental education, and community engagement. Representatives of UCOR have introduced environmental justice topics and initiatives and provided the organization with resources to apply for J40 and environmental grant opportunities. UCOR hosted SEEED to present to the workforce as part of Earth Day events. As part of their Green Construction Program, SEEED develops green solar homes that are sold below market value to low-income families, creating equity and giving them the opportunity to build generational wealth. This partnership helps inform the workforce about energy equity, and environmental justice activities taking place in underserved communities.

UCOR has established formal Memoranda of Understanding with a Minority Serving Institution, Florida International University (FIU) in Miami, Florida. UCOR hosted one student from the DOE Fellows program at FIU. The company hosted site visits with its HBCU Partnership schools Tennessee State University in Nashville, TN and Benedict College in Columbia, SC to grow DOE's future workforce. UCOR hosted four interns from the Mentorship for Environmental Scholars Program, which provides HBCU students with exposure to DOE EM careers. These actions support our mission and increase our environmental justice efforts.

3.4. Quality Assurance Program

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, self-assessments, and surveillances conducted by the organization or on behalf of the organization manager.

Management and self-assessments are performed by the organization/function with primary responsibility for the work, process, or system being assessed. Management assessments are periodic introspective self-analyses, conducted by or on behalf of management, to evaluate management systems, processes, and programs ensuring the organization's work is properly focused on achieving desired results. Self-assessments are lower-level assessments that can be implemented at any time to document review of emerging issues, facility walkdowns, observation checklists, or similar reviews that do not require extensive planning, approval, or resources. Surveillance (e.g., radiological protection, quality, and safety and health) is performed by functional organizations to evaluate functional program implementation at projects or operational areas.

Issues identified from internal and external assessments are documented, analyses are performed, and corrective actions are developed and tracked to closure. Analyses are conducted periodically to identify adverse trends and opportunities for improvement for senior management action.

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 2023, 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 for emergency use. TDEC originally issued an operating permit (069346P) covering six stationary emergency reciprocating internal combustion engine (e-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 e-RICE generators and one stationary e-RICE firewater booster pump. On July 19, 2018, TDEC provided a Notice of Authorization to UCOR for coverage under Permit-by-Rule for all of the ETTP stationary e-RICE (TDEC 2017b). During 2020 all generators and the firewater booster pump were either removed from the ETTP site or transferred to new owners; UCOR then surrendered its Permit-by-Rule authorization. No stationary e-RICE units were operated by UCOR at ETTP in 2023.

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 such as demolitions and all other actions involving asbestos-containing materials (ACM) are fully compliant with 40 CFR Part 61, Subpart M, *National Emission Standards for Hazardous Air Pollutants*, "National Emission Standard for Asbestos" (EPA 1984, EPA 1990). This includes using approved engineering controls and work practices, inspections, and monitoring for proper removal and waste disposal of ACM. Most demolition and ACM abatement activities at ETTP 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.

Non-CERCLA planned demolition or renovation activities were individually reviewed for applicability of the TDEC notification requirements of the rule. During 2023, one Notification of Demolition and/or Asbestos Renovation was submitted to TDEC for non-CERCLA ETTP activities. There were no regulated asbestos-containing material demolitions during 2023.

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 2023, 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 2023.

Stratospheric Ozone Protection

The management of ODSs at ETTP is subject to regulations in 40 CFR Part 82, Subpart F, "Recycling and Emissions Reduction" (EPA 1993); 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 3.8 illustrates the historical on-site ODS inventory at ETTP. During 2023, the ODS inventory was zero.

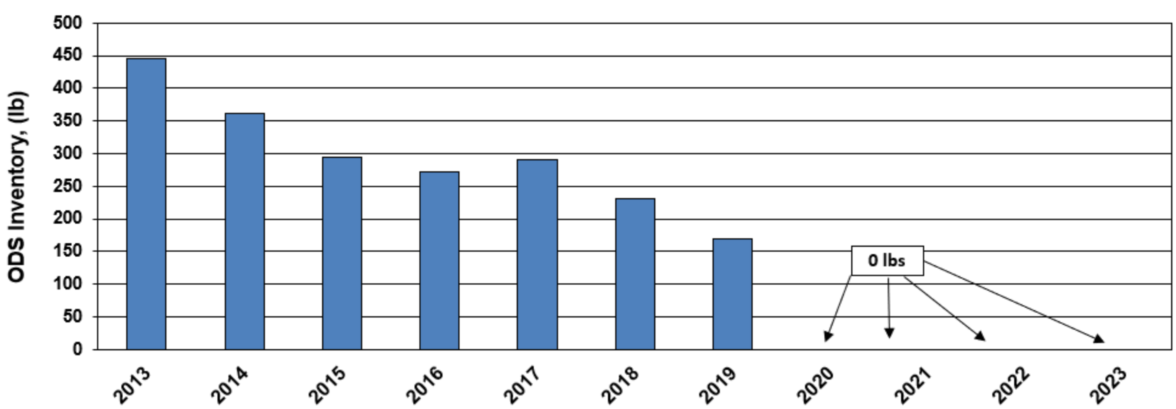


Figure 3.8. East Tennessee Technology Park total on-site ozone-depleting substances inventory, 10-year history

3.5.1.2. Fugitive Particulate Emissions

ETTP has been the location of 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)* (EPA 1989). 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 National Emission Standards for Hazardous Air Pollutants for radionuclides (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. The only ETTP Rad-NESHAP source that operated during 2023—the K-1407 Chromium Water Treatment System (CWTS) Volatile Organic Compound (VOC) Air Stripper—is 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.

Quarterly radiochemical analyses are performed on composited samples collected at all ETTP ambient air sampling stations. The selected isotopes of interest were ^{234}uranium (^{234}U), ^{235}uranium (^{235}U), and ^{238}uranium (^{238}U), with the ^{99}technetium (^{99}Tc) inorganic analysis results included as a dose contributor. The concentration for each of the nuclides at each monitoring station are presented in Table 3.4 for the 2023 reporting period. Only one radionuclide analyzed at ETTP ambient air locations was detected; that result was for ^{235}U at station K11 in the second quarter of 2023. Dose calculations using the concentration results are included in Chapter 7, Table 7.5.

Table 3.4. Radionuclides in ambient air at East Tennessee Technology Park, January 2023 through December 2023

Station	Concentration (μCi/mL)[a]			
	^{99}Tc	^{234}U	^{235}U	^{238}U
K11[b]	ND[c]	ND	5.05E-20	ND
K12[b]	ND	ND	ND	ND

[a] *μCi/mL = microcuries/milliliter*

[b] *K11 and K12 represent an on-site business exposure equivalent to half of a yearly exposure at this location.*

[c] *ND = not detectable*

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 2018, UCOR-4257/R2). The plan satisfies the QA requirements in 40 CFR Part 61, Method 114 (EPA 1989), for ensuring that the radionuclide air emission measurements from ETTP are representative of 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, *Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities*, (TDEC 2018). 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, DOE 2020a).

3.5.1.5. Greenhouse Gas Emissions

The EPA rule for mandatory reporting of GHGs (also referred to as the "Greenhouse Gas Reporting Program") was enacted October 30 2009, under 40 CFR Part 98 (EPA 2009). 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 review was performed of ETTP processes and equipment categorically identified under 40 CFR Part 98.2 (EPA 2009), whose emissions must be included as part of a facility's annual GHG report, starting with the CY 2010 reporting period. Based on total GHG emissions from all ETTP stationary sources during 2023, 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 CO_2e 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 comfort heating systems, hot water systems, and power generators. Figure 3.9 shows the five-year trend up through 2023 of ETTP total GHG stationary emissions. For CY 2023, GHG emissions totaled 225 MT CO_2e, which is 0.9 percent of the 25,000 MT CO_2e per year threshold for reporting. The increase starting in 2020 resulted from the leasing of several large bays in Building K-1036; these bays are heated with natural gas.

EO 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*, was published in the Federal Register on October 8, 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.

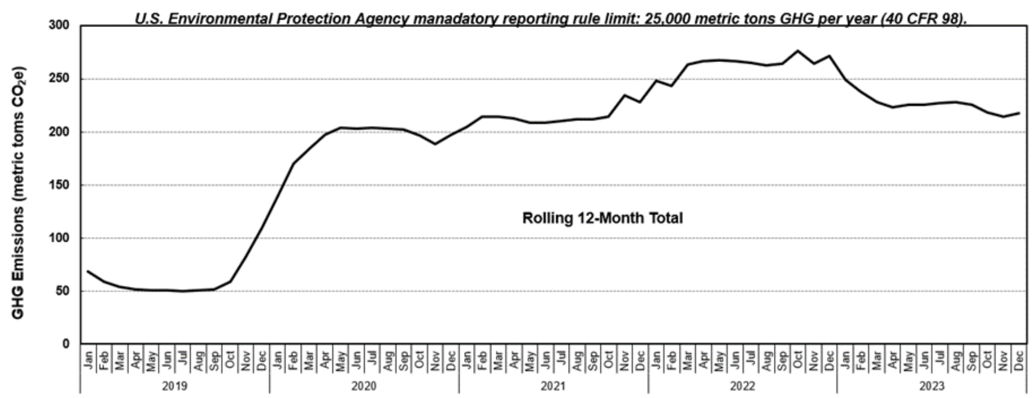
One goal of this order was to establish a FY 2020 Scopes 1 and 2 reduction target of 28 percent, as compared to the 2008 baseline year.

EO 13693, *Planning for Federal Sustainability in the Next Decade,* was published in the Federal Register on March 25, 2015. This order superseded EO 13514 and established a new Scope 1 and Scope 2 federal-wide 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.

EO 13834, *Efficient Federal Operations*, was published in the Federal Register on May 22, 2018.

This order superseded EO 13693. It requires continued tracking and reporting of GHG emissions, but no specific federal-wide total reduction target.

The information reported here includes GHG emissions from the industrial landfills at Y-12 that are managed and operated by UCOR. The landfills



Note: *Shown in carbon dioxide equivalent (CO_2e)*

Acronyms:

CFR = Code of Federal Regulations

GHG = greenhouse gas

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

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 Scopes 1 and 2 GHG emissions reduction target of 28 percent by FY 2020 and the EO 13693 Scopes 1 and 2 GHG emissions reduction target of 40 percent by FY 2025.

Scopes 1 and 2 GHG emissions for FY 2023, including the landfills, totaled 15,226 MT CO_2e, which is a 76 percent reduction from emissions in the FY 2008 baseline year.

Figure 3.11 shows the relative distribution and amounts of all ETTP FY 2023 GHG emissions for Scopes 1, 2, and 3, including the industrial landfills at Y-12. 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 on-site combustion of fuels (stationary and mobile sources), lower consumption of electricity, and a smaller workforce. The total amount of GHG emissions for Scopes 1, 2, and 3, including landfills at Y-12, for FY 2023 was 23,391 MT CO_2e.

The American Innovation and Manufacturing (AIM) Act of 2020 is a bill that aims to combat climate change by significantly reducing hydrofluorocarbons (HFCs), chemicals commonly used in refrigerants. The AIM Act directs the EPA to implement an 85 percent phasedown of the production and consumption of HFCs by 2035. Operations at ETTP are winding down to the point where insignificant HFC emissions are taking place.

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 influent stream. Potential total VOC emissions from the CWTS air stripper were calculated to be 0.009 ton/year in 2023, as compared to an emission limit of 5 tons/year.

A variety of minor pollutant-emitting sources released airborne pollutants from ETTP operations, such as 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 are regulated through the risk management planning regulations under 40 CFR Part 68 (EPA 1994). 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 chemical inventories at ETTP with the risk management plan threshold quantities listed in 40 CFR Part 68.130 (EPA 1994) was conducted. This is an ongoing action that documents the potential applicability for maintaining and distributing a risk management plan and ensuring threshold quantities are not exceeded.

Operations at ETTP are winding down to where insignificant air pollutant emissions are taking place.

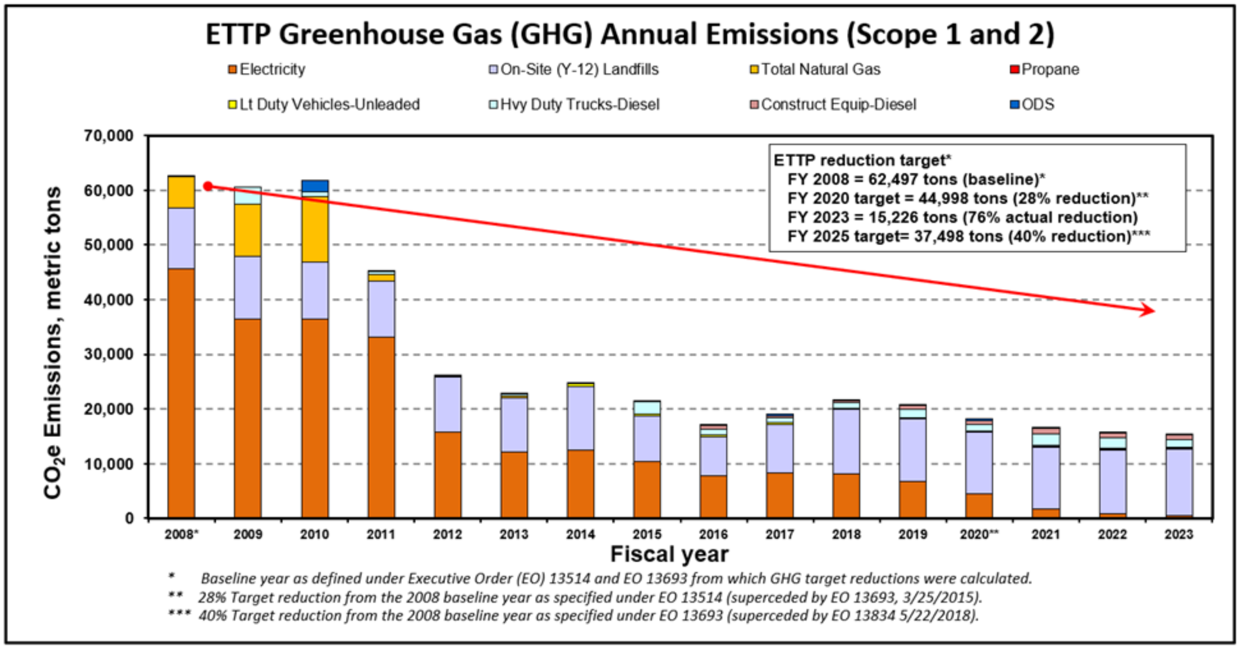
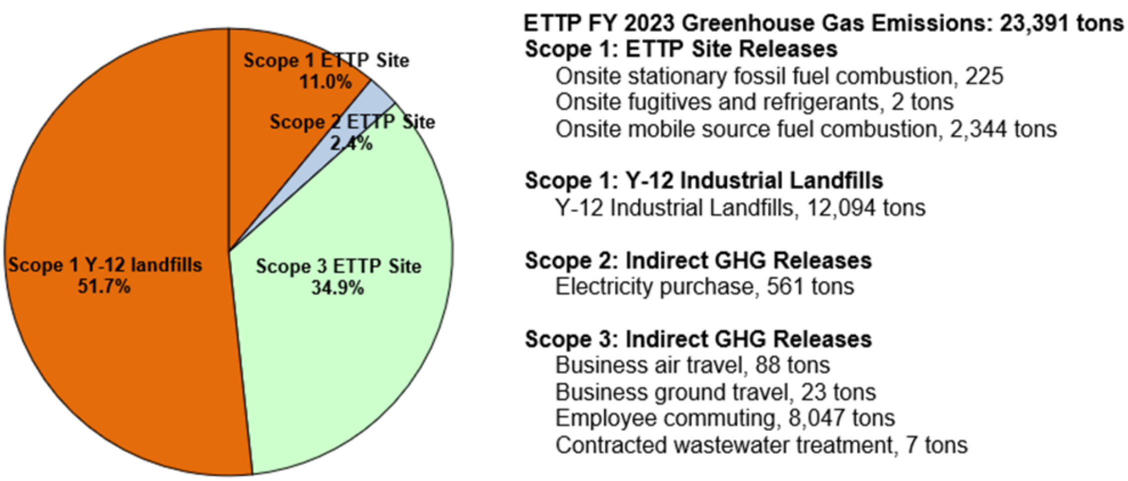


Figure 3.10. East Tennessee Technology Park greenhouse gas annual emissions (Scopes 1 and 2, including industrial landfills at Y-12)



Acronyms:

ETTP = East Tennessee Technology Park

Y-12 = Y-12 National Security Complex

GHG = greenhouse gas

Figure 3.11. FY 2023 East Tennessee Technology Park greenhouse gas emissions by scope

At ETTP, there are no processes or facilities containing inventories of chemicals in quantities exceeding thresholds specified in rules pursuant to CAA.

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 and implemented 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:

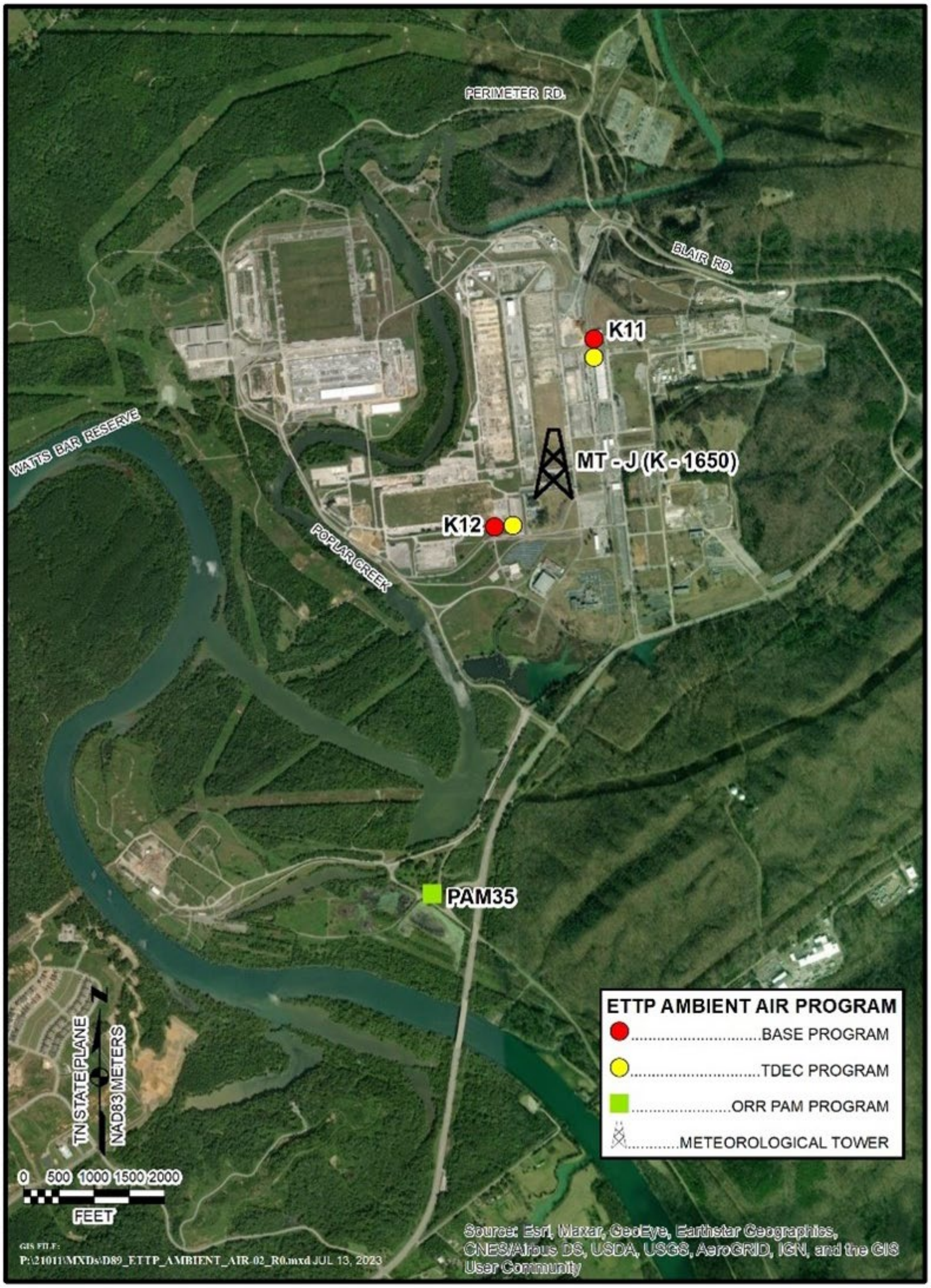
- Tracking of long-term trends of airborne concentration levels of selected air contaminant species
- Measurement of the highest concentrations of the selected air contaminant species that occur in the vicinity of ETTP operations
- Evaluation of the potential impact on air contaminant emissions from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

The three sampling programs in the ETTP area are designated as the Environmental Compliance (EC) program, TDEC program, and the ORR perimeter air monitoring program. Figure 3.12 shows an example of a typical EC program air monitoring station. Figure 3.13 shows the locations of all ambient air sampling stations in and around ETTP that were active during the 2023 reporting period.

The EC program consisted of two sampling locations throughout 2023. All projects are operating similar high-volume sampling systems. The EC, TDEC, and perimeter air monitoring samplers operate continuously with exposed filters collected weekly. The radiological monitoring results for samples collected at the one ETTP area perimeter air monitoring station are the responsibility of UT-Battelle, LLC. TDEC is responsible for the data collected from their samplers. UT-Battelle, LLC and TDEC results are not included with the EC data presented in this section. However, results from the other programs are requested periodically for comparison.

The analytical parameters were chosen with regard to existing and proposed regulations and with respect to activities at ETTP. The principal reason for EC 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 are either on-site (on ORR) or off-site. K11 and K12 were key sampling locations regarding the potential dose impact on the most exposed member of the public at an on-site business location during slab removals, small structures demolition, excavation and removal of contaminated soils, and other activities.

Figure 3.12. East Tennessee Technology Park ambient air monitoring station (UCOR on the left, TDEC on the right)



Acronyms:

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

Figure 3.13. East Tennessee Technology Park ambient air monitoring station locations

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 controls, a survey of all on-site tenants is reviewed every six months through a request for the most recent ETTP reindustrialization map.

All EC program stations collected continuous samples for radiological analyses during 2023. These analyses of samples from the EC stations test for the isotopes ^{234}U, ^{235}U, ^{238}U, and ^{99}Tc.

Stations K11 and K12 are located to provide a conservative measurement of the impact to on-site members of the public.

3.6. Water Quality Program

Water quality is monitored via multiple programs at ETTP. Storm water monitoring is conducted through the NPDES Program (Section 3.6.1) and the Storm Water Pollution Prevention Program (Section 3.6.2). Surface water monitoring is conducted through the Environmental Monitoring Program (EMP) (Section 3.6.3). Groundwater monitoring is conducted through the Water Resources Protection Program (Section 3.6.4).

3.6.1. National Pollutant Discharge Elimination System Permit Monitoring

NPDES monitoring is conducted to demonstrate compliance with the ETTP NPDES Permit. The current NPDES permit was issued on February 4, 2022, became effective on April 1, 2022, and will expire on March 31, 2027. Under this ETTP NPDES Permit, 20 representative outfalls are monitored annually (Figure 3.14). All twenty (20) representative outfalls are sampled annually for total suspended solids (TSS), pH, and flow. Additionally, select outfalls are sampled annually for zinc (Outfall 142), oil and grease (Outfall 190), PCBs (Outfalls 280, 690), benzidine (Outfall 430), and semiannually for total chromium and hexavalent chromium (Outfall 170). There were no permit noncompliances in 2023.

3.6.2. Storm Water Pollution Prevention Program

In addition to the NPDES permit required monitoring, storm water is also monitored for a variety of substances, including radionuclides, metals, and organic compounds (UCOR-4028b, *East Tennessee Technology Park Storm Water Pollution Prevention Program Sampling and Analysis Plan, Oak Ridge, Tennessee*, UCOR 2023b). Routine storm water pollution prevention plan (SWPPP) monitoring is conducted at various locations that vary from year to year depending on activities going on within the drainage basins and historical monitoring results. SWPPP monitoring includes stream impairment monitoring, radiological monitoring, D&D and RA monitoring, CERCLA Phased Construction Completion Report (PCCR) monitoring, legacy contamination monitoring, and investigative monitoring.

Figure 3.14. Storm water outfall monitoring

3.6.2.1. Radiologic Monitoring of Storm Water

Radiological monitoring is conducted to determine compliance with applicable dose standards. Composite samples from five outfalls were collected following a rain event and analyzed for gross alpha activity, gross beta activity, and specific radionuclides. The estimated discharge of radionuclides from ETTP via the storm water drainage system was calculated based on the radiological monitoring results, daily rainfall data for CY 2023, and flow rates. Table 3.5 presents the total calculated discharge of radionuclides from storm water discharged to off-site waters from ETTP in CY 2023.

Table 3.5. Radionuclides released to off-site waters from the East Tennessee Technology Park storm water system in 2023

Isotope	^{234}U	^{235}U	^{238}U	^{99}Tc
Activity level (curies)	0.00617	0.00066	0.00517	0.0739

3.6.2.2. Demolition and Remedial Action Monitoring of Storm Water

Demolition and RA monitoring is conducted to evaluate the effectiveness of demolition and RAs and to ensure that storm water controls are preventing sediment and contaminants from discharging into receiving waters. Grab samples from select outfalls are collected prior to the start of demolition/RAs, following each 1-in. rain event during demolition/RAs, and after completion of demolition/RA activities.

3.6.2.3. K-25 Building ^{99}Tc Contaminated Soil Remedial Action Monitoring

Demolition of the K-25 Building was completed in 2014. The last section of the east wing that was demolished was contaminated with the radioactive isotope ^{99}Tc. Rain and dust control water that contacted the ^{99}Tc-contaminated piping and other building materials is believed to have caused the migration of ^{99}Tc into soils beneath the east wing debris pile during demolition. Remediation of the ^{99}Tc-contaminated soils within the K-25 footprint was completed in 2020. Storm water monitoring in Outfalls 190 and 490, located downgradient of the former K-25 Building, continued in 2023.

Outfall 190 is sampled quarterly. Except for the sample collected in July 2021, ^{99}Tc has not been detected in storm water samples from Outfall 190 since July 2013. 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 Outfall 190.

Outfall 490 is sampled semiannually. Technetium-99 was detected in the storm water samples from Outfall 490 in February 2023 and August 2023 but was well below the reference standard of 390,000 picocuries/liter (pCi/L). Outfall 490 discharges into the K-1007-P1 Pond. Discharges from the K-1007-P1 Pond to Poplar Creek are monitored routinely as an exit pathway location per the ETTP EMP. The ^{99}Tc data is evaluated to determine the contribution of ^{99}Tc from the Outfall 490 drainage area to the total ^{99}Tc discharge from the K-1007-P1 pond, as further discussed in Section 3.6.3, "Surface Water Monitoring."

3.6.2.4. EU-21 Remedial Action Monitoring

The EU-21 area is located between the east and west wings of the former K-25 Building and includes the slab associated with the former K-1024 Maintenance Shop. The K-1024 Maintenance Shop was used for the repair and calibration of instruments and equipment used in the K-25 uranium enrichment process. The maintenance shop used solvents, including TCE, for cleaning instruments and equipment. As an accepted practice at the time, solvents were frequently discharged into the floor drains, then entered the storm drain network. The main source of TCE in the EU-21 area is presumed to be from Catch Basin 7097, located on the south side of the former K-1024 Building. Although TCE is the primary contaminant of concern for the EU-21 soil RA, mercury droplets were discovered during removal of buried pipe. K-1024 was also used for cleaning mercury from line recorder chemical traps between 1946 and 1947 and the equipment shop had a problem with spilled mercury and mercury vapors.

Prior to the soil RA, the storm drain system within the proposed excavation and clean layback footprints was isolated from the active system in order to prevent sediment and contaminants from discharging to Poplar Creek via Outfalls 230 and 240. Outfall 210 receives water from the storm drain system located on the east side of the K-25 east wing (well outside of the excavation and layback footprints). All of the catch basins located on the west side of the K-25 west wing were previously plugged under a separate program.

Baseline samples were not collected prior to the start of the soil RA due to dry conditions. Monitoring of Outfalls 210, 230, and 240 is being conducted during 1-in. rain events and analyzed for VOCs, metals, mercury, and TSS. TCE has not been detected in any of the samples collected from Outfalls 210, 230, or 240 in 2023. Several other parameters have been detected, but only lead exceeded reference standards during the June 2023 rain event. Storm water monitoring will continue following each 1-in. rain event until the RA is complete. A final sampling event will be conducted once excavation and waste shipments have been completed.

3.6.2.5. EU-39 Remedial Action Monitoring

Outfall 170 is located downgradient of the EU-39 slab removal RA area. The EU-39 area includes the concrete slabs for the former K-1420 Decontamination and Uranium Recovery Facility, K-1421 Incinerator, and K-1422 Storage Building. The former K-1420 Decontamination and Uranium Recovery Facility provided radiological decontamination, uranium recovery, and metal plating capabilities and served as a storage area for drums of uranium-cascade motor lubricant oil containing PCBs and uranium. The K-1421 Incinerator was used to burn waste oil sludge and low-level contaminated combustibles such as gloves, coveralls, wood, paper, and plastic. The K-1422 Storage Building was used for storage of fissile materials and, reportedly, for uranium hexafluoride cylinder charging or emptying.

Prior to the slab removal RA, lined berms were installed around the K-1420, K-1421, and K-1422 slab to contain sediment, particulates, and debris within the excavation area and to divert sheet flow during rain events. The catch basin leading to Outfall 158, located northeast of the K-1420 pad, was plugged prior to slab demolition. The stormwater pipes leading to Outfall 160, north of K-1420 were cut and capped north of the catch basin. There is no discharge pipe in the project area to Outfall 168. Only sheet flow would potentially impact these three outfalls during the slab removal RA. Therefore, stormwater samples are obtained from Outfall 170, which is located downstream from the project area.

Monitoring of Outfall 170 is conducted during a qualifying major storm event (as defined in UCOR-4028, UCOR-2023b) and at the discretion of the EC Lead (based on field conditions and the location of remedial activities) and analyzed for uranium isotopes, radium-thorium decay series, ^{99}Tc, alpha activity, beta activity, VOCs, PCBs, metals, and TSS. The alpha activity result of 17.2 pCi/L, from the June 2023 storm event, was the only result to exceed a reference standard in 2023. Stormwater monitoring will continue for the duration of the EU-39 RA.

3.6.2.6. EU-35 Remedial Action Monitoring

Outfall 180 is located downgradient of the EU-35 soil RA area. The EU-35 Soil RA 3 area is located in the area of the former K-1407-B Pond. The K-1407-B Pond was primarily used as a settling pond for metal hydroxide sludge and other waste streams that were precipitated/neutralized in the adjacent K-1407-A Neutralization Pit Facility but also received waste from many other nearby facilities. The pond was clean closed under the RCRA in 1994 and covered with 4–10 ft of fill above the contaminated soil. An estimated 2-3 ft of contaminated soil is located between the fill layer and the water table in these areas.

Prior to the soil removal RA, lined berms were installed around open excavations, contaminated soil stockpiles, and any debris to minimize water run-on and to contain contaminated water, debris, sediment, and particulates within the excavation areas. The stormwater pipes in the northwestern corner of K-1407 B were temporarily plugged prior to excavation. Stormwater samples were obtained from Outfall 180, which is located downstream from the project area.

Monitoring of Outfall 180 will be conducted during qualifying major storm events (as defined in UCOR-4028, UCOR-2023b) and at the discretion of the EC Lead (based on field conditions and the location of remedial activities) and analyzed for uranium and thorium isotopes, ^{99}Tc, alpha activity, beta activity, VOCs, PCBs, metals, mercury, and TSS. A baseline and qualifying major storm event sample were collected in 2022. The RA was then delayed but began again in late 2023. No sampling took place in 2023 for this RA. Stormwater monitoring will continue for the duration of the EU-35 RA.

3.6.2.7. EU-16 Remedial Action Monitoring

Outfalls 292, 294, and 296 are located within the drainage area associated with the EU-16 soil RA area. The EU-16 area is located north of the former K-802 Basin area and adjacent to Poplar Creek. The EU-16 area was primarily used for drum storage and a scrap yard for K-25 operations. Excavation was planned for the following four areas at EU-16: K-1064 Salvage Material Yard, K-1064-H Shed Area, K-1064-M North Trash Slope, and the Z2-EU16B-277 Sample Area. The K-1064 Salvage Material Yard was used to stage radiologically contaminated and uncontaminated equipment and materials. The K-1064-H Shed Area was part of the Drum Storage and Burn Area. The K-1064-M North Trash Slope was used for unofficial dumping of construction materials, oils, and solvents. There are no known activities that occurred within the Z2 EU16B-277 area.

Prior to excavation, lined berms were installed around excavation footprints to prevent sediment and runoff from reaching Poplar Creek directly or via the storm drain network discharging at Outfalls 292, 294, and 296 on the west side of the site. Catch basins and drainage pipes outside the footprints were protected with sediment socks or other controls.

Monitoring of Outfalls 292, 294, and 296 was conducted during qualifying major storm events (as defined in UCOR-4028, UCOR-2023b) and at the discretion of the EC Lead (based on field conditions and the location of remedial activities) and analyzed for uranium isotopes, thorium isotopes, ^{99}Tc, alpha activity, beta activity, VOCs (Outfall 292 only), metals, and TSS. Post RA samples were collected during the June 2023 qualifying major storm event. Outfall 296 was not sampled due to no flow conditions. Alpha activity, copper, and PCBs were the only results that exceeded a reference standard during the June 2023 post RA sampling effort.

3.6.2.8. Monitoring of Outfalls Designated in the CERCLA Phased Construction Completion Reports

When environmental restoration activities at ETTP are conducted in phases, progress may be documented in a CERCLA PCCR. When this occurs, a PCCR is prepared to document the completed work (e.g., demolition) and interim requirements for remaining slabs. If radiological surveys indicate that a slab exceeds the release criteria in DOE Order 5400.5, Chg. 2, *Radiation Protection of the Public and the Environment* (DOE 1993a), then interim access controls are implemented, the slab is posted, and the slab is included in the radiological surveillance and monitoring program. Environmental requirements in the radiological surveillance and monitoring program include sampling designated outfall(s) once every NPDES permit cycle for gross alpha activity, gross beta activity, uranium isotopes, and ^{99}Tc. The designated outfall(s) are selected based on the drainage area and proximity to the slab(s).

Four outfalls were designated for sampling in CERCLA PCCRs in 2023. Grab samples were collected from Outfalls 270, 280, 294, and 297 and analyzed for gross alpha activity, gross beta activity, uranium isotopes, and ^{99}Tc. The CERCLA PCCR monitoring results are presented in Table 3.6.

3.6.2.9. Legacy Mercury Contamination Monitoring of Storm Water

Legacy mercury contamination monitoring is conducted to evaluate mercury concentrations over time and to determine if outfalls are contributing mercury to site waterways.

Outfalls 180 and 190 discharge storm water from large areas on the north side of ETTP into Mitchell Branch. There were numerous historical mercury operations within Outfalls 180 and 190 drainage areas and the Mitchell Branch subwatershed. Due to contaminated sediment within storm water networks and potential infiltration into the piping, these are potential contributors to the continuing legacy mercury discharges to Mitchell Branch.

The mercury concentrations detected from grab samples in Outfalls 180 and 190 during 2023 are presented in Table 3.7.

The mercury concentrations over time in Outfalls 180, 190, and the K-1700 Weir on Mitchel Branch are presented in Figure 3.15. In 2023, no mercury grab sample results exceeded the reference standard of 51 nanograms/liter (ng/L).

Table 3.6. CERCLA PCCR monitoring results for 2023

Parameter	Reference standard	Outfall 270 (3/2/2023)	Outfall 280 (1/17/2023)	Outfall 294 (3/2/2023)	Outfall 297 (5/9/2023)
Alpha activity (pCi/L)[a]	15	3.45 U	12	6.19	15.8
Beta activity (pCi/L)	50	39.6	14	**146**	18
^{99}Tc (pCi/L)	390,000	2.14 U	3.41 U	18	6.5 U
$^{233/234}$U (pCi/L)	1,200	0.699	5.15	5.49	13.5
$^{235/236}$U (pCi/L)	1,300	0.11 U	0.324 U	0.57	0.829
^{238}U (pCi/L)	1,400	0.62	2.39	4.13	7.75

[a] *pCi/L = picocuries/liter*

Note: *Results in bold exceed the reference standard. Reference standards for gross alpha and gross beta measurements correspond to the National Primary Drinking Water Standard (40 CFR Part 141, National Primary Drinking Water Regulations, Subparts B and G, EPA 1975). Reference standards for radionuclides equal the derived concentration standard (DCS) for ingested water (DOE-STD-1196-2022, Derived Concentration Technical Standard, DOE 2022a.*

Table 3.7. Mercury results for Outfalls 180, 190, and 05A/05A-2 in 2023

Sampling location	Reference standard (ng/L)[a]	1/9/2023 (ng/L)	4/3/2023 (ng/L)	7/10/2023 (ng/L)	10/31/2023 (ng/L)
Outfall 180	51	21.2	43.1	25.6	47.8
Outfall 190	51	9.99	7.265	6.6	32.8

[a] *ng/L = nanograms/liter*

Note: *Results in bold exceed the reference standard. The reference standard for mercury corresponds to TDEC Rule 0400-40-03-.03(4)(j), Organisms Only Criteria.*

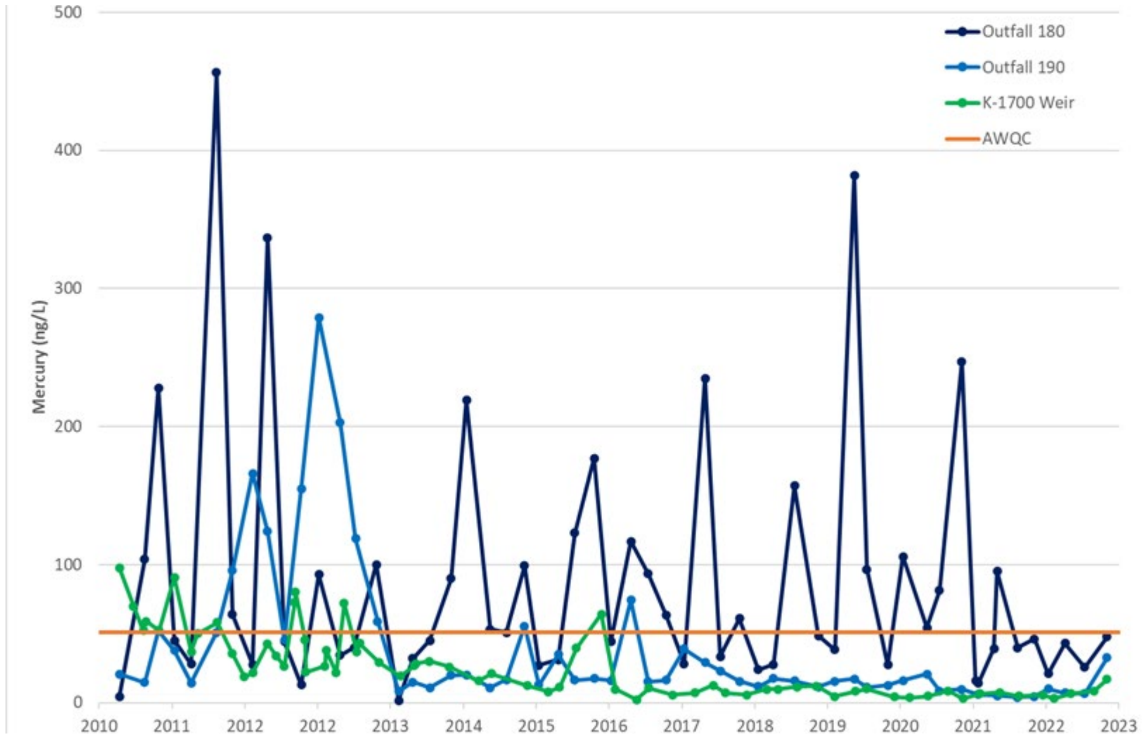


Figure 3.15. Mercury concentrations at Outfalls 180 and 190, and the K-1700 Weir

3.6.2.10. Investigative Monitoring of Storm Water

Investigative monitoring is conducted based on elevated analytical results, CERCLA requirements, and/or changes in site conditions. Investigative monitoring was conducted at Outfall 780 network in 2023.

Outfall 780 Investigative Monitoring

Outfall 780 is located in the Old Powerhouse Area. In 2018, a select group of non-representative outfalls was sampled to determine if they were contributing mercury and PCBs to site waterways. Outfall 780 had elevated concentrations of some metals, mercury, and PCBs. Recent activities being conducted in the area were not suspected as the cause of the elevated concentrations, although process knowledge indicated that they could be legacy contaminants. Outfall 780 once carried storm water runoff from former Buildings K-724 and K-725. These buildings were originally part of the S-50 Thermal Diffusion Plant; Building K-725 was later used for beryllium processing. It contained mercury traps that occasionally released mercury. In addition, mercury was reportedly “swept down the floor drains” and into the storm drain system during cleanup activities in the 1970s. Mercury may also have been present in the dust collection system and transported to the storm drain system via storm water runoff during demolition of K-725 in the 1990s. Outfall 780 also received storm water from the K-722 area, where approximately 1,000 gal of oil was landfarmed for dust suppression in the 1980s.

A commercial wood yard and chipping facility operated at the K-722 site until summer of 2023. A commercial fiberglass recycling company involved in the storing and recycling of decommissioned windmill parts began operating in the Old Powerhouse Area in spring of 2022. Their operations expanded into the area previously occupied by the commercial woodchipper in the summer of 2023. While these commercial operations are not suspected as the source of these contaminants; it is possible that their operations (large delivery trucks and equipment) have contributed to mobilizing contaminants that may have been present and dormant for years.

Outfall 780 was sampled in January 2023 for parameters including radionuclides, VOCs, PCBs, metals, mercury, and TSS. Copper, lead, PCBs, and mercury were detected in elevated concentrations that exceeded their respective reference standards. Additional investigative monitoring of contaminants at Outfalls 780, 830, 880, and 890, whose networks receive stormwater from the areas associated with current commercial operations, is planned as part of the SWPPP in 2024.

3.6.2.11. Chromium Water Treatment System and Plume Monitoring

The CWTS (Figure 3.16) was constructed to intercept a plume of contaminated groundwater before it enters Mitchell Branch.

Figure 3.16. The Chromium Water Treatment System

The CWTS consists of interceptor wells, pumps, holding tanks, a treatment system, and an air stripper. Effluent is discharged through the pipeline that originally carried effluent from the Central Neutralization Facility (which was previously demolished). In CY 2023, monitoring was conducted at monitoring well 289 (TP-289), the chromium collection system wells, Outfall 170, and Mitchell Branch kilometer (MIK) 0.79. Figures 3.17 and 3.18 show the results for the analyses for total chromium and hexavalent chromium, respectively.

The analytical data indicate that both total and hexavalent chromium levels at TP-289 and the collection wells may fluctuate slightly but are relatively consistent over the long term. In 2023, concentrations of hexavalent chromium at Outfall 170 and MIK 0.79 were only detected in January 2023 with no results exceeding the ambient water quality criterion (AWQC) of 11 micrograms/liter (μg/L). Results for total chromium at Outfall 170 and MIK 0.79 were within historic ranges, and well below the AWQC for total chromium of 100 μg/L. These results demonstrate the continuing positive impact of the collection well system to minimize the release of chromium into Mitchell Branch.

3.6.2.12. Flow Weighted Mercury Sampling

Monitoring of pollutant loading (flux monitoring) is conducted as part of the SWPP Program SAPs to support the requirement defined in Section 5.9.1 of the ETTP NPDES permit to properly monitor mercury flux at Outfalls 180 and 190.

As part of the flow-weighted sampling effort at these outfalls, aliquots must be collected during a qualifying storm for the first three (3) hours, or for the duration of the storm if it is less than three (3) hours in duration. A qualifying storm event is one in which greater than 0.1 in. of rainfall occurs after a period of at least 72 hours following any previous storm event with rainfall of 0.1 in. or greater. Equal volume aliquots should be collected at variable time intervals commensurate with the flow volume that has passed. A minimum of three (3) sample aliquots must be collected to qualify as a valid sampling event. Flow-weighted composite samples can be collected manually or automatically.

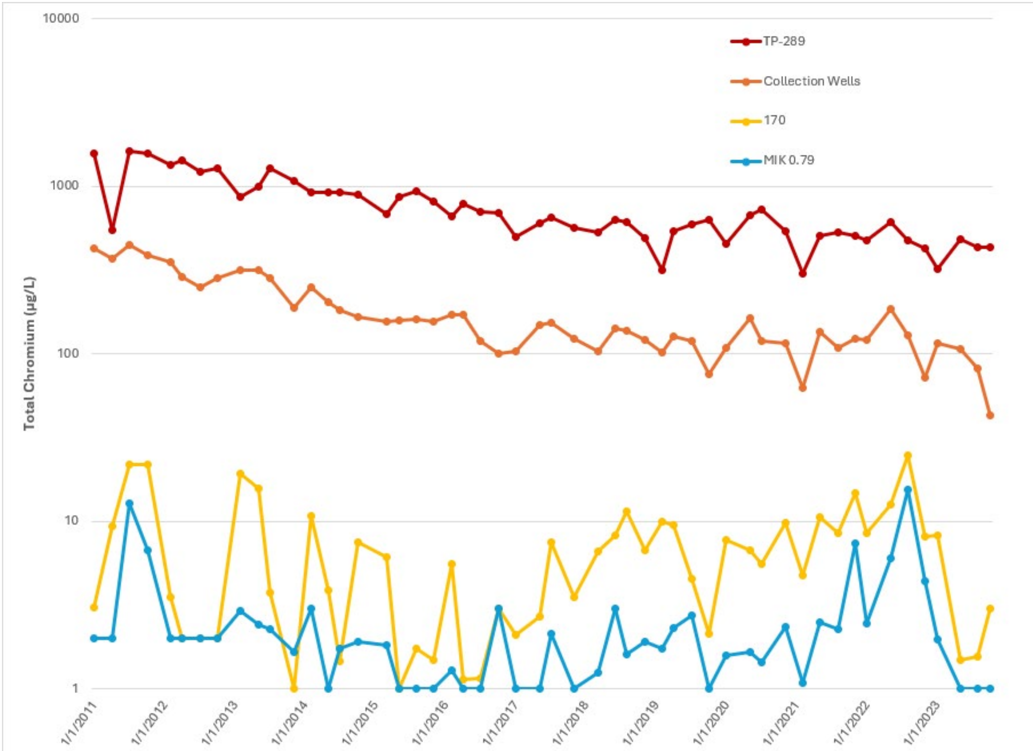


Figure 3.17. Total chromium sample results for the chromium collection system

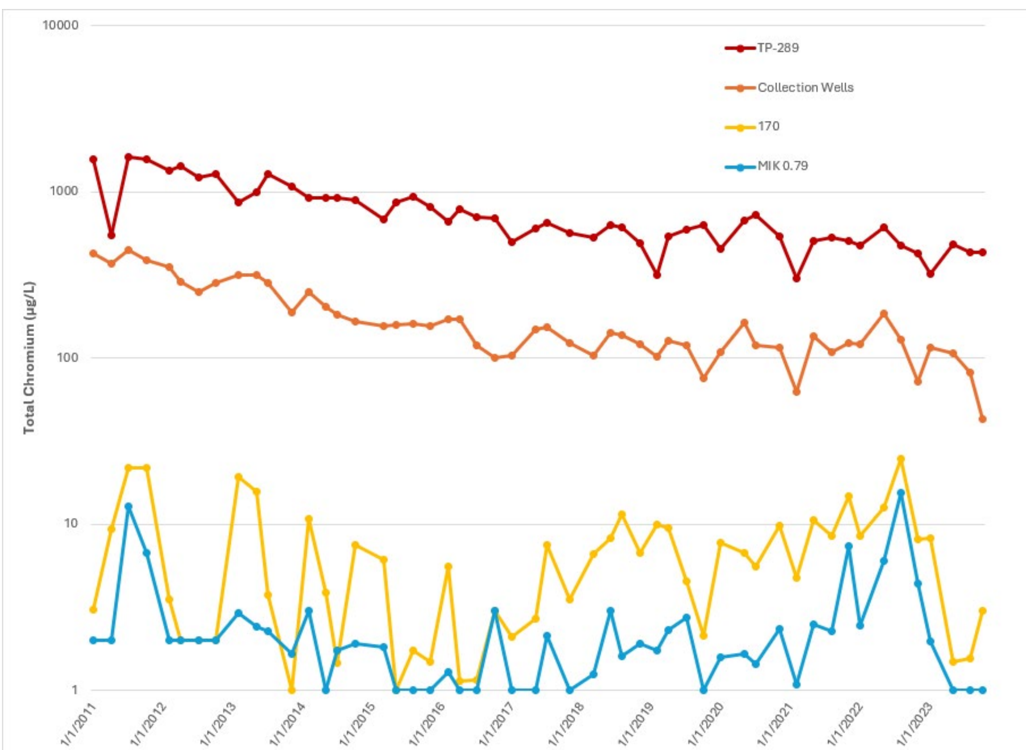


Figure 3.18. Hexavalent chromium sample results for the chromium collection system

Several sample results exceeded reference standards and were elevated when compared to historical results. In an effort to further investigate these findings, an additional flow-weighted sampling event took place at Outfall 190. Additionally, mercury sampling at these locations as well as nearby surface water locations is planned for 2024. Flow-weighted sample results from 2023 are shown in Table 3.8. Surface Water Monitoring.

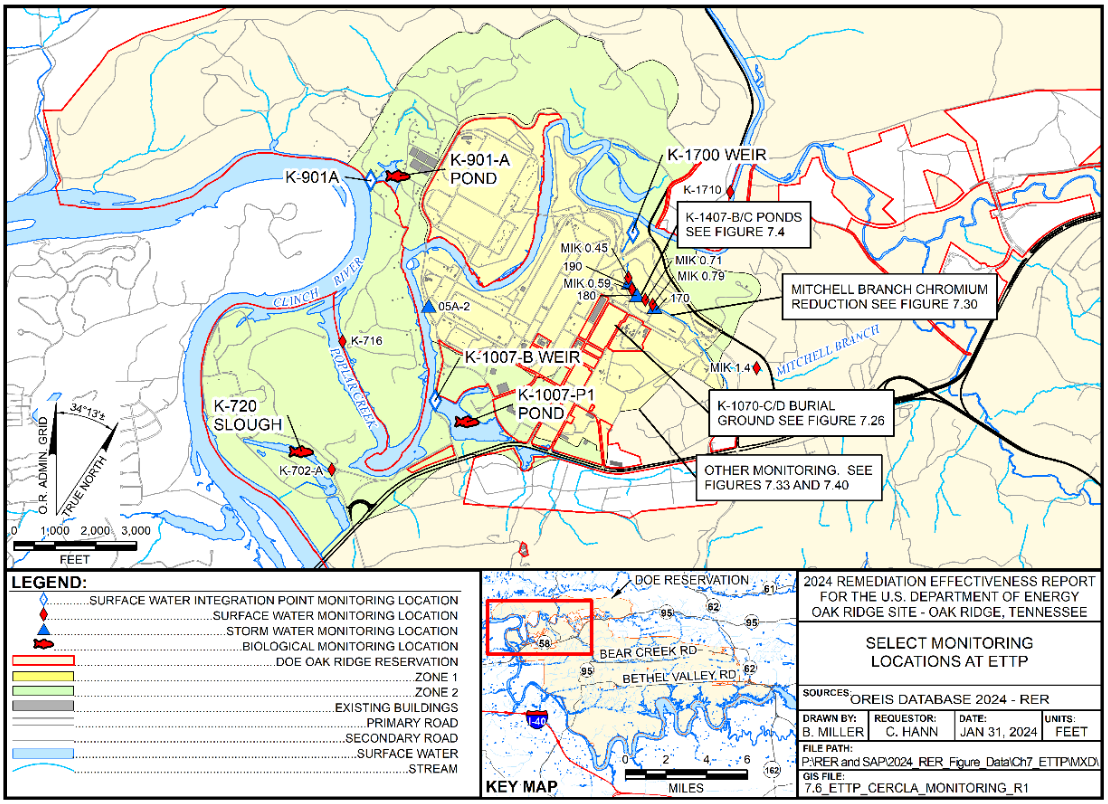
3.6.3. Surface Water Monitoring

During 2023, the ETTP EMP personnel conducted environmental surveillance activities at 12 surface water locations (Figures 3.19 and 3.20) to monitor surface water conditions at watershed exit pathway locations (K-702-A Slough, K-1700, K-1007-B, and K-901-A) or ambient stream conditions (Clinch River kilometers [CRKs] 16 and 23; K-1710; K-716; and MIKs 0.45, 0.59, 0.71, and 1.4). Monitoring locations K-1700 and MIKs 0.45, 0.59, 0.71, and 1.4 were sampled quarterly; and monitoring locations CRKs 16 and 23, K-716, K-1007-B, K-901-A, and the K-702-A slough were sampled semiannually.

Table 3.8. Flow-weighted sampling results from Outfalls 180 and 190

Outfall	Date	Mercury result (ng/L)[a]	Total storm event Precipitation (inches)
180	6/20/2023	**464**	1.16
	8/7/2023	**84.6**	1.05
	9/19/2023	**1070**	0.41
190	4/24/2023	**83.7**	0.65
	5/1/2023	23	0.16
	6/20/2023	**593**	1.04
	8/7/2023	25.1	1.29

[a] *Results in bold exceed the reference standard. The reference standard for mercury (51 ng/L) corresponds to TDEC Rule 0400-40-03-.03(4)(j), "Recreation - Organisms Only Criteria."*



Acronyms:

CRK = Clinch River kilometer

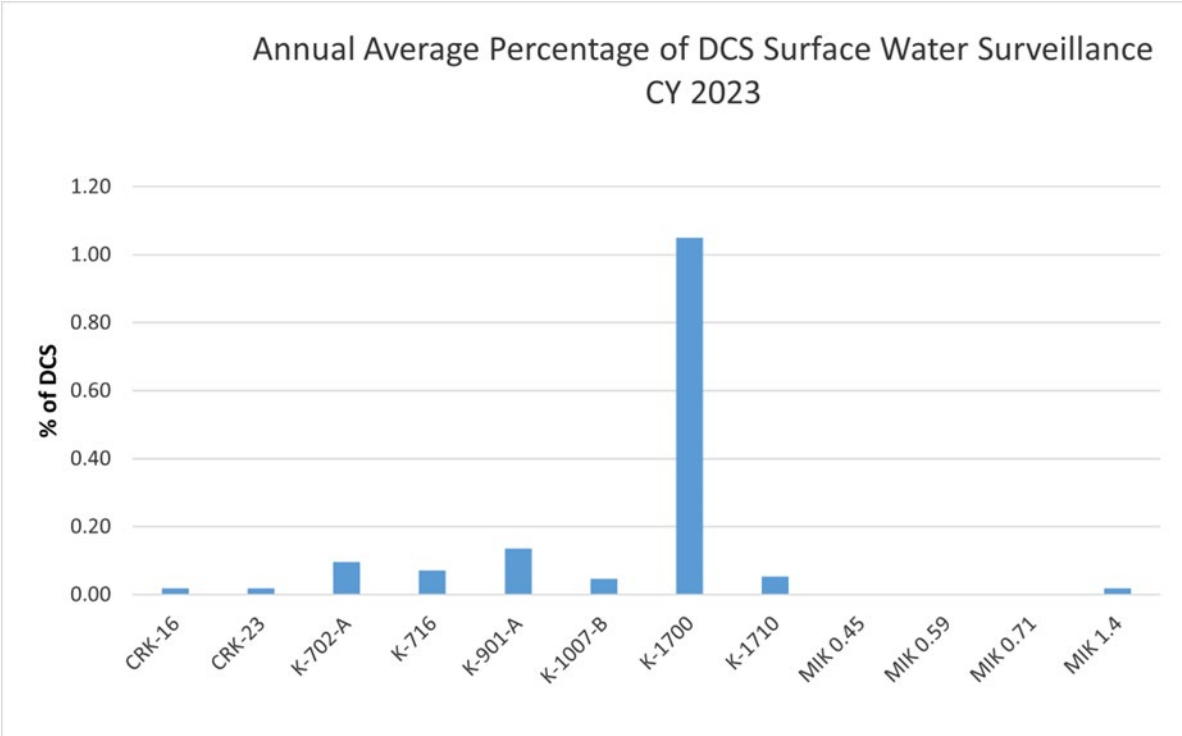
MIK = Mitchell Branch kilometer

Figure 3.19. Select surface water monitoring locations at East Tennessee Technology Park locations

Figure 3.20. Surface water surveillance monitoring

Results of radiological monitoring were compared with the derived concentration standard (DCS) values in the DOE Standard, *Derived Concentration Technical Standard* (DOE 2022a).

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 sum of fractions (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 2023, 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 (shown below in Figure 3.21).



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

Figure 3.21. Annual average percentage of derived concentration standards at surface water monitoring locations, 2023

EMP surface water monitoring results show that conditions in the ETTP waterways usually meet Ambient Water Quality.

At K-1700, the annual average SOF was 0.0105 (1.05 percent). At MIKs 0.45, 0.59, and 0.71, quarterly monitoring is conducted for ^{99}Tc only.

Depending on the monitoring location, water samples may be analyzed for pH, selected metals, and VOCs. In 2023, 1835 analytical results and 179 field readings were collected under the EMP. The vast majority of these results were well within the appropriate AWQC. Sample results that exceeded an applicable AWQC are summarized in Table 3.9. The June 2023 sample from K-716 was taken after a period of significant rainfall, which resulted in a visibly muddy sample with significant suspended sediments. The sediments in the sample likely contributed to the elevated lead and mercury result. In order to investigate this result further, an additional sample was collected in August at K-716 with the result being within the historical range and below AWQC for this location. The low dissolved oxygen measured at K-901A and K-1007B, both collected on August 24, 2023, are within the historic ranges for these locations and are attributed to high temperatures.

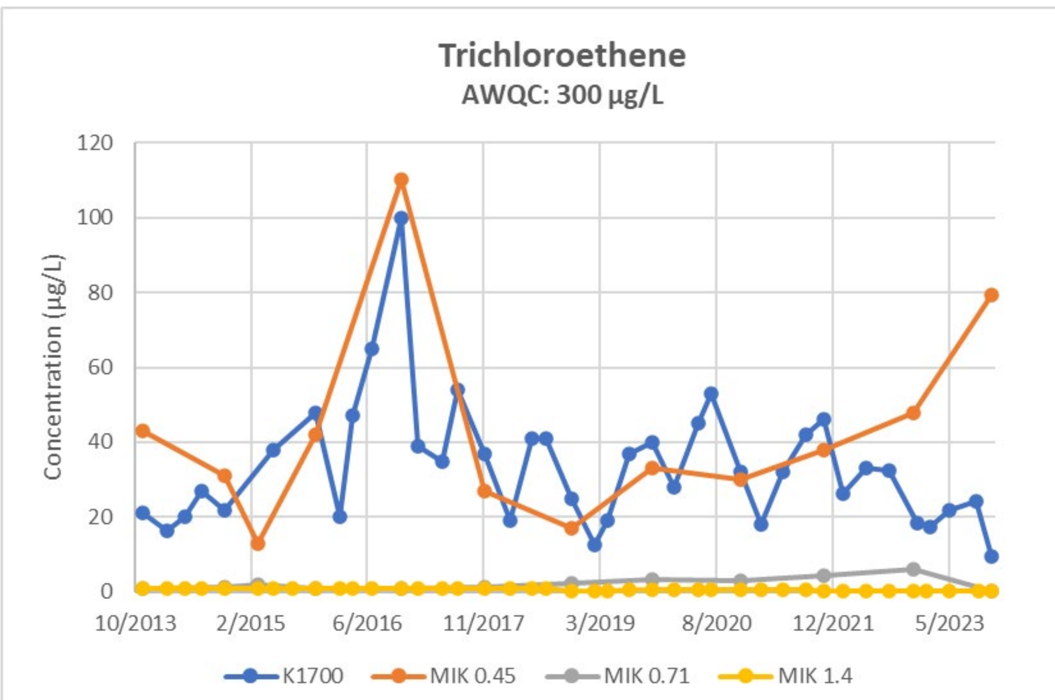
Figure 3.22 illustrates the concentrations of TCE from the Mitchell Branch monitoring locations. Although VOCs are routinely detected at K-1700 and MIK 0.45, they are rarely detected at other surface water surveillance locations across ETTP.

Table 3.9. Water quality criteria exceedances CY 2023

Location ID	Collection Date	Chemical Name	Reference Standard[a]	Result
K-1007B	2/7/2023	PCBs (μg/L)	0.00064	0.039 P J
K-1007B	8/24/2023	PCBs (μg/L)	0.00064	0.036 J
K-1700	8/28/2023	PCBs (μg/L)	0.00064	0.0427 J
K716	6/22/2023	Lead (μg/L) Mercury (ng/L)	2.5, 51	2.7, 89
K-901A	8/24/2023	Lead (μg/L)	2.5	4.52
K-901A	8/24/2023	Dissolved Oxygen (mg/L)	5	4.2
K-1007B	8/24/2023	Dissolved Oxygen (mg/L)	5	**3.7**

[a] *Tennessee Department of Environment and Conservation, Water Quality Control Board. 2019. Rules of the Tennessee Department of Environment and Conservation, Chapter 0400-40-03-.03, General Water Quality Criteria, Criteria for Water Uses. Tennessee Department of Environment and Conservation. Nashville, TN. (TDEC 2019)*

***Note: Results in bold** exceed the reference standard. The reference standards for lead corresponds to TDEC Rule 0400-40-03-.03(3)(g), Fish and Aquatic Life – Criterion Continuous Concentration. The reference standards for mercury corresponds to TDEC Rule 0400-40-03-.03(4)(j), Recreation Organisms Only Criteria.*



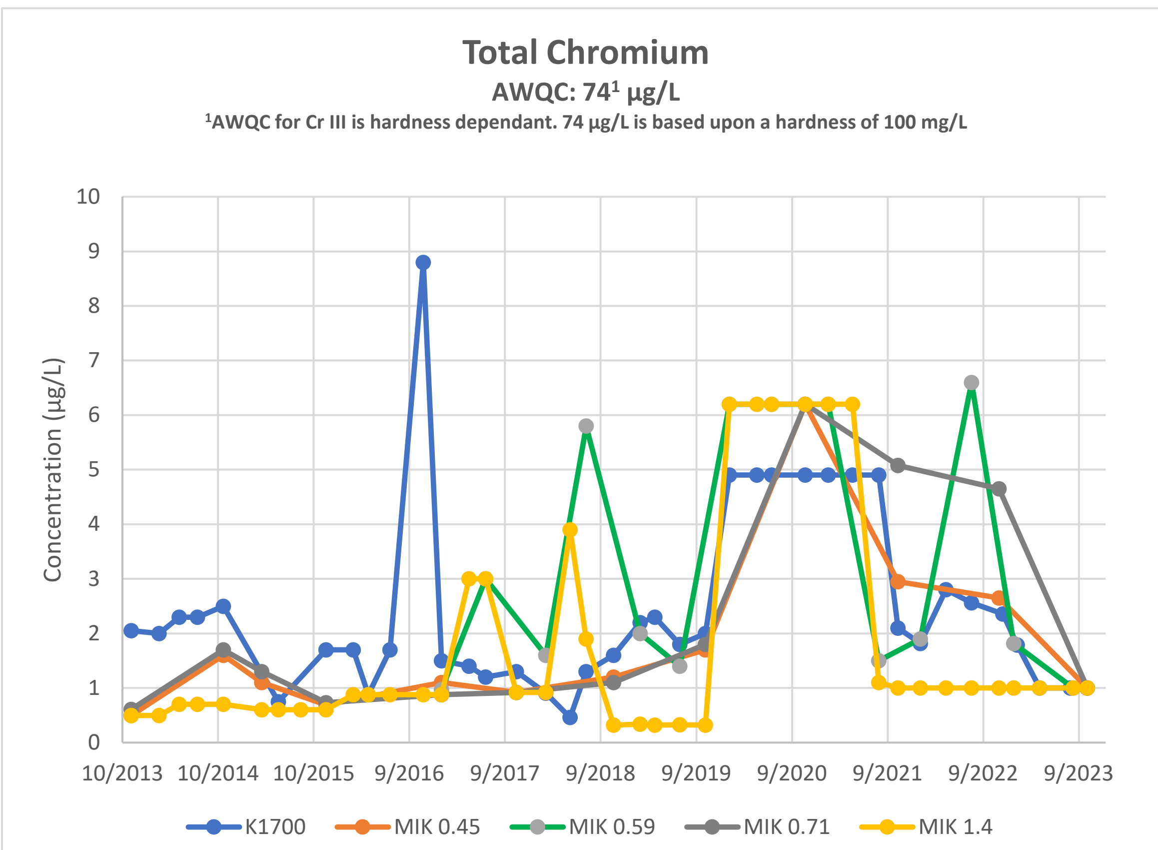
***Acronym:** MIK = Mitchell Branch kilometer*

Figure 3.22. Trichloroethene concentrations in Mitchell Branch

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 2016. Furthermore, even at the increased levels, the results are still well within the AWQC. Concentrations of TCE and total 1,2-dichloroethylene (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. In addition, vinyl chloride (VC) has sometimes been detected in Mitchell Branch water. 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; these compounds have generally not been detected in storm water during the monitoring of network discharges. 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 3.23). In 2023, hexavalent chromium levels in Mitchell Branch were all below the AWQC of 11 µg/L.

In CY 2023, ETTP did not conduct surface water monitoring for per- and polyfluoroalkyl substances (commonly known as "PFAS"). Instead, groundwater was sampled for these compounds. See Section 3.6.4 for details.



Note: *(1) The AWQC for Cr(III), which is hardness-dependent, is 74 µg/L, based on a hardness of 100 mg/L in the receiving waters. The AWQC for Cr(VI) is 11 µg/L.*

Acronyms: *AWQC = ambient water quality criterion MIK = Mitchell Branch kilometer*

Figure 3.23. Total chromium concentrations in Mitchell Branch

3.6.4. Groundwater Monitoring at ETTP

ETTP was divided into two zones to complete the primary source RA work. Zone 1 comprises 1,300 acres outside the ETTP main plant area, and Zone 2 comprises 800 acres of the ETTP main plant area. Actions have been ongoing to characterize and address soil, buried waste, and subsurface structures for protection of human health and the environment and to limit further groundwater contamination through source reduction or removal.

Groundwater at ETTP will be addressed, in part, under the *Interim Record of Decision for Groundwater in the Main Plant Area at the East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2949&D1, DOE 2023b) and the *Record of Decision for Groundwater in the K-31/K-33 Area at the East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2950&D1, DOE 2023c), both submitted in CY 2023. Cleanup of the remaining groundwater will be addressed under the future Main Plant Area Groundwater Final ROD and the Zone 1 Groundwater Plumes ROD.

In FY 2023, planning for the ETTP future RODs continued as follows:

- The East Tennessee Technology Park Main Plant Groundwater Focused Feasibility Study, Oak Ridge, Tennessee (DOE/OR/01-2894&D2, DOE 2022b) and the Proposed Plan for an Interim Record of Decision for Groundwater in Main Plant Area at East Tennessee Technology Park, Oak Ridge, Tennessee (DOE/OR/01-2921&D2/R1, DOE 2023d) were approved by EPA and TDEC.
- The Remedial Investigation/Feasibility Study Report for the K-31/K-33 Area at the East Tennessee Technology Park, Oak Ridge, Tennessee (DOE/OR/01-2893&D2, DOE 2022c) was approved by EPA and TDEC through an erratum, and the Proposed Plan for the Record of Decision for Groundwater in the K-31/K-33 Area at the East Tennessee Technology Park, Oak Ridge, Tennessee (DOE/OR/01-2922&D2, DOE 2023e) was approved by EPA and TDEC.
- The Zone 1 Groundwater Plumes Remedial Investigation Work Plan, East Tennessee Technology Park, Oak Ridge, Tennessee (DOE/OR/01-2903&D2, DOE 2022d) was approved by EPA and TDEC and the Addendum to the Zone 1 Groundwater Plumes Remedial Investigation Work Plan for the K-720 Fly Ash Pile, East Tennessee Technology Park, Oak Ridge, Tennessee (DOE/OR/01-2903&D2/A1, DOE 2023f) was submitted to and approved by EPA and TDEC.

The data screen and trend assignments show contaminant concentration trends are highly variable across the site. Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Derived Concentrations (MCL-DCs) for radionuclides are used as screening levels for groundwater and are not ROD performance standards. RODs for ETTP groundwater are pending. A summary of continued baseline groundwater monitoring in accordance with the *East Tennessee Technology Park Administrative Watershed Remedial Action Report Comprehensive Monitoring Plan, Oak Ridge, Tennessee* (DOE/OR/01-2477&D4; DOE 2020b) follows:

- 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. Although most VOCs exhibit significant decreasing trends over the past ten years, these trends are generally indeterminate over the past five years. The continued detection of VOCs at concentrations above 1,000 µg/L and the relatively steady concentrations over recent years suggest the presence of DNAPL in the vicinity of the former K-1407-B Pond.
- VOC concentrations in wells monitored downgradient of K-1070-C/D show a broad area is affected by past disposal releases of liquid VOCs at G-Pit. The persistent, high concentrations of these VOCs in nearby wells suggest an ongoing contaminant source release.
- In the K-31/K-33 area, only nickel was measured at levels slightly greater than the

MCL and Tennessee groundwater criteria at well UNW-043. Nickel in this well shows a decreasing concentration trend.

- At the K-27/K-29 area, groundwater contamination migrates toward Poplar Creek in both north and south directions from the former area facilities.
  - Alpha activity and total uranium concentrations in BRW-016 in the north exit pathway continued to exceed the MCL in FY 2023. This well was inundated by water from D&D runoff in FY 2019. Vinyl chloride and cis-1,2-DCE also exceeded the MCL in the northern portion of the K-27/K-29 area north exit pathway in FY 2023.
  - Chromium and nickel exceeded the MCL and Tennessee groundwater criteria screening concentration (0.1 mg/L) in the unfiltered samples from well UNW-096 in the south/west exit pathway. TCE also exceeded the MCL screening concentration (0.005 mg/L) in two wells (UNW-038 and UNW-096). The 5-year TCE trends in the K-27/K-29 southern area are stable to increasing at these two wells.
- VOCs are present in groundwater at the now-remediated K-1070-A Burial Ground in the northwestern portion of ETTP. Groundwater contaminated primarily with TCE discharges at downgradient spring 21-002, which flows into the northern end of the K-901-A Holding Pond. Although TCE concentrations fluctuate above and below the MCL screening concentration of 5 µg/L, six of the last 12 samples collected at spring 21-002 have exceeded the MCL for TCE.
- TCE is the most significant groundwater contaminant detected at spring PC-0, which is submerged beneath the Watts Bar lake level from April to October each year, and is located on the shore of PC near the confluence with the CR. During FY 2023, the maximum detected TCE concentration of 7 µg/L slightly exceeded the MCL of 5 µg/L. The PC-0 spring exhibits a decreasing trend in TCE concentration over the past 10-year and 5-year periods.

3.6.4.1. K-1407-B/C Ponds

The K-1407-B Pond, 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, K-1420 plating wastes that generated F006 hazardous wastes pond sludge, 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 ETTP. 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 *Remedial Action Report for the K-1407-B Holding Pond and the K-1407-C Retention Basin, Oak Ridge, Tennessee* (DOE 1995) proposed semiannual groundwater monitoring for nitrate, metals, VOCs, and selected radionuclides, including gross alpha and beta activity, ^{99}Tc, ^{90}Strontium, ^{137}Cesium, ^{230}Thorium, ^{232}Thorium, ^{234}U, and ^{238}U. Target concentrations for these parameters were not established (DOE 1993b, DOE 1995). However, as recommended by EPA with concurrence from TDEC, monitoring for the constituents listed for the K-1407-B Pond is conducted in wells UNW-003, UNW-009, and the Mitchell Branch Weir (K-1700 Weir.

The primary groundwater contaminants in the K-1407-B/C Ponds area are VOCs. VOCs are widespread and persistent in this portion of ETTP, including contaminant sources upgradient of the ponds. Figure 3.24 presents the combined unconsolidated and bedrock plume boundaries for total VOCs, at the top of the map (north of 14th Street).

DOE has compiled analytical data from groundwater monitoring well UNW-003 to evaluate concentration trends for regulated contaminants. Data are compared to EPA's

National Primary Drinking Water Regulations MCLs or MCL-DCs for radionuclides, for screening purposes and for identifying constituents and wells for trend analysis. The MCLs and MCL-DCs are not criteria identified in the 1993 K-1407-B/C Ponds ROD.

In recent years, large seasonal variations in VOC concentrations have been measured at well UNW-003, which continues to exhibit high concentrations of VOCs in the unconsolidated zone at the K-1407-B pond. DOE suspects a dense non-aqueous phase liquid source exists somewhere beneath the former pond site based on persistent high VOC concentrations in both shallow and deeper groundwater wells. Data are consistent in showing significant decreasing contaminant concentration trends for five VOCs (1,1-DCE, cis-1,2-DCE, tetrachloroethene [PCE], TCE, and VC) at this location over the past 10 years. However, no trends could be determined over the past five years for these VOCs, but significant decreasing contaminant concentration trends are present for the maximum concentration evaluations for these same five VOCs over the past five years. The FY 2023 results from UNW-003 remain consistent with the plume boundary depicted in Figure 3.24.

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

The K-1070-C/D G-Pit was the primary source of organic contaminant releases to soil and groundwater in the area immediately west of the K-1070-C/D Waste Disposal 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 (DOE 1998). The contents of the pit were excavated and a soil cover was placed over the concrete pad earlier. Residual contaminated groundwater in the K-1070-C/D G-Pit and Burial Ground area will be addressed in a future decision. 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 (downgradient) of the K-1070-C/D Burial Ground are analyzed for VOCs and general water quality parameters. Monitoring at the site focuses on providing data for evaluating changes in contaminant concentrations near the source units or potentially discharging to surface water within the ETTP boundaries.

Following G-Pit remediation, monitoring wells UNW-114, TMW-011, and UNW-064 (see Figure 3.24) were selected to monitor the VOC plume leaving the K-1070-C/D Burial Ground because they were located in the principal known downgradient groundwater pathway. Well monitoring results show elevated VOC concentrations. The VOC concentrations at these three wells began to decrease prior to excavating the G-Pit contents (during FY 2000) and continue to decrease. Although 1,1,1-trichloroethane (1,1,1-TCA) was formerly present at concentrations far greater than its 0.2 mg/L MCL, natural biodegradation and advective groundwater processes within the monitoring zone have reduced 1,1,1-TCA concentrations to less than the drinking water standard. Several direct-push technology monitoring points were installed to the west of UNW-114 during investigations conducted 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 to measure VOC concentrations and their fluctuations downgradient of G-Pit.

DOE has compiled analytical data from K-1070-C/D groundwater monitoring to evaluate concentration trends for regulated contaminants. Data are compared to EPA's National Primary Drinking Water Regulations MCL, for screening purposes; however, MCLs are not identified as criteria in the ROD (DOE 1997). Groundwater contaminant trends in the area downgradient of the G-Pit source are mostly stable to indeterminate, with decreasing trends for PCE and TCE at well UNW-114 for the 10-year evaluation period. Although most contaminants exhibit stable, indeterminate, or decreasing trends over the past 5-year and 10 year periods, concentrations of 1,1-DCA and VC at well UNW-114 have exhibited increasing concentrations since 2008 and 2009, respectively. Seasonal variations in VOC concentrations are very commonly observed. The FY 2023 results from UNW-114, UNW-064, and TMW-011 remain generally consistent with the plume boundary depicted in Figure 3.24.

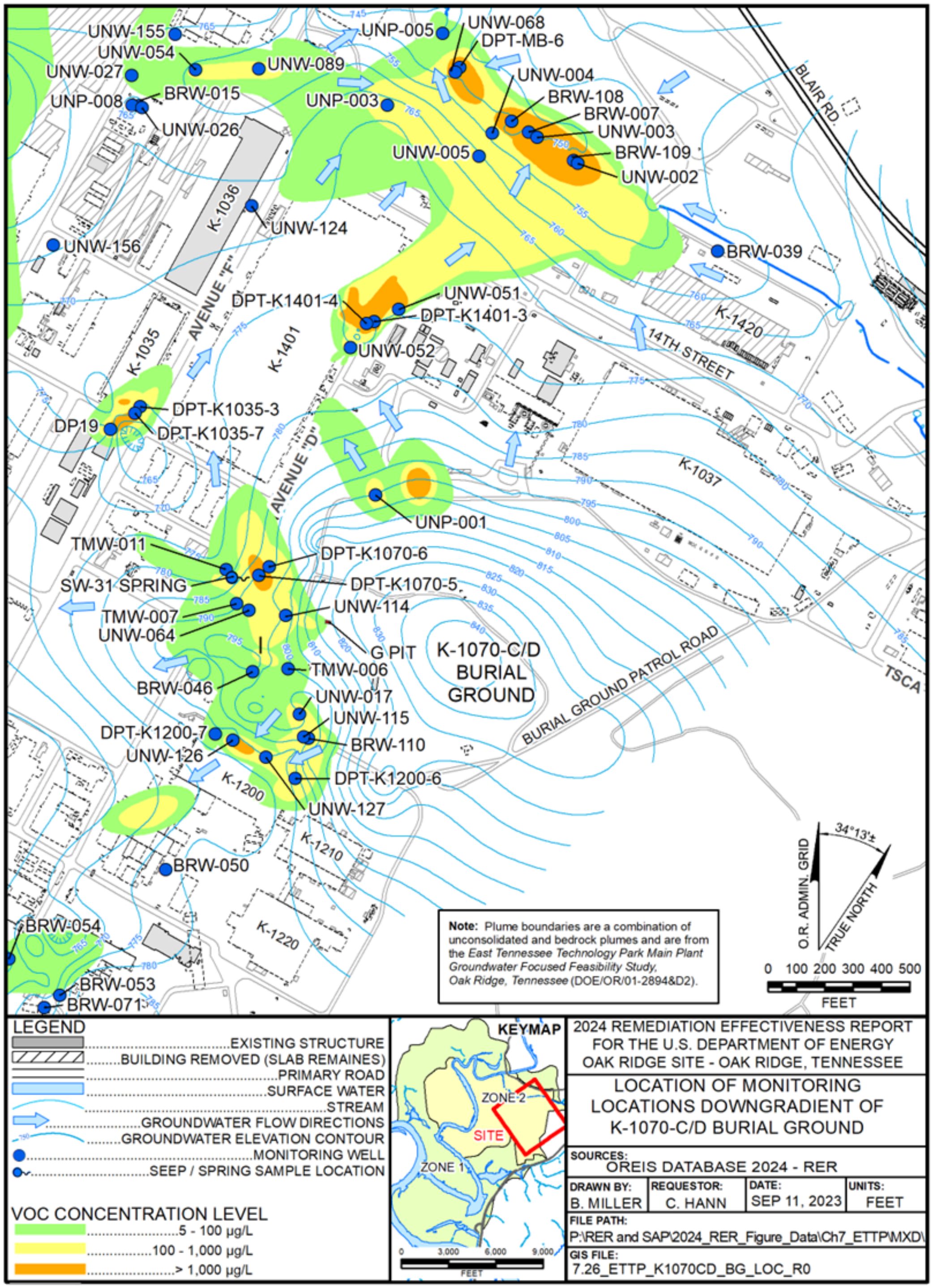


Figure 3.24. Location of monitoring locations downgradient of K-1070-C/D Burial Ground

Well UNW-064 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 2002–2005, but have remained relatively stable since that time period. Trend evaluations for VOCs in well UNW-064 for a 10- year period indicate no significant trend for 1,1-DCE and TCE and a stable trend for VC. The most recent five-year period trends indicate a stable trend for 1,1-DCE; a decreasing trend for TCE, with a stable trend for the annual maximum concentrations; and no trend for VC.

Well TMW-011 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 the seasonal signature is reversed, with higher concentrations in summer than during winter. This relationship suggests 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.

Overall, throughout the monitoring period of record, there have been decreases in the parent VOC (1,1,1-TCA and TCE) concentrations, with slight increases in concentrations of some of the degradation pathway compounds (e.g., 1,1-dichloroethane and VC) in the vicinity of the source (UNW-064 and UNW-114). The FY 2023 increase in VC concentrations at UNW-064 and UNW-114, which generally correlate to TCE and other precursor compound (i.e., cis-1,2-DCE) concentration decreases, likely represents the result of natural biodegradation from intrinsic dehalogenating bacteria in groundwater in the vicinity of these wells.

3.6.4.3. Groundwater Pathway Plumes

Figure 3.25 presents the current sitewide contaminant plume map for the sum of VOC plumes from the Main Plant Area Focused Feasibility Study (DOE 2022b), K-31/K-33 Remedial Investigation/Feasibility Study (DOE 2022c), and Zone 1 Remedial Investigation Work Plan (DOE 2022d). Figure 3.25 also shows the locations of exit pathway monitoring wells throughout the ETTP site that are routinely sampled by the Water Resources Restoration Program (WRRP) for known COCs, inferred groundwater flow directions in plume areas, and direction of surface water flow. As shown, the inferred groundwater flow directions are based on the water table piezometric surface contours. Shallow groundwater plumes generally flow in conformance to the local gradients, although in some areas, especially where geologic structures such as bedrock folding, fracturing, and karst development occur, groundwater may flow through secondary porosity features in directions oblique to inferred gradients.

For each of these exit pathway wells, DOE has compiled analytical data for groundwater contaminants for the past 10 years. The compiled data are compared to EPA's National Primary Drinking Water Regulations MCLs or MCL-DCs for radionuclides. The summary of trend evaluations for the exit pathway wells in increments of the past 10 years and the last 5 years of monitoring show that, in general, contaminants that have exceeded their respective MCL concentrations have decreased in concentrations. Trends also show mixed results of statistically significant decreases in some cases, increasing trends in other cases, and some instances in which trends are indeterminate or stable. Some metals (e.g., chromium and nickel) tend to be measured at or above MCL concentrations, with a tendency for particle-associated metals to lead to these MCL exceedances based on often-lower metal concentrations in filtered sample aliquots.

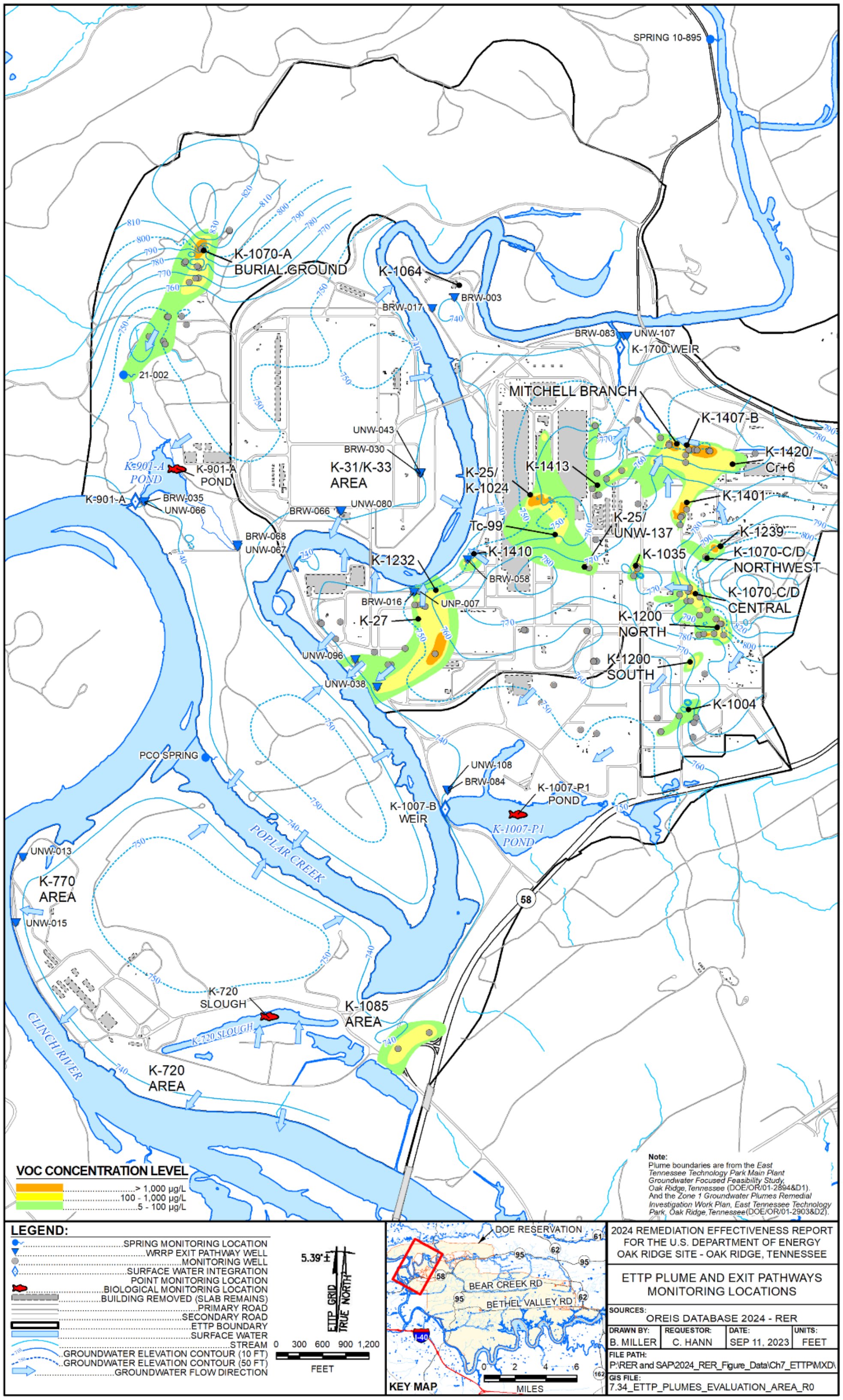


Figure 3.25. East Tennessee Technology Park plume and exit pathways monitoring locations

Mitchell Branch

The Mitchell Branch groundwater exit pathway is monitored using surface water data from the K-1700 Weir on Mitchell Branch. Wells BRW-083 and UNW-107, located near the mouth of Mitchell Branch, have also 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 flowpaths that can fluctuate with seasonal hydraulic head conditions, which are strongly affected by rainfall and long-term and short-term Watts Bar Reservoir fluctuations. During FY 2023, only low estimated concentrations of VOCs were detected in semiannual samples from one of these monitoring wells. The VOCs cis-1,2-DCE; trans-1,2-DCE; and TCE were detected in the unconsolidated monitoring well UNW-107 at concentrations less than 1 μg/L in FY 2023.

K-1064 Peninsula Area

Exit pathway wells BRW-003 and BRW-017 monitor metals and VOCs in groundwater at the K-1064 Peninsula Burn area. Metals detected in groundwater at the site include arsenic and chromium; however, during FY 2023, concentrations of these metals were less than their respective MCLs. Historically, VOC contaminants exceeded MCLs in wells BRW-003 and BRW-017; however, regulated VOC concentrations have declined to below screening levels.

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. During FY 2023, only nickel was detected at concentrations greater than its MCL. Nickel was detected in FY 2023 in both filtered and unfiltered samples from UNW-043 at concentrations above the MCL screening concentration (0.1 mg/L). However, trend evaluations for nickel in UNW-043 indicate declining 5-year and 10-year concentrations at this well. Nickel was detected in FY 2023 below 80 percent of the MCL screening concentration in UNW-080 filtered and unfiltered samples.

K-27/K-29 exit pathway areas

Groundwater discharges toward Poplar Creek in both a northward pathway beneath the K-1232 area and in a south-to-westward pathway, as shown earlier on Figure 3.25. 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.

During FY 2019, a high alpha activity result occurred in well BRW-016 in September 2019. This result was likely caused by infiltration of water down the well bore associated with D&D activities in the area. DOE redeveloped the well to remove residual infiltrated contamination to the extent practical. The well was pumped and swabbed to remove as much sediment and contaminated water as possible and was returned to service. A subsequent sample collected in March 2020 showed large reductions in contaminant concentrations compared to the levels measured prior to well redevelopment, and the August 2020 alpha activity decreased further but remained greater than the 15-pCi/L MCL screening concentrations. Alpha activity remained lower in FY 2023 with a concentration of 46 pCi/L but remained greater than the MCL screening concentration. VOCs have exceeded MCLs in the K-27/K-29 area northern pathway. However, in FY 2023, VC was the only VOC detected above its MCL screening concentration (0.002 mg/L), with a maximum detected concentration of 0.021 mg/L in well BRW-058. Trend evaluations for well BRW-058 indicate significant upward trends for the prior 10-year period and no determinate trend over the five-year period for VC at this well.

In the south/west exit pathway from the K-27/K-29 area, TCE is persistent in the exit pathway wells and exceeds the MCL at both wells, with stable trends at well UNW-038 and increasing trends at well UNW-096 over the 10-year and 5-year periods. Chromium concentrations were greater than the MCL in samples from well UNW-096 in FY 2023. Nickel concentrations equaled or exceeded the Tennessee MCL of 0.1 mg/L in well UNW-096 in unfiltered and filtered FY 2023 samples, with maximum concentrations of 0.25 and 0.15 mg/L, respectively.

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 3.25). During FY 2023, no regulated contaminants have equaled or exceeded their respective MCLs.

K-901-A Holding Pond and Duct Island areas

Exit pathway groundwater in the K-901-A Holding Pond area (Figure 3.25) is monitored by four wells (BRW-035, BRW-068, UNW-066, and UNW-067) and two springs (21-002 that flows into the K-901-A Holding Pond, and PC-0 that discharges into Poplar Creek on the west side of Duct Island). No regulated contaminants equaled or exceeded MCL concentrations at any of the four wells in FY 2023 samples.

TCE is the most significant groundwater contaminant detected in the springs. Spring PC-0 was added to the sampling program in 2004.

During April–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 spring PC-0 is presumed to be legacy waste disposed of at the former K-1070-F contractor's spoil area located on Duct Island. The TCE concentrations in spring PC-0 have varied between non-detectable levels and 26 µg/L and have decreased from their highest measured value in 2006. During FY 2023, the maximum TCE concentration in spring PC-0 quarterly samples was 7 µg/L measured in a sample collected in December 2022. The February 2023 sample for TCE also exceeded the MCL with a concentration of 5.2 µg/L. TCE concentrations in the remaining FY 2023 samples were all below the MCL screening concentration of 5 µg/L, and TCE shows a significant decreasing trend for both the 10-year and 5-year periods.

TCE that originates from the now-remediated K-1070-A Burial Ground is the principal contaminant detected at spring 21-002.

The conceptual behavior of this TCE contaminant plume is described by higher concentration, but lower flow, during the dry season with apparently subdued effects of rainfall on spring TCE concentrations. During the wet season, the overall TCE concentrations at spring 21-002 are lower; however, wet-season, increased rainfall-driven, groundwater-flow pulses push TCE concentration pulses through conduits that discharge at spring 21-002. TCE exceeded the MCL in FY 2023 samples collected at spring 21-002 with a maximum concentration of 17 µg/L detected in the December 2022 sample. TCE concentrations show a downward trend for the past 10-year period and no determinate trend for the past 5-year period at spring 21-002. Because 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, there is uncertainty associated with the contaminant trend directions assigned to the spring data.

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 (Figure 3.25). Alpha activity measured in samples from well UNW-015 has exceeded the 15-pCi/L MCL once within the past 10 years. During FY 2023, the maximum alpha activity was 13 pCi/L, which is below the 15-pCi/L MCL, and no other regulated contaminants exceeded their MCLs in these two wells.

3.7. Biological Monitoring

The ETTP Biological Monitoring and Abatement Program (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 3.26 shows the major water bodies at ETTP and Figure 3.27 shows the BMAP monitoring locations along Mitchell Branch.

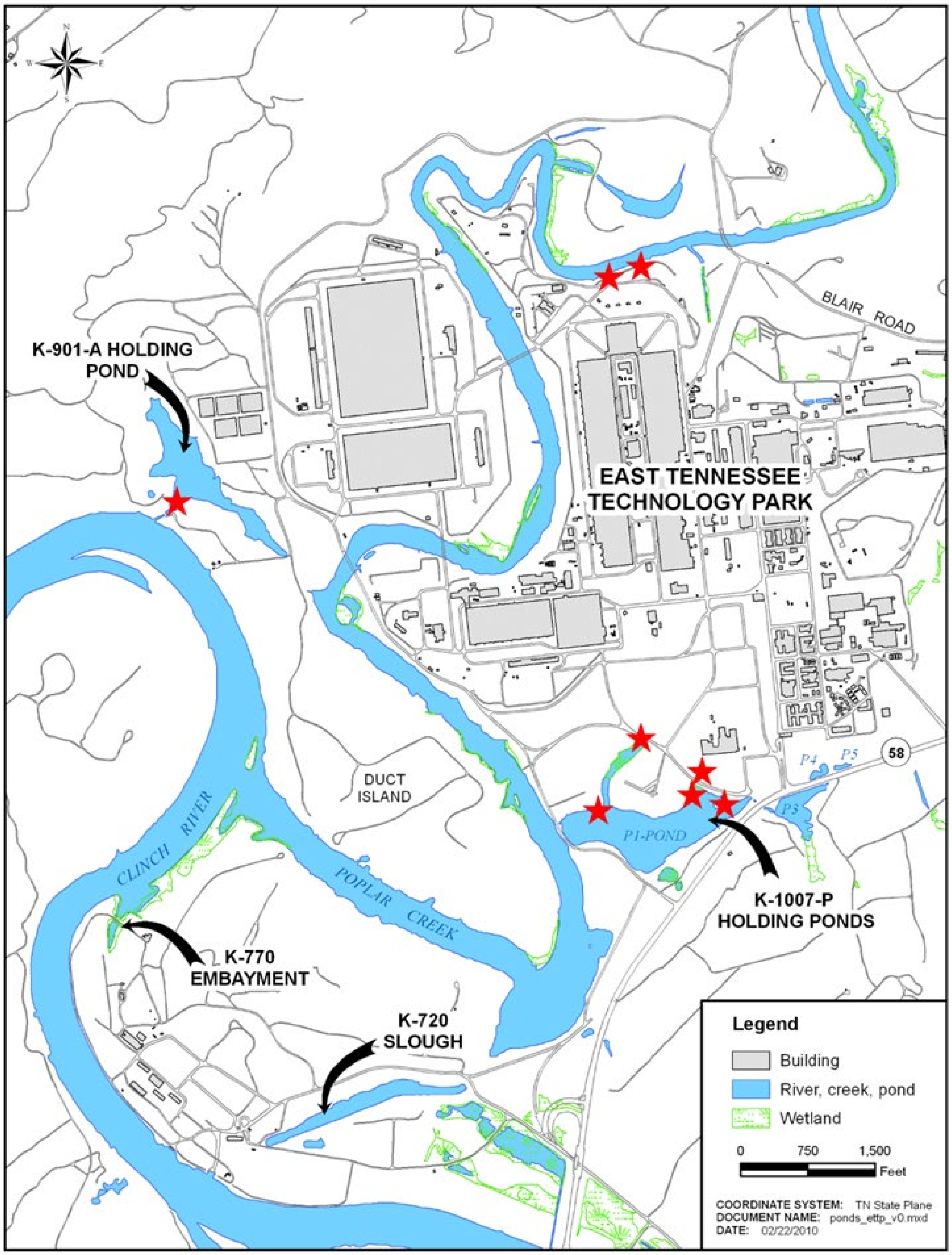
3.7.1. Task 1: Bioaccumulation Monitoring

Bioaccumulation monitoring for the ETTP BMAP has focused on evaluating the impact of 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. However, more recent 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 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.

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 off-site 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, fish bioaccumulation data have become important measures of compliance for both the CWA and CERCLA.

For Hg, the EPA National Recommended Water Quality Criterion for Hg in fish (0.3 micrograms/gram [μg/g]) is used as the trigger point for fish consumption advisories in Tennessee, the target concentration for NPDES 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 AWQC for Hg of 51 ng/L in water, based on organisms only, and 50 ng/L for recreation-water and organisms. 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 reservoir (Melton Hill, Watts Bar, and Fort Loudon). However, most conventional PCB water analyses have detection limits much higher than the PCB AWQC.



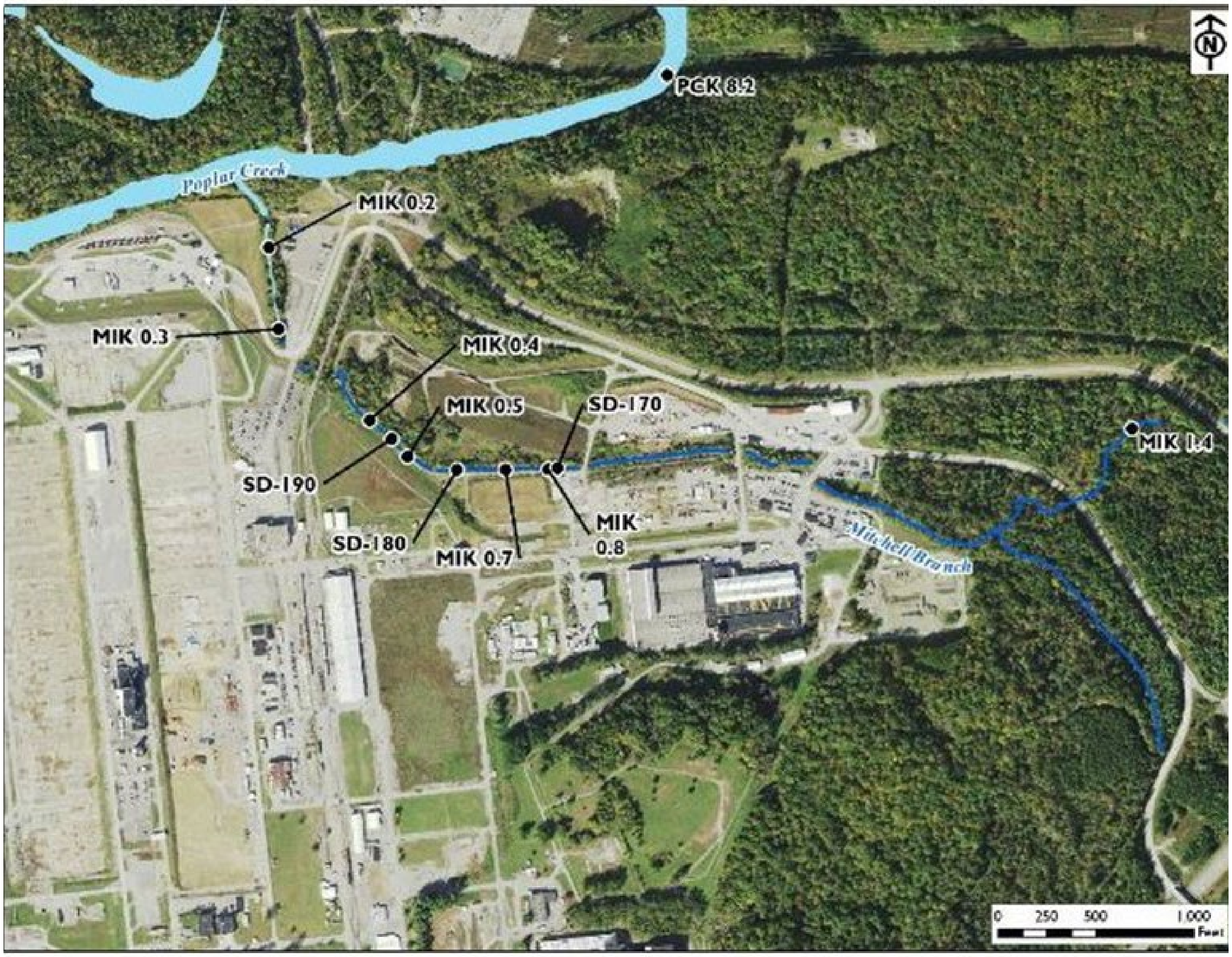
Note: *Red stars indicate clam sampling locations in and around the ETTP complex in 2023 (Mitchell Branch sites not shown).*

Acronyms:

CRM = Clinch River mile PCK = Poplar Creek kilometer MIK = Mitchell Branch kilometer

SD = storm drain

Figure 3.26. Water bodies at the East Tennessee Technology Park



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

Figure 3.27. Major storm water outfalls and biological monitoring locations on Mitchell Branch

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 that has been used by 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. The fish PCB concentrations at and near ETTP are 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 Meigs County, Tennessee) and are divided into groups of 10 clams of equal mass. In 2023, clams were placed in baskets to be deployed at strategic locations around ETTP (i.e., in and around storm drains) for a four-week exposure period (May 11– June 8, 2023). Two clam baskets were placed at each site with 10 clams in each basket.

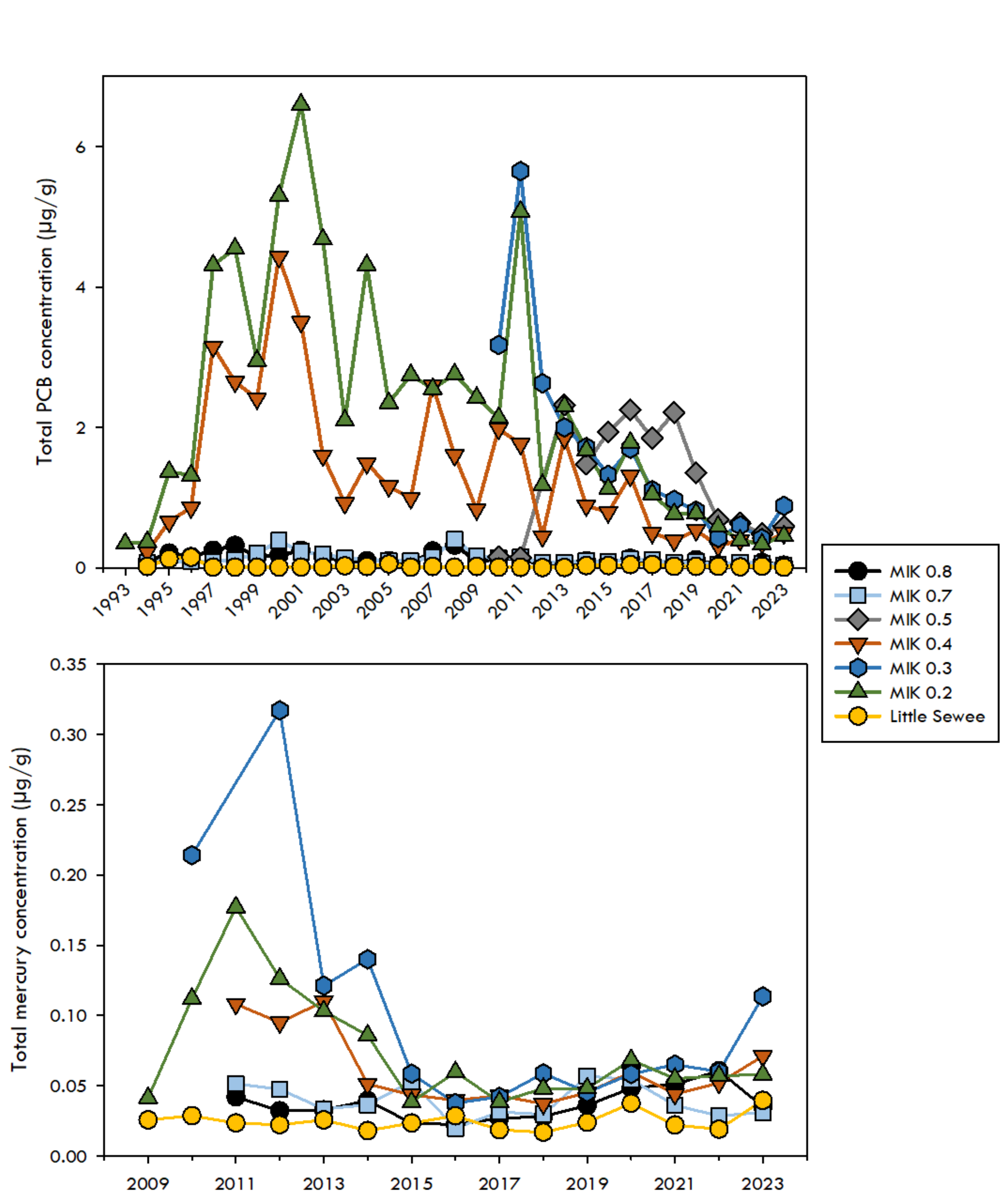
Because these animals are sedentary filter feeders, they accumulate contaminants that are present in the water and in suspended particles at a given site. They are useful indicators of the bioavailable (and therefore potentially toxic) portion of contaminants that enter the environment at a given location, 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 25 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 hot spots 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 TSS from the outfalls of K-1007-P1 and K-901-A, upper and lower storm drain (SD)-100, and an uncontaminated reference site (upper First Creek, ORNL). Samples are collected four times each year (March/April, June, July, and August).

3.7.1.1. Mitchell Branch

Figure 3.28 shows long-term monitoring results in caged clams deployed 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. In 2023 PCB concentrations in clams in this stretch of the creek continued to be slightly elevated (~0.5–0.9 µg/g) with respect to other Mitchell Branch and reference sites. 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 increase in PCB concentrations at all lower Mitchell Branch sites in 2016, concentrations have generally trended downward since. PCB concentrations in the upper portion of Mitchell Branch were similar to previous years' concentrations and were slightly elevated (0.04 µg/g) with respect to the reference site (0.01 µg/g).

Mercury concentrations in clams deployed in Mitchell Branch in 2023 were generally similar to concentrations seen in 2022, except at MIK 0.3, where the Hg concentration nearly doubled (from 0.06 to 0.11; Figure 3.29). Within the Mitchell Branch system, the highest Hg concentrations were seen in clams deployed at SD180 (0.15 µg/g). Clams deployed in SD150 (upstream of MIK 0.8) had Hg concentrations similar to those of the reference site (0.03 and 0.04 µg/g, respectively). Mercury concentrations in clams deployed at the K-1007-P1 and K-901-A Ponds were again comparable to reference site concentrations. Unlike in fish tissue, MeHg in the soft tissues of clams generally made up a small proportion of Hg_T (Figure 3.29). MeHg concentrations in clams remained low in 2023, comparable to concentrations in 2022, with the exception of a slight increase in MeHg at MIK 0.2 (from 0.03 to 0.04 µg/g).

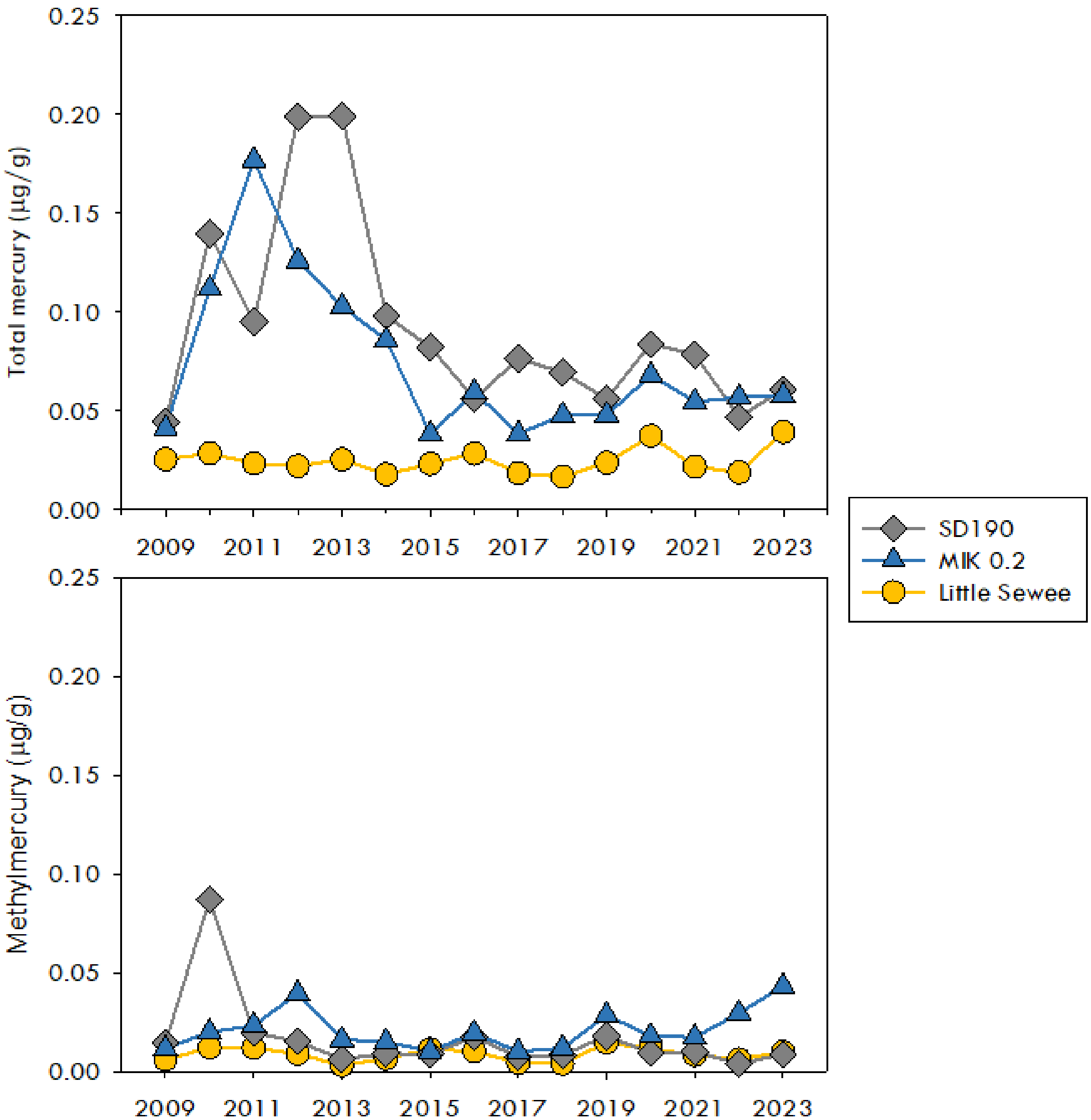


Notes:

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 (Meigs County, Tenn.).*
3. *Total PCBs is defined as the sum of Aroclors 1248, 1254, and 1260.*

Acronyms*: MIK = Mitchell Branch kilometer PCB = polychlorinated biphenyl*

Figure 3.28. Mean total PCB (Top: µg/g, wet wt; 1993–2023) and mercury (Bottom: µg/g wet wt; 2009–2023) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch



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)*

Acronyms: *MIK = Mitchell Branch kilometer* *SD = storm drain*

Figure 3.29. Total (top panel) and methylmercury (bottom panel) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch (µg/g wet wt; 2009–2023)

Figure 3.30 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 2023 (0.59 ± 0.1 µg/g) were lower than those seen in 2022 (0.71 ± 0.1 µg/g) but remained comparable to concentrations seen at this site in recent years. 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 2023, the mean PCB concentration in sunfish fillets collected from MIK 0.2 was below this limit, but was above the most conservative limit of 0.02 µg/g. While the observed fish tissue concentrations in Mitchell Branch are lower than they have historically been, they are still two to three orders of magnitude higher than concentrations seen in the same species at the Hinds Creek reference site in Anderson County.

Total mercury has been monitored more sporadically in redbreast sunfish fillets at MIK 0.2. Figure 3.30 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 concentrations have 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. Mean mercury concentrations in redbreast at this site remained just above the mercury tissue criterion, averaging 0.37 + 0.03 µg/g in 2023.

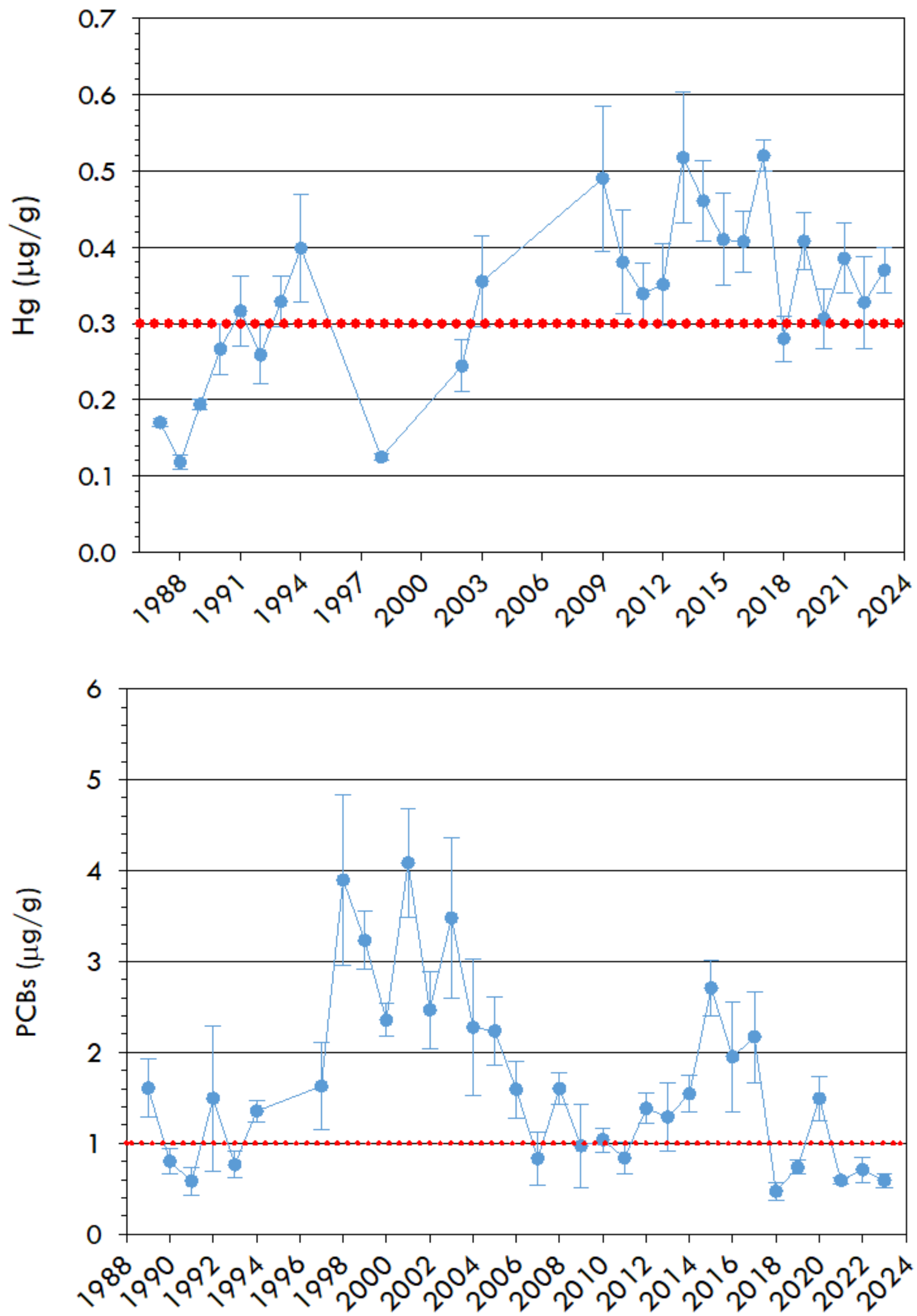
3.7.1.2. 1007-P1 Pond

Over the past decade, mean aqueous PCB concentrations in the K-1007-P1 Pond have fluctuated significantly but have generally been lower than concentrations seen before 2009 remediation activities (e.g., 50 ng/L in 2023 compared with 161 ng/L in 2007; Figure 3.31). Concentrations in 2023 were slightly higher than in 2022, but still were also comparable to the lowest recorded average PCB concentration since remediation (26 ng/L in 2015). PCBs tend to be particle associated and are positively correlated with TSS. The fluctuations in PCB and TSS concentrations in water in the K-1007-P1 Pond could be related to fluctuations in aquatic plant coverage, which can affect sediment stability. The aqueous PCB concentrations measured in the K-1007-P1 Pond are above concentrations seen at the First Creek reference site (0.16 ng/L in 2023) and are above the state of Tennessee water quality criterion for the protection of fish and wildlife (14 ng/L).

PCB concentrations in clams placed at lower and upper SD-100 locations have fluctuated significantly since remediation actions in 2009, but were on an overall decreasing trajectory until the significant increases seen in 2017 and 2018 (Figure 3.32). However, in 2022, PCB concentrations at both upper and lower SD100 began increasing and continued to increase in 2023 to the highest concentration since 2005 and 2007, respectively. Although an order of magnitude lower than concentrations at upper SD100, PCB concentrations in clams placed at the K-1007-P1 Pond outfall followed the same temporal trends as the those at SD100 locations, with a slight increase 2022 and 2023. PCB concentrations at SD120 and SD490 remained similar to values seen since 2012. Total Hg and MeHg concentrations in clams deployed at the K-1007-P1 Pond were lower than concentrations in clams deployed at the reference site, Little Sewee Creek. (Figure 3.32).

Similar trends have been observed in fish tissue PCB concentrations in the K-1007-P1 Pond (Figure 3.33). 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 6 whole body composites (10 bluegill per composite) from the K-1007-P1 Pond were analyzed for PCBs in 2023 to assess the ecological and human health risks associated with PCB contamination in this pond.

While PCB concentrations in fish and in caged clams at K-1007-P1 Holding Pond have been fluctuating for the past few years, in 2023 biota concentrations decreased such that both fillets

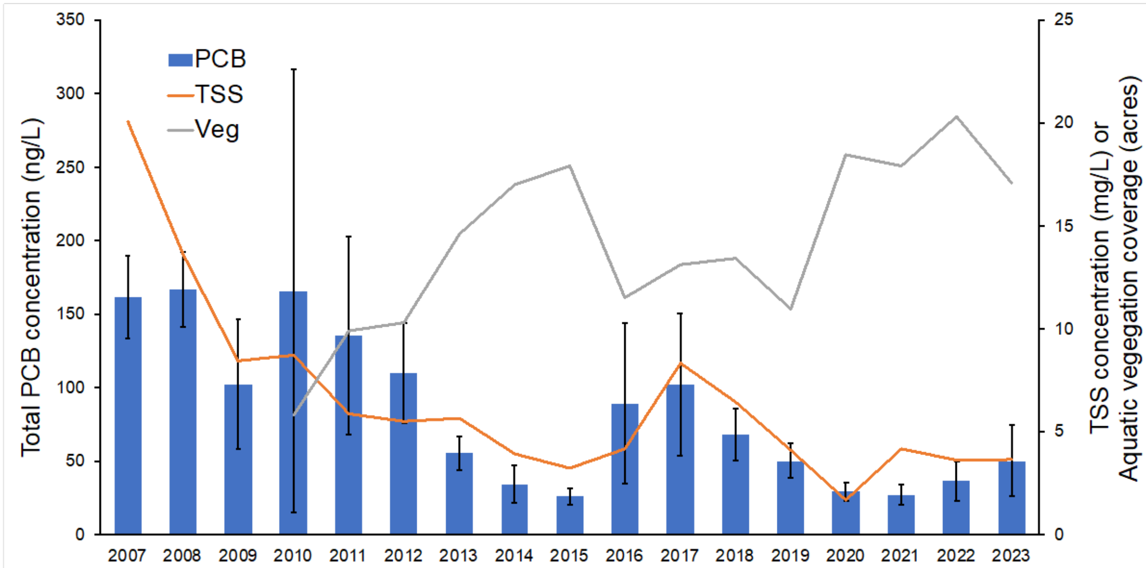


Notes:

1. *N = 6 fish per year.*
2. *Shown in red is the fish advisory level for mercury in fish fillets (0.3 µg/g).*

Acronyms*: Hg = mercury MIK = Mitchell Branch kilometer PCB = polychlorinated biphenyl*

Figure 3.30. Mean mercury (top panel) and PCBs (bottom panel) concentrations (µg/g, wet wt) in redbreast sunfish fillets in Mitchell Branch (MIK 0.2), 1989–2023



Notes:

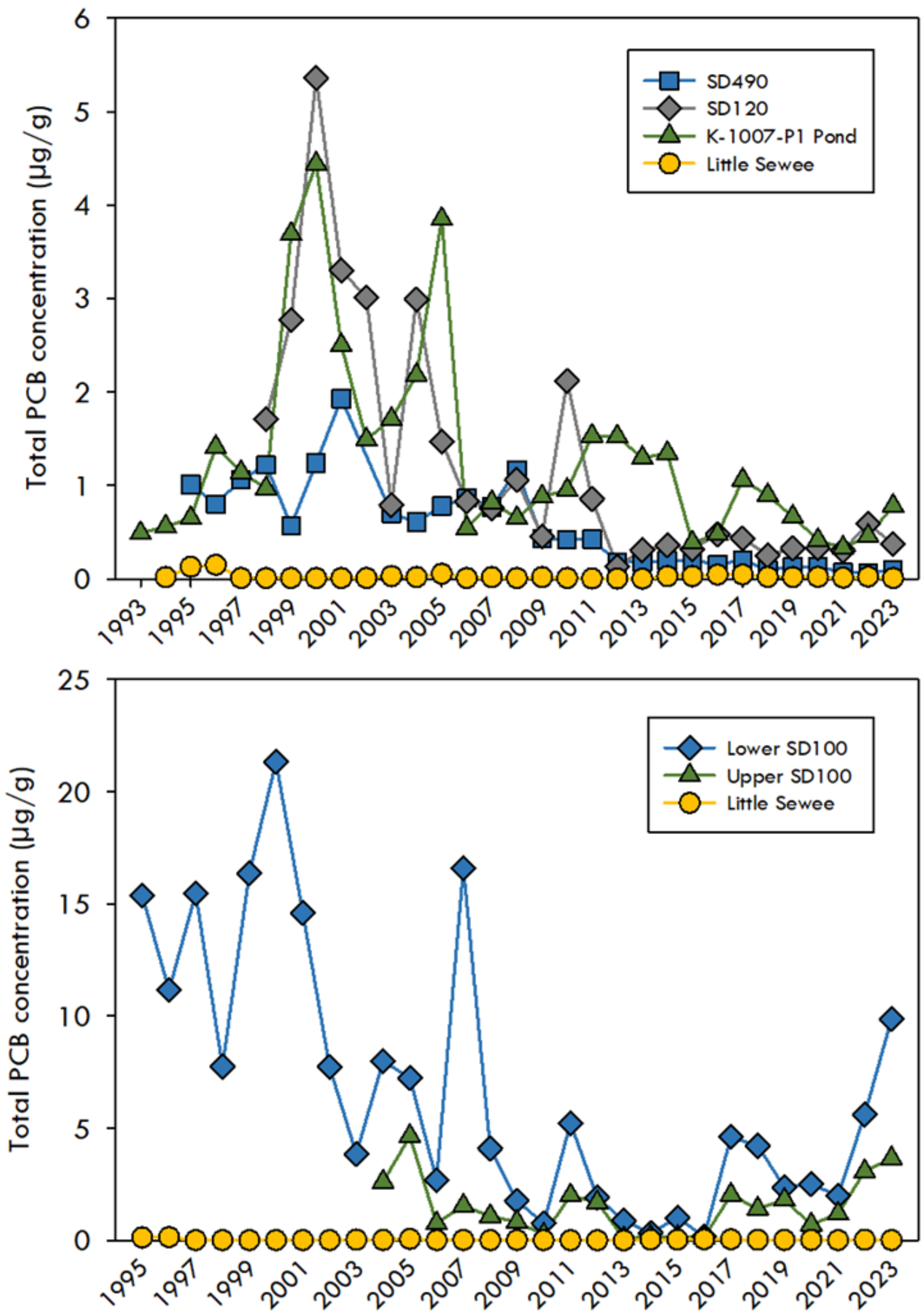
1. *Means for PCBs in water and TSS are based on results across all collections made each year.*
2. *Note that mean concentrations of PCBs in water from First Creek were <1.5 ng/L in all years.*

Acronyms: *PCB = polychlorinated biphenyl* *TSS = total suspended solids*

Figure 3.31. Mean aqueous total PCB concentrations, total suspended solids, and vegetation cover in the K-1007-P1 Pond, 2007–2023

and whole-body concentrations in bluegill were below the targets for this pond. Mean PCB concentrations in bluegill fillets in the K-1007-P1 Pond decreased from 0.69 µg/g in 2022 to 0.23 µg/g in 2023, remaining below the remediation goal for this pond (1 µg/g total PCBs in fillets). Mean concentrations in whole-body bluegill decreased from 1.91 µg/g in 2022 to 0.99 µg/g in 2023, also remaining below the remediation target for whole body fish in this pond (2.3 µg/g in whole-body composites). (See Figures 3.33 and 3.34, and Table 3.10.)

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, and fluctuations in vegetation cover (Figures 3.33 and 3.34).

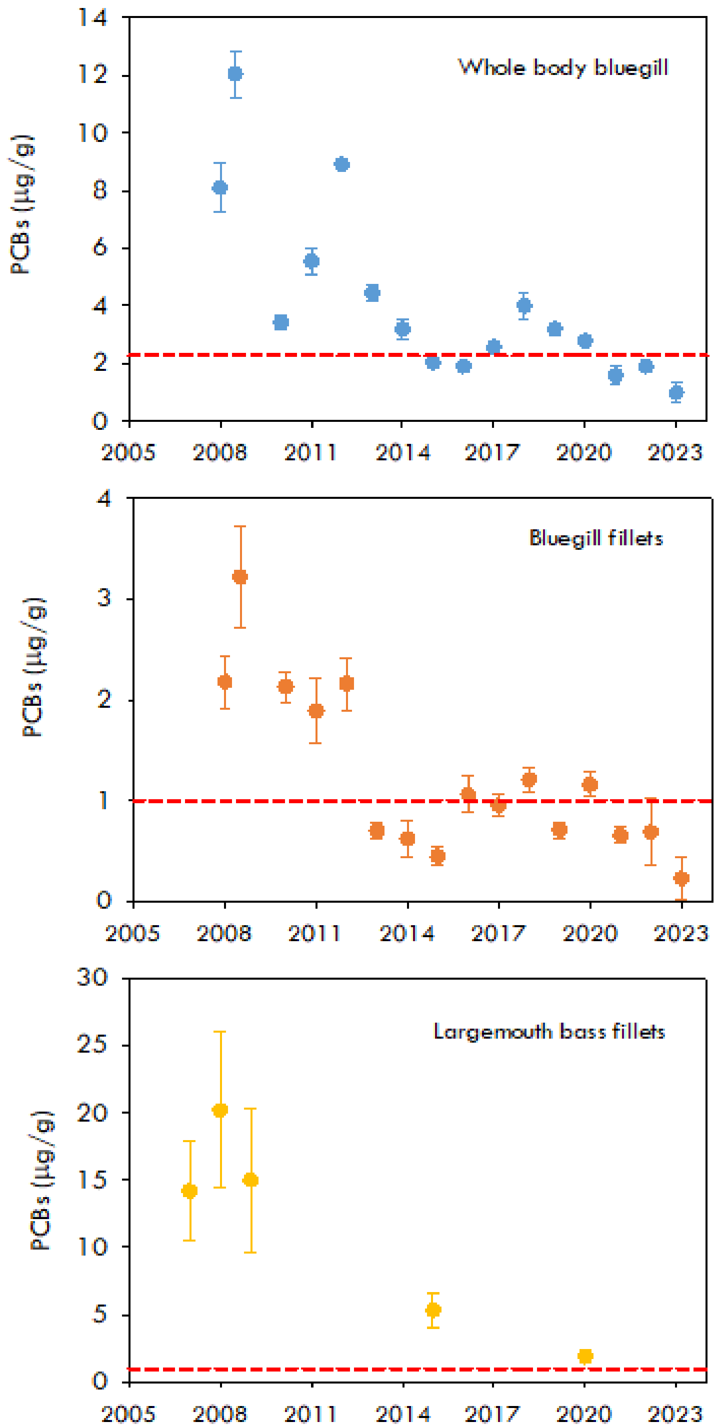


Notes:

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 shows the SD-490 location; lower graph photo shows placement of clam cages in the Upper SD-100 location.*

Acronyms: *PCB = polychlorinated biphenyl SD = storm drain*

Figure 3.32. Mean total PCB concentrations (µg/g, wet wt) in caged clams placed at K-1007-P1 outfalls compared with reference stream clams (Little Sewee Creek), 1993–2023

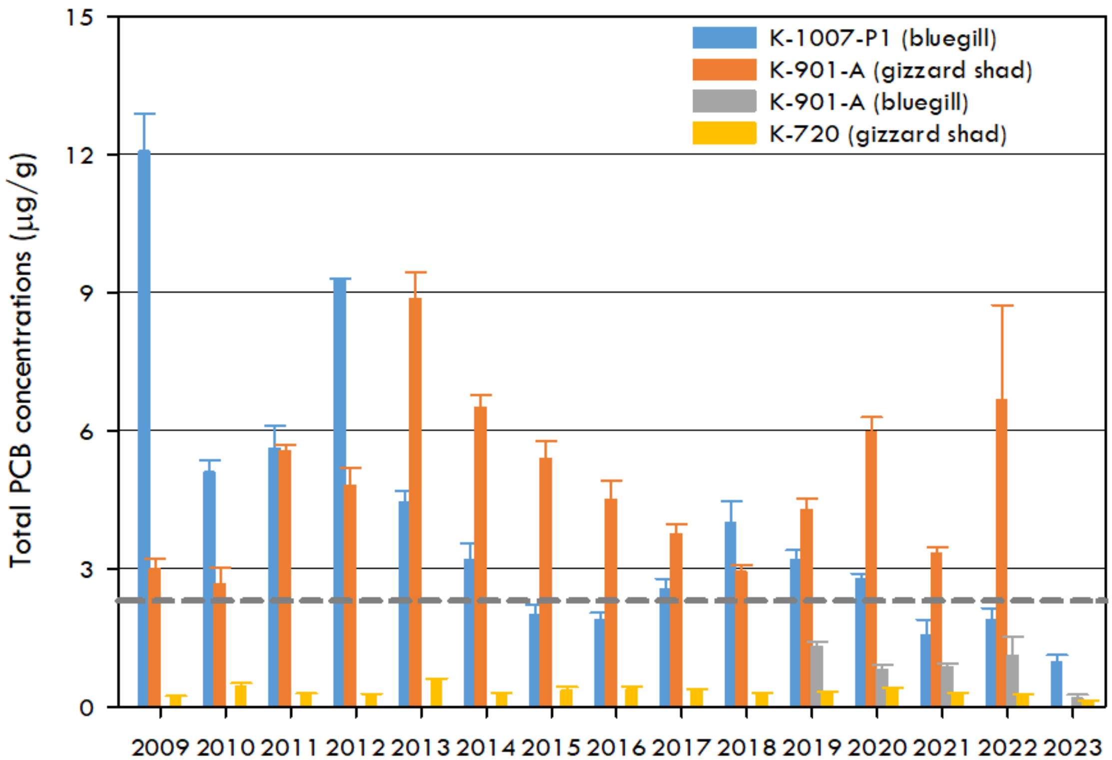


Notes:

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.*

Acronym: *PCB = polychlorinated biphenyl*

Figure 3.33. Mean PCB concentrations (µg/g, wet wt) in fish from the K-1007-P1 Pond, 2007–2023



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.*

Acronym: *PCB = polychlorinated biphenyl*

Figure 3.34. Mean (+1 standard error) total PCB concentrations (µg/g, wet wt) in whole body fish from K1007-P1 Pond, K-901-A Holding Pond, and K-720 Slough, 2009–2023

Table 3.10. Average concentrations of total PCBs in fillets and whole-body composites of fish collected in 2023 near the East Tennessee Technology Park

Site	Species	Sample type	Sample size (n)	Total PCBs (mean ± SD)	Range of PCB values	No. > target (PCBs)/n	Total Hg (mean + SD)
K-1007-P1 Pond	Bluegill	Fillet	20	0.23 ± 0.21	0.03–0.89	0/20	—
		Whole-body composite	6	0.99 ± 0.33	0.58–1.43	0/6	—
K-901-A Pond	Common carp	Fillet	1	0.54	—	0/1	—
	Bluegill	Fillet	12	0.05 ± 0.02	0.03–0.08	0/20	—
K-720 Slough	Largemouth bass	Fillet	12	0.02 ± 0.01	0.02–0.03	0/12	—
	Common carp	Fillet	8	0.09 ± 0.08	0.02–0.24	0/8	—
	Gizzard shad	Whole-body composite	6	0.12 ± 0.01	0.10–0.13	0/6	—
CRM 11.0	Bluegill	Whole-body composite	6	0.02 ± 0.002	0.02–0.03	0/6	—
	Gizzard shad	Whole-body composite	6	0.09 ± 0.02	0.05–0.13	0/6	—
PCM 1.0	Bluegill	Whole-body composite	6	0.06 ± 0.03	0.05–0.12	0/6	—
	Gizzard shad	Whole-body composite	1	0.23	—	0/1	—
Mitchell Branch	Redbreast sunfish	Fillet	5	0.59 ± 0.18	0.33–0.83	0/5	0.37 ± 0.06
Hinds Creek	Redbreast sunfish	Fillet	6	0.02 ± 0.02	0.01–0.05	0/6	0.12 ± 0.06

Notes:

1. *Average concentrations = µg/g, wet wt.*
2. *Total PCBs = Aroclors 1248, 1254, and 1260.*
3. *Values are mean concentrations (µg/g) ± 1 SE.*
4. *Each whole-body composite sample is composed of 10 individual fish.*
5. *Also shown are the ranges of values observed for PCBs and the number of fish whose fillet PCB concentrations exceeded 1 µg/g out of the total number of fish (or composites) sampled (n). (1 µg/g total PCBs in fish fillets and 2.3 µg/g in whole-body composites.*

Acronyms and abbreviations:

CRM = Clinch River mile

PCB = polychlorinated biphenyl

SE = standard error

n = sample size number

No. = number

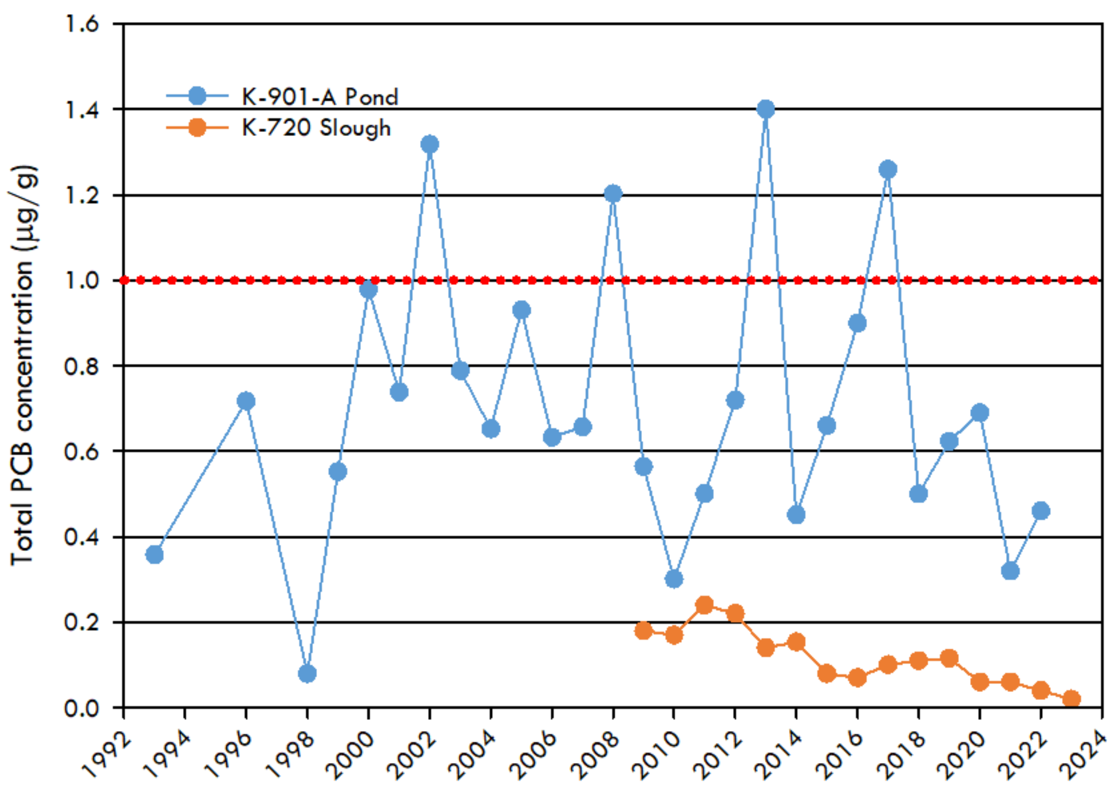
PCM = Poplar Creek mile

3.7.1.3. K-901-A Pond

The target fish species for analysis of PCBs in the K-901-A Holding Pond were gizzard shad (*Dorosoma cepedianum*) and largemouth bass (*Micropterus salmoides*), but the vegetation planting in this pond was so successful that the habitat for these larger fish has been decreasing and they have become less abundant. In 2023, only one common carp and 12 bluegill were collected for analysis.

The PCB concentration in the carp collected in 2023 was 0.54 µg/g, which is similar to the mean concentration in largemouth bass seen in 2022 (0.46 µg/g) and was below the target concentration set for the K-1007-P1 Pond of 1 µg/g total PCBs (Figure 3.35). The mean PCB concentration in bluegill fillets in the K-901-A Pond was 0.05 µg/g, which is below the concentrations seen in the K-1007-P1 Pond, and well below the target set for the Ponds.

PCB concentrations in clams deployed in the K-901-A Pond were comparable to those deployed at the reference site, Little Sewee Creek and were lower in 2023 (0.03 µg/g) than in 2022 (0.05 µg/g; Figure 3.36).



Notes:

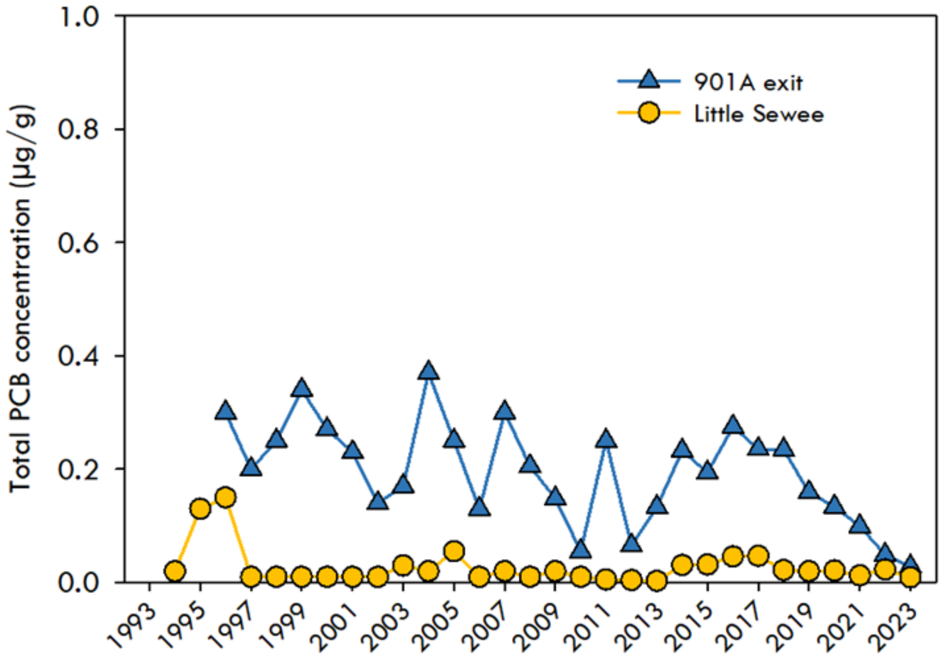
1. *Mean PCBs (± 1 SE) in largemouth bass fillets, 1993-2023 (µg/g).*
2. *N = 6 fish per year, when possible.*
3. *The dotted red line shows the advisory level for PCBs in fish fillets (1 µg/g).*

Acronyms:

PCB = polychlorinated biphenyl

SE = standard error

Figure 3.35. Mean total PCB concentrations in largemouth bass from the K-901-A Pond and the K-720 Slough



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, Tenn.).*

Acronym:

PCB = polychlorinated biphenyl

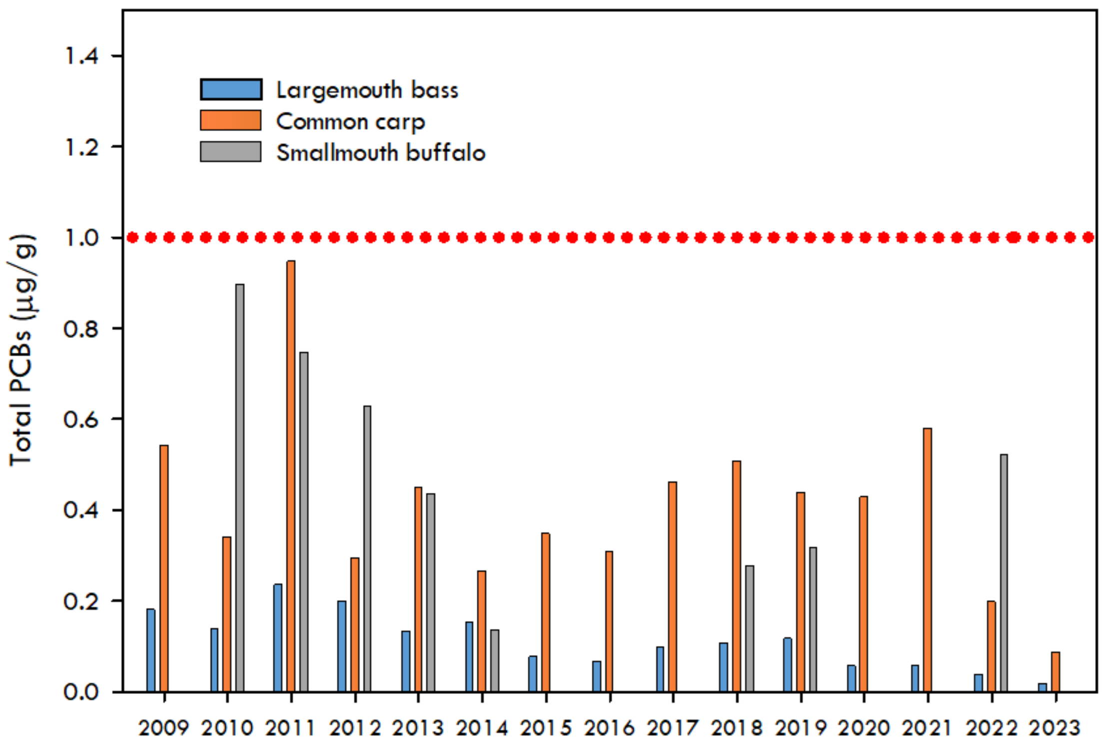
Figure 3.36. Mean total PCB (µg/g, wet wt; 1993–2023) concentrations in the soft tissues of caged Asiatic clams deployed in the K-901-A Pond for a 4-week period

3.7.1.4. K-720 Slough

Routine bioaccumulation monitoring in the K-720 Slough began in 2009 (Figure 3.37). 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 3.37 also shows the temporal trends in fish fillet concentrations in the slough. In 2023, 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 3.10). PCB concentrations in largemouth bass collected from the K-720 Slough have been steadily decreasing since monitoring began (shown earlier in Figure 3.35), averaging 0.02 µg/g in 2023. This concentration is just at the most conservative guideline for PCBs in the State of Tennessee (0.02 ug/g, based on TMDL calculations).

Concentrations in carp collected from the slough were slightly higher than concentrations in bass, averaging 0.09 µg/g in 2023. 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 0.12 µg/g in 2023.



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.*

Acronym:

PCB = polychlorinated biphenyl

Figure 3.37. Mean total PCB (µg/g, wet wt; 2009–2023) concentrations in the fillets of largemouth bass, common carp, and smallmouth buffalo collected from the K-720 Slough

3.7.2. Task 2: Instream Benthic Macroinvertebrate Communities

Benthic macroinvertebrate communities in Mitchell Branch are sampled using ORNL and TDEC protocols (Figures 3.38 and 3.39). 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 sitewide remediation continues (e.g., chromium release into Mitchell Branch).

Long-term monitoring of pollution-intolerant benthic macroinvertebrates such as stoneflies, mayflies, and caddisflies helps us understand changes in ecological health of Mitchell Branch in response to remedial action at ETTP.

Figure 3.38. Collecting an invertebrate sample using Oak Ridge National Laboratory Biological Monitoring and Abatement Program protocols

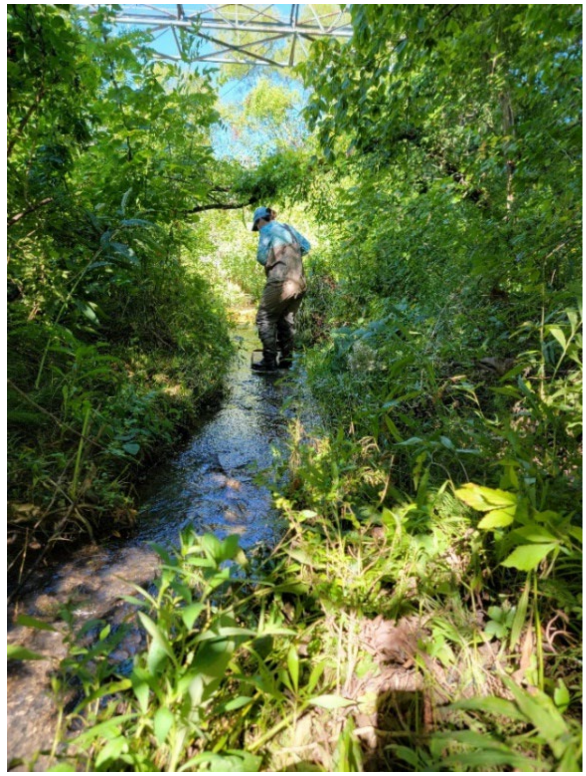


Figure 3.39. Sampling for benthic macroinvertebrates with TDEC protocols

3.7.2.1. 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 RAs 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 2023 following ORNL BMAP quantitative sampling protocols and samples collected annually (August/September) with TDEC semi-quantitative sampling protocols for estimating the Tennessee Macroinvertebrate Biotic Index (TMI) and the Habitat Index (TDEC 2021). 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 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 ORR (ORNL BMAP and WRRP/Bear Creek Biological Monitoring Program) (as shown earlier in Table 3.10). 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 ORR.

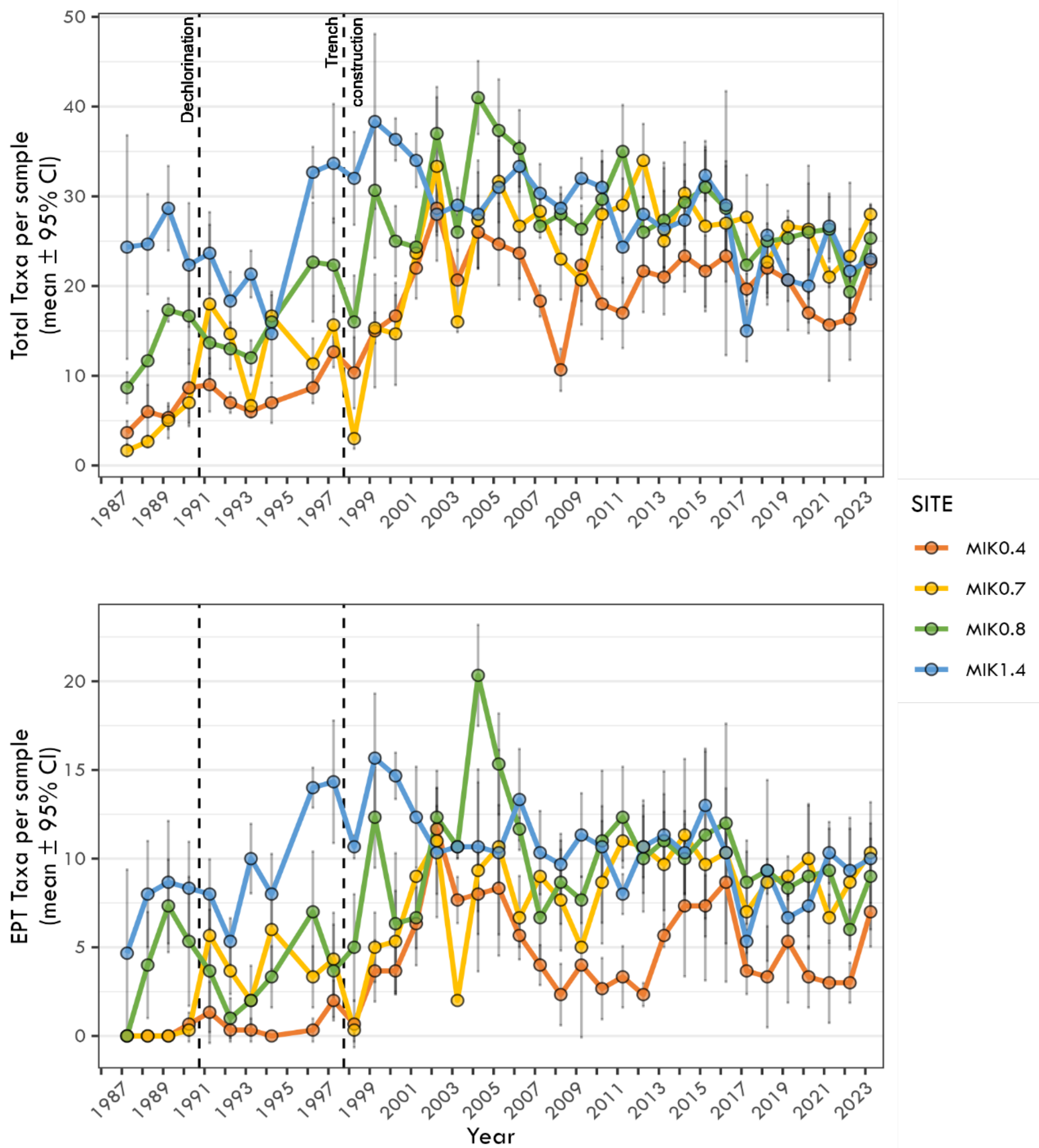
3.7.2.2. Mitchell Branch–ORNL and TDEC Protocols

Total 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 [mayflies, stoneflies, and caddisflies] per sample) measured using ORNL protocols has varied over the measurement period (1987–2023) in all Mitchell Branch sites (Figure 3.40). Both total taxa richness and EPT taxa richness increased in MIKs 0.4, 0.7, and 0.8 from 1987 to the late 1990s, and then reached fairly consistent values, albeit with considerable year to year variation (Figure 3.40). Total taxa richness and EPT taxa richness have been fairly consistent throughout the measurement period in the reference site, MIK 1.4, though values have been lower in five of the past seven years (Figure 3.40). In April 2023, total taxonomic richness (i.e., the total number of taxa per sample) and Ephemeroptera, Plecoptera, and Trichoptera (EPT; mayflies, stoneflies, and caddisflies, respectively) taxonomic richness increased at all Mitchell Branch sites in comparison with values from April 2022 (Figure 3.40). Value of both richness metric were lowest at MIK 0.4 and highest at MIK 0.7. The increase in EPT taxonomic richness at MIK 0.8 returned EPT taxa to values similar to those observed prior to 2022. The increased EPT richness observed at MIK 0.4 in 2023 represents a marked departure from the consistently lower values observed since 2017 (Figure 3.40).

The percent density of the pollution-intolerant taxa (higher values are indicative of better conditions) was highest at MIK 1.4, the reference site, and lowest at MIK 0.4 in 2023—a trend that has been observed over most of the time series (Figure 3.41). The percent density of pollution-tolerant taxa (lower values are indicative of better conditions) in 2023 was lowest at MIK 1.4 and highest at MIK 0.7 (Figure 3.41). In 2023, the percent density of pollution-tolerant taxa at MIK 1.4 was consistent with values observed prior to 2019 and 2020, when values had increased nearly 25 percent from representative levels observed over the monitoring period (Figure 3.41). These results suggest that the invertebrate community in Mitchell Branch continues to be mildly to moderately degraded downstream of MIK 1.4.

Based on TDEC protocols (TDEC 2021), scores for the TMI (Tennessee Macroinvertebrate Index) in 2023 rated the invertebrate community at MIK 1.4 as above biocriteria guidelines, whereas scores for communities in the three lower Mitchell Branch sites fell below biocriteria guidelines (Figure 3.42, Table 3.11). From 2022 to 2023, TMI scores increased at all sites except MIK 0.4, where the score decreased slightly. The decreased score at MIK 0.4 in 2023 reflected a decrease in the North Carolina Biotic Index (NCBI) score, which indicates that more pollution-tolerant invertebrates were present (Table 3.11). The TMI score at MIK 0.7 improved due to increased percentage of EPT taxa, while scores at both MIK 0.7 and MIK 0.8 improved due to increased total taxa richness and decreased percentage of nutrient-tolerant invertebrates. The improved score at MIK 1.4 reflected increases in EPT taxa richness and the percentage of clinger taxa (Table 3.11). Since sampling using TDEC protocols began in 2008 in Mitchell Branch, TMI scores at have almost always rated the invertebrate community at MIK 1.4 as passing biocriteria guidelines, while MIK 0.4, MIK 0.7, and MIK 0.8 have generally been rated as falling below biocriteria guidelines. (Figure 3.42).

Based on TDEC stream habitat protocols, habitat quality was above the ecoregion 67f guideline at all sites within Mitchell Branch (Figure 3.42). Habitat scores increased at all sites in 2023, remaining above the habitat quality threshold over the past four years (Figure 3.42). In general, these increases were driven by decreased sediment deposition and embeddedness of riffles. Small riparian width, particularly on the left bank, remains an issue at all sites except MIK 1.4. Habitat conditions related to riffle stability (i.e., frequency of reoxygenation zones) and channel flow improved or remained constant at all sites.



Note: *Samples were not collected in April 1995.*

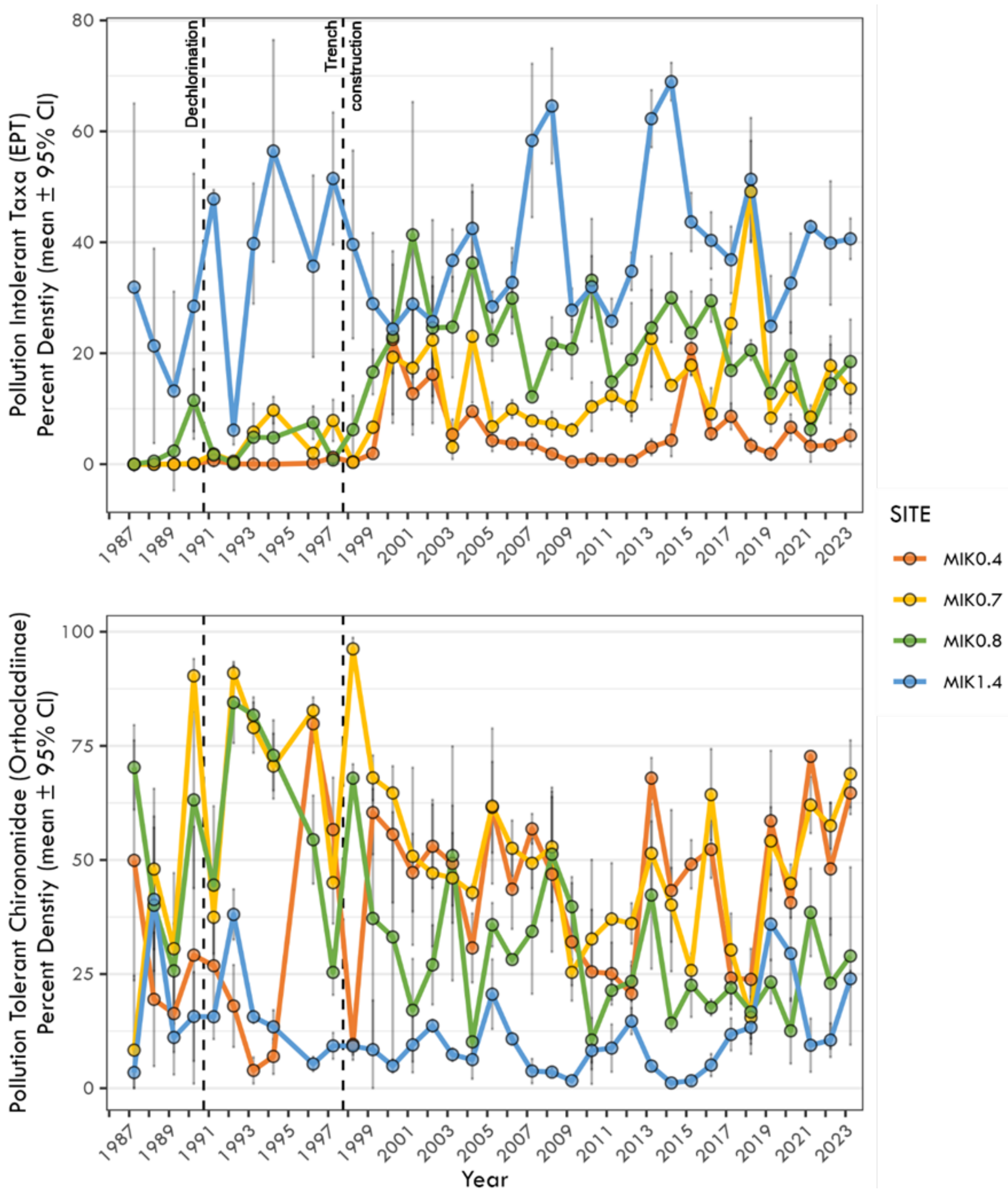
Acronyms:

EPT = Ephemeroptera, Plecoptera, and Trichoptera

MIK = Mitchell Branch kilometer

CI = confidence interval

Figure 3.40. Mean (± 95 percent confidence interval) total taxonomic richness (top) and richness of the pollution-intolerant taxa per sample (bottom) for Mitchell Branch sites, April 1987–2023



Notes:

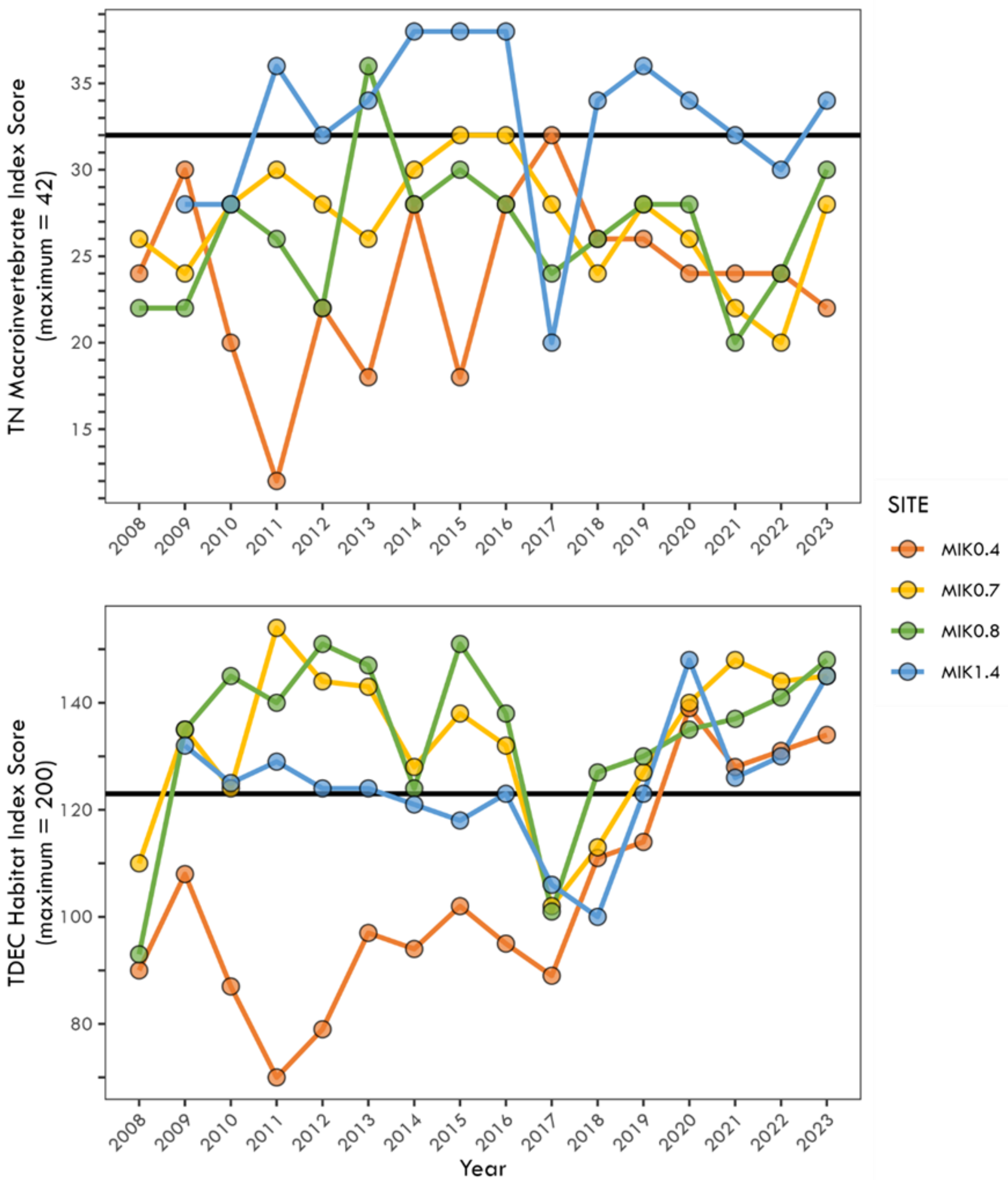
1. *Pollution-intolerant taxa, i.e., stoneflies, mayflies, and caddisflies or Ephemeroptera, Plecoptera, and Trichoptera taxa (top).*
2. *Percentages were based on total densities for each site.*
3. *Samples were not collected in April 1995.*

Acronyms:

MIK = Mitchell Branch kilometer *CI = confidence interval*

EPT = Ephemeroptera, Plecoptera, and Trichoptera (pollution-intolerant taxa)

Figure 3.41. Mean percent density of pollution-intolerant taxa and of the pollution-tolerant Orthocladiinae midge larvae (Chironomidae) at Mitchell Branch sites, April 1987–2023



Notes:

1. *Mitchell Branch site MIK 1.4 was not sampled with TDEC protocols in 2008.*
2. *The horizontal line on each graph shows the rating threshold for each index for ecoregion 67f; TDEC macroinvertebrate index threshold is 32; TDEC habitat index threshold is 123. Values above the thresholds are indicative of passing biocriteria or habitat guidelines.*

Figure 3.42. Temporal trends in the TDEC Macroinvertebrate Index (top) and Stream Habitat Index (bottom) scores for four Mitchell Branch sites, August 2008–2023

Table 3.11. Tennessee Macroinvertebrate Index metric values and scores and index scores for Mitchell Branch, August 17, 2023[a,b,c]

Site	Metric values							Metric scores							TMI[d]
	Taxa rich	EPT rich	%EPT	%OC	NCBI	%Cling	%TN Nuttol	Taxa rich	EPT rich	%EPT	%OC	NCBI	%Cling	%TN Nuttol	
MIK 0.4	19	3	5.1	9.2	4.8	72.3	50.8	2	0	0	6	4	6	4	22
MIK 0.7	29	7	31	9.5	5.3	51	48.5	4	2	4	6	4	4	4	28
MIK 0.8	28	10	26.5	9.5	5.5	56.1	39.2	4	4	2	6	4	6	4	30
MIK 1.4	30	11	35.9	3.2	4.6	55.9	39.5	4	4	4	6	6	6	4	34

[a] *TMI metric calculations and scoring and index calculations are based on Tennessee Department of Environment and Conservation (TDEC) protocols for ecoregion 67f: TDEC 2021, Quality System Standard Operating Procedures for Macroinvertebrate Stream Surveys, TDEC Division of Water Resources, Nashville, Tennessee. Available* ***here****.*

[b] *Taxa rich = Taxa richness; EPT rich = Ephemeroptera, Plecoptera, and Trichoptera (mayflies, stoneflies, and caddisflies) taxa richness; %EPT = EPT abundance excluding Cheumatopsyche spp.; %OC = percent abundance of oligochaetes (worms) and chironomids (nonbiting midges); NCBI = North Carolina Biotic Index; %Cling = percent abundance of taxa that build fixed retreats or otherwise attach to substrate surfaces in flowing water excluding Cheumatopsyche spp; %TN Nuttol. = percent abundance of nutrient-tolerant organisms.*

[c] *MIK = Mitchell Branch kilometer*

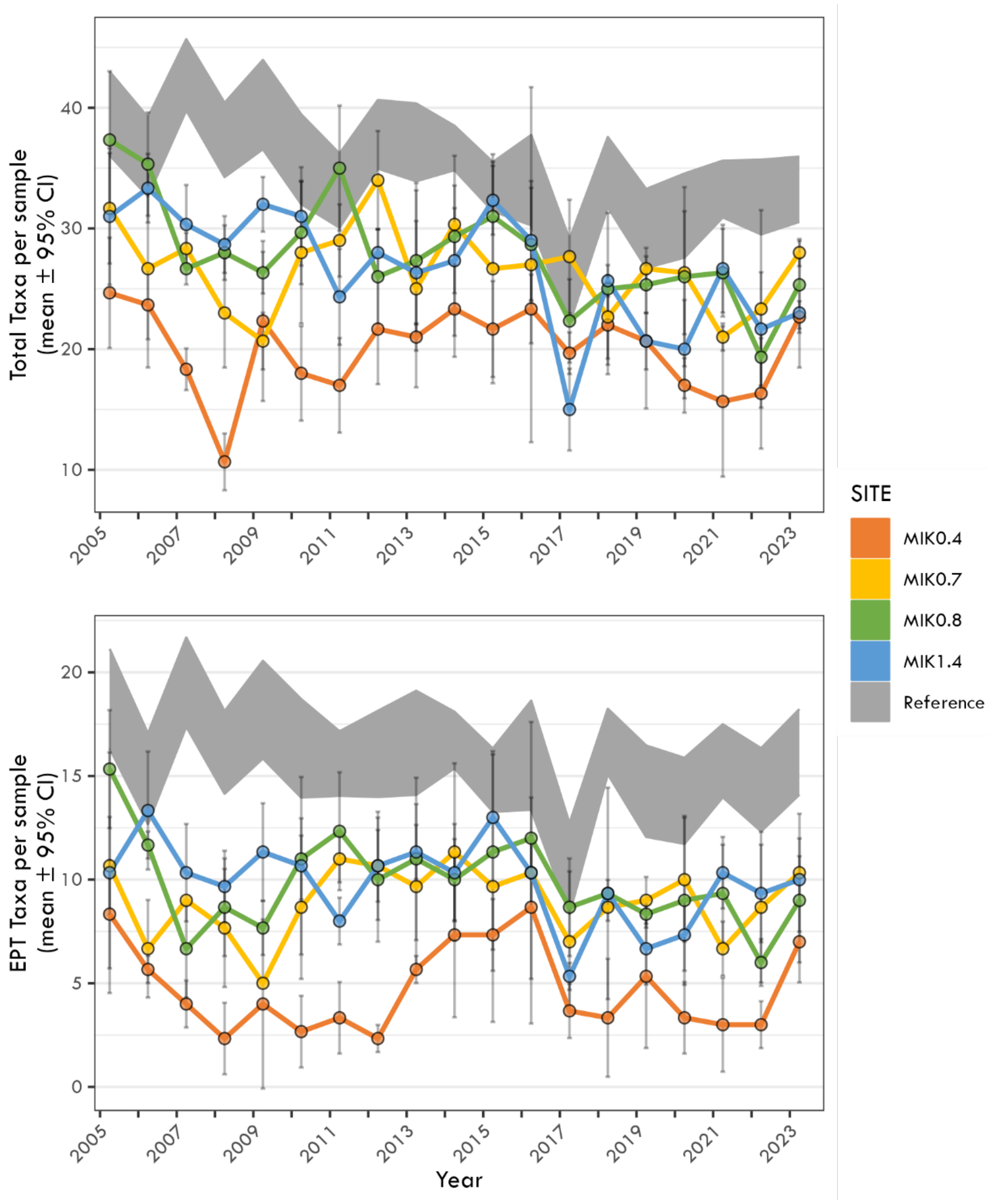
[d] *TMI = Tennessee Macroinvertebrate Index score. TMI is the total index score, and higher index scores indicate higher-quality conditions. A score of ≥ 32 is considered to pass biocriteria guidelines.*

3.7.2.3. Comparison between Mitchell Branch and Other Reference Sites on ORR

In Figure 3.43, the benthic macroinvertebrate communities in Mitchell Branch are compared to ORR reference streams over a 18-year period. Mean values for total taxa richness and taxa richness of pollution-intolerant (EPT) taxa for Mitchell Branch are shown in Figure 3.43, and percent density of the pollution-intolerant and pollution-tolerant taxa are shown in Figure 3.44. Also shown in gray shading in Figures 3.43 and 3.44 is the 95 percent confidence interval for the five reference sites on ORR—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 2023, total taxa richness and taxa richness of pollution-intolerant taxa at all Mitchell Branch sites, including MIK 1.4, were less than both the 95 percent confidence interval for the five reference sites (Figure 3.43). This trend was observed since these comparisons began in 2005, with some exceptions (e.g., 2011, 2017). In contrast to richness metrics, the mean percent densities of pollution-intolerant and pollution-tolerant taxa at MIK 1.4 were not often outside of the 95 percent confidence interval for the reference sites (Figure 3.44). While the percent density of pollution intolerant taxa remained similar at MIK 1.4 in 2023, the percent density of pollution-tolerant taxa at MIK 1.4 increased, rising above the 95 percent confidence interval for reference sites (Figure 3.44). Since 2005, the mean percent density of pollution-intolerant taxa at MIK 0.7 and MIK 0.8 have largely remained below the reference 95 percent confidence interval, while the percent density of pollution-tolerant taxa at these sites were higher than the reference 95 percent confidence interval. MIK 0.4 has remained well outside the 95 percent confidence intervals for reference sites since 2005 (Figure 3.44).

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 below the lower distribution of expected reference conditions on ORR. Factors potentially contributing to excursions of invertebrate community metrics outside of the 95 percent confidence interval for other reference sites include the somewhat smaller size of MIK 1.4 compared with the other reference sites (based on watershed area, Table 3.12), which may limit the range of invertebrate species that can colonize and thrive at the site, and habitat characteristics that have typically contributed to the lower-quality habitat at the site, such as low flow and poor substrate quality (seen earlier in Figures 3.41 and 3.42). These results also support the contention that sites downstream of MIK 1.4 continue to exhibit evidence of mild to moderate degradation.



Note: *The gray shading on each graph shows the 95% confidence interval of values at five additional reference stream sites on ORR from 2005 to 2023.*

Acronyms:

CI = confidence interval

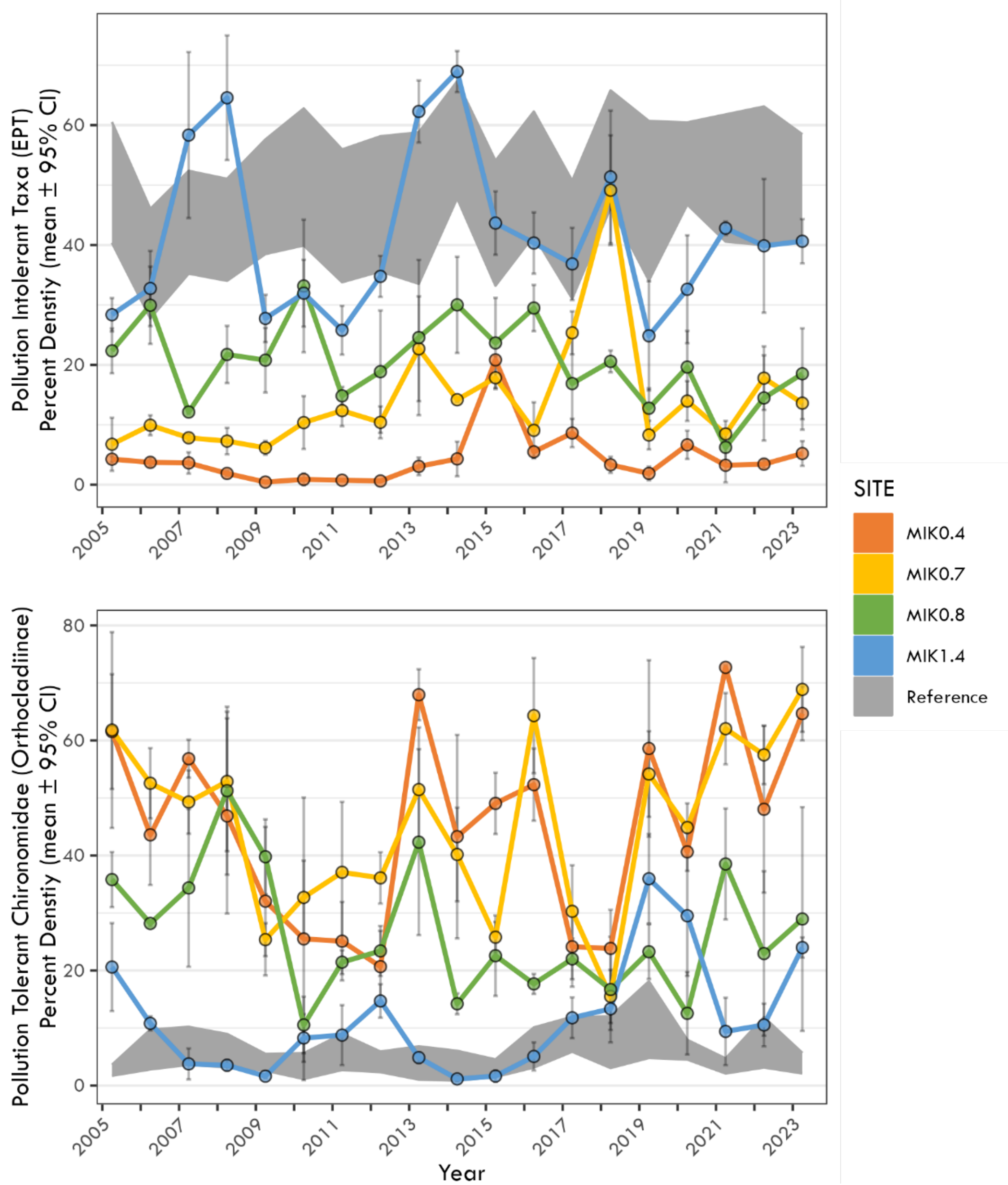
EPT = Ephemeroptera, Plecoptera, and Trichoptera

MIK = Mitchell Branch kilometer

MIK 1.4 = reference site

ORR = Oak Ridge Reservation

Figure 3.43. Mean total taxonomic richness (top) and pollution-intolerant taxa per sample (bottom) for the benthic macroinvertebrate community at Mitchell Branch and the 95% confidence interval for ORR reference sites, April 2005–2023



Notes:

1. *Pollution-intolerant taxa, i.e., stoneflies, mayflies, and caddisflies or Ephemeroptera, Plecoptera, and Trichoptera taxa (top).*
2. *Pollution-tolerant Orthocladiinae midge larvae (bottom).*
3. *Percentages were based on total densities for each site.*
4. *The gray shading on each graph shows the 95% confidence interval for values at five additional reference sites on ORR from 2005 to 2023.*

Acronyms:

CI = confidence interval *MIK 1.4 = reference site* *EPT = Ephemeroptera, Plecoptera, and Trichoptera*
ORR = Oak Ridge Reservation *MIK = Mitchell Branch kilometer*

Figure 3.44. Mean percent density of pollution-intolerant taxa (top) and pollution-tolerant Chironomidae (bottom) in Mitchell Branch the 95% confidence interval for ORR reference sites, April 2005–2023

Table 3.12. Stream sites included in the comparison between Mitchell Branch and other reference sites on the Oak Ridge Reservation

Site	Location		Watershed area (km^2)	Program
	Latitude (N)	Longitude (W)		
Mitchell Branch				
MIK 0.4	35.93859	84.39040	1.554	ETTP BMAP
MIK 0.7	35.93786	84.38792	1.347	ETTP BMAP
MIK 0.8	35.93786	84.38682	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)	35.92670	84.32355	0.596	ORNL BMAP
Fifth Creek (FFK 1.0)	35.93228	84.31746	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

Acronyms:
BMAP = Biological Monitoring and Abatement Program
BMP = Biological Monitoring Program
ETTP = East Tennessee Technology Park
km^2 = square kilometers
MIK = Mitchell Branch kilometer
N = north
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
W = west
WRRP = Water Resources Restoration Program

3.7.3. 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 each spring.

Mitchell Branch Fish Community

Historically, the fish community in Mitchell Branch was most severely affected in the late 1980s and early 1990s. After some recovery in the mid-1990s, Mitchell Branch was affected 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 3.45). 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 (Figure 3.46).

Figure 3.45. Construction of lined section of Mitchell Branch, MIK 0.7, in 1998

Figure 3.46. More recent habitat conditions at Mitchell Branch in 2023

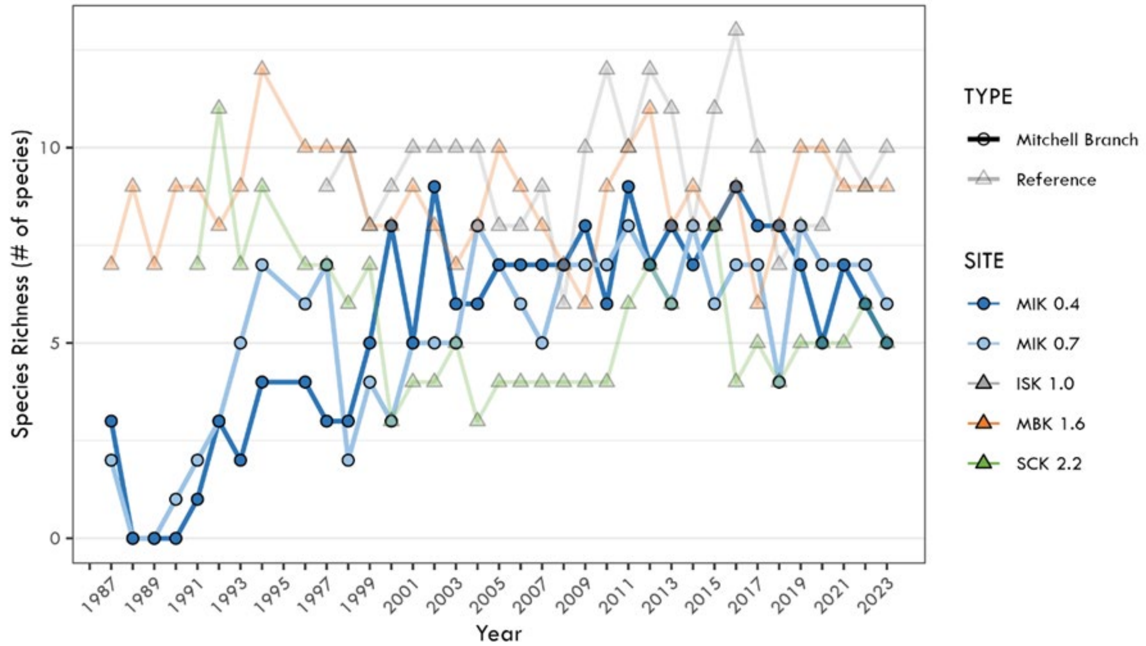
This has added to the complexity of the habitat available for fishes to colonize. Since 2000, the fish community has had relatively stable species diversity but rather large variations in fish density and biomass, which are often reflective of unstable, impaired streams. Streams that experience high 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 stream channel and 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 East Fork Poplar Creek where tolerant species dominate the concrete- and bedrock-lined channel, which supports little riparian protection. In addition, extremely low precipitation amounts, which often occur in the summer, result in very low flows in many area streams. Small first and second order streams without springs or groundwater influence are most severely affected by these conditions. This may partially explain the decreased density and biomass numbers observed in some years and the apparent return of higher values in following years.

At both MIK 0.4 and MIK 0.7, the 2023 sample of fish community parameters indicated continued variation. Species richness (number of species) at both sites decreased slightly compared to 2022 values (Figure 3.47).

Both sites have species richness comparable with similar sized reference streams. Density (number of fish) at both sites still remains well above reference conditions (Figure 3.48). Biomass (weight) also remains elevated at both sites (Figure 3.49). Both the lower Mitchell Branch site and the upper site had reduced diversity and density of sensitive fish species in 2023 compared to reference sites.

Over the last decade, there has been a slight uptick in the occurrence of sensitive fish species at both sampled sites in Mitchell Branch, which can be attributed to the regular presence of fish such as banded sculpin (*Cottus carolinae*) that appear to be a resident species in Mitchell Branch, and also occasional occurrences of other more sensitive fish. In 2023, no new species were observed in the two sites and the resident banded sculpin were very limited. However, new species of darters, suckers, and sunfish continue to be discovered within Mitchell Branch every year, and some represent unique sensitive species in this reach of stream.

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.



Acronyms:

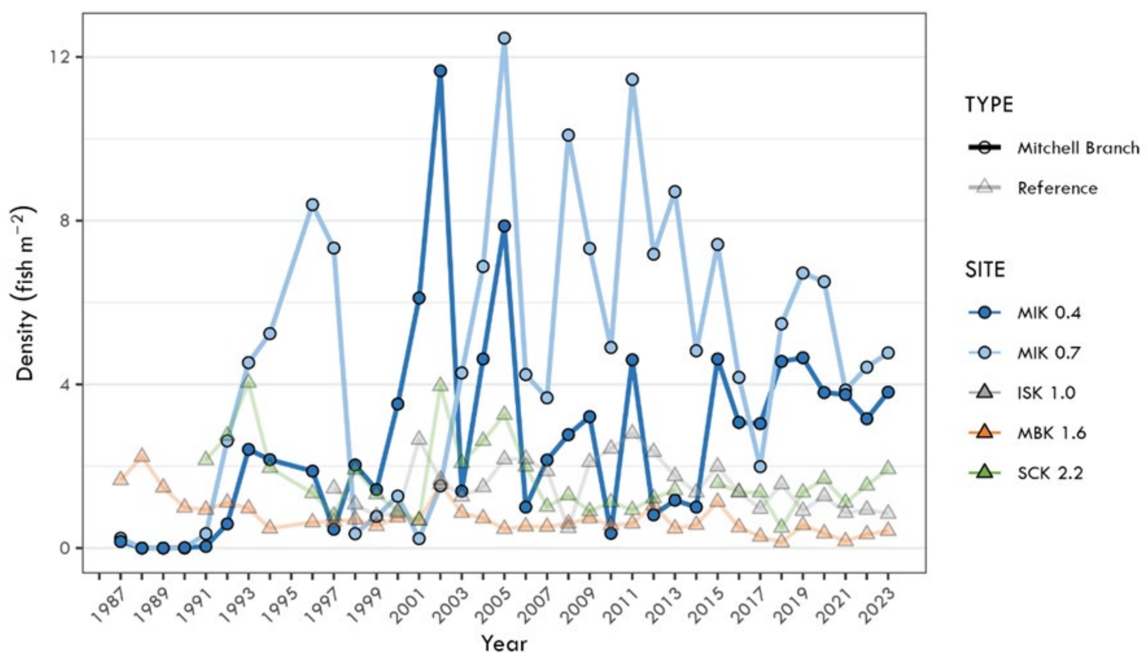
ISK = Ish Creek

MBK = Mill Branch kilometer

MIK = Mitchell Branch kilometer

SCK = Scarboro Creek

Figure 3.47. Species richness for the fish communities at sites in Mitchell Branch and in reference streams Mill Branch, Scarboro Creek, and Ish Creek, 1987–2023



Acronyms:

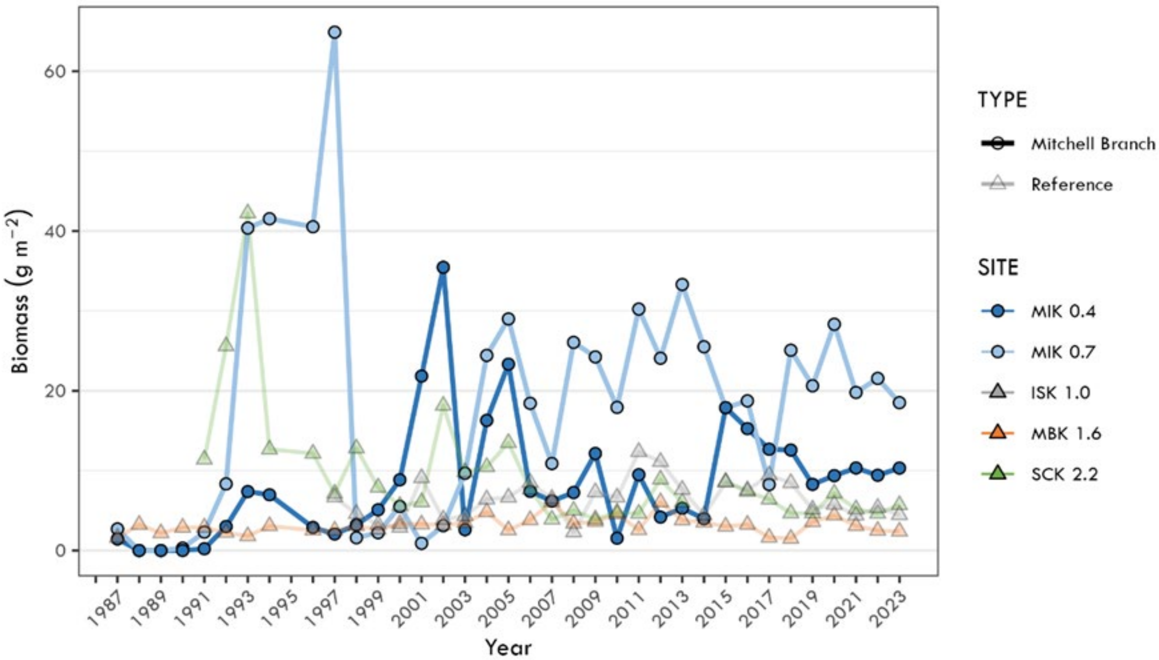
ISK = Ish Creek

MBK = Mill Branch kilometer

MIK = Mitchell Branch kilometer

SCK = Scarboro Creek

Figure 3.48. Density for the fish communities at sites in Mitchell Branch and in reference streams Mill Branch, Scarboro Creek, and Ish Creek, 1987–2023



Acronyms:

ISK = Ish Creek | *MIK = Mitchell Branch kilometer*

MBK = Mill Branch kilometer | *SCK = Scarboro Creek*

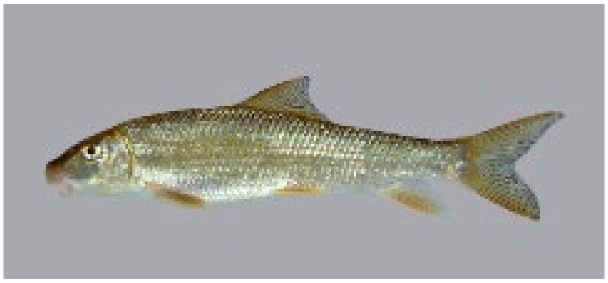
Figure 3.49. Biomass for the fish communities at sites in Mitchell Branch and in reference streams Mill Branch, Scarboro Creek, and Ish Creek, 1987–2023

During routine bioaccumulation sampling, several species of fish are collected regularly at MIK 0.2 that are infrequently observed in the Mitchell Branch fish community monitoring activities at the upstream sites. These included four pollution-sensitive species: black redhorse (*Moxostoma duquesnei*), snubnose darter (*Etheostoma simoterum*, greenside darter (*Etheostoma blennioides*), and northern hogsucker (*Hypentelium nigricans*) (clockwise, Figure 3.50). 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.

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 RAs 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.

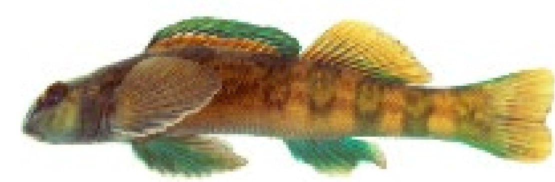
Overall, the K-1007-P1 Pond fish community surveys conducted in February 2023 revealed the presence of nine species of fish. An observation of particular importance from previous surveys is the abundance of sunfish species (bluegill, redear sunfish, and warmouth), which constitute



Black redhorse *(Moxostoma duquesnei)*

Snubnose darter *(Etheostoma simoterum)*

Northern hogsucker *(Hypentelium nigricans)*



Greenside darter *(Etheostoma blennioides)*

Photos: Chris Bryant

Figure 3.50. Sensitive fish species observed in lower Mitchell Branch

approximately 93 percent of the total fish population (Figure 3.51). 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 likely to continue, given the habitat conditions currently in the pond (i.e., abundant prey sources and open water). Gizzard shad (*Dorosoma cepedianum*) continue to be present in the pond and are suspected of reproducing some years. Although they constituted a much larger portion of the fish population in 2020 than in previous years, they have been almost absent in subsequent sampling. Their abundance has had some minor fluctuations each year but in general has remained relatively low compared with earlier years.

3.8. Environmental Management and Waste Management Activities

Remediation activities were underway across ETTP in 2023. Wastes were generated during these operations and were handled in accordance with the applicable regulations.

3.8.1. Waste Management Activities

Most of the waste generated during FY 2023 cleanup activities in Oak Ridge went to disposal facilities on the Oak Ridge Reservation—namely, the EMWMF and the Oak Ridge Reservation Landfills (ORRL). These facilities are owned by DOE and operated/maintained by UCOR. They have been vital to cleanup progress and success, Enabling OREM to accomplish more cleanup by avoiding costly and unnecessary cross-country shipments.

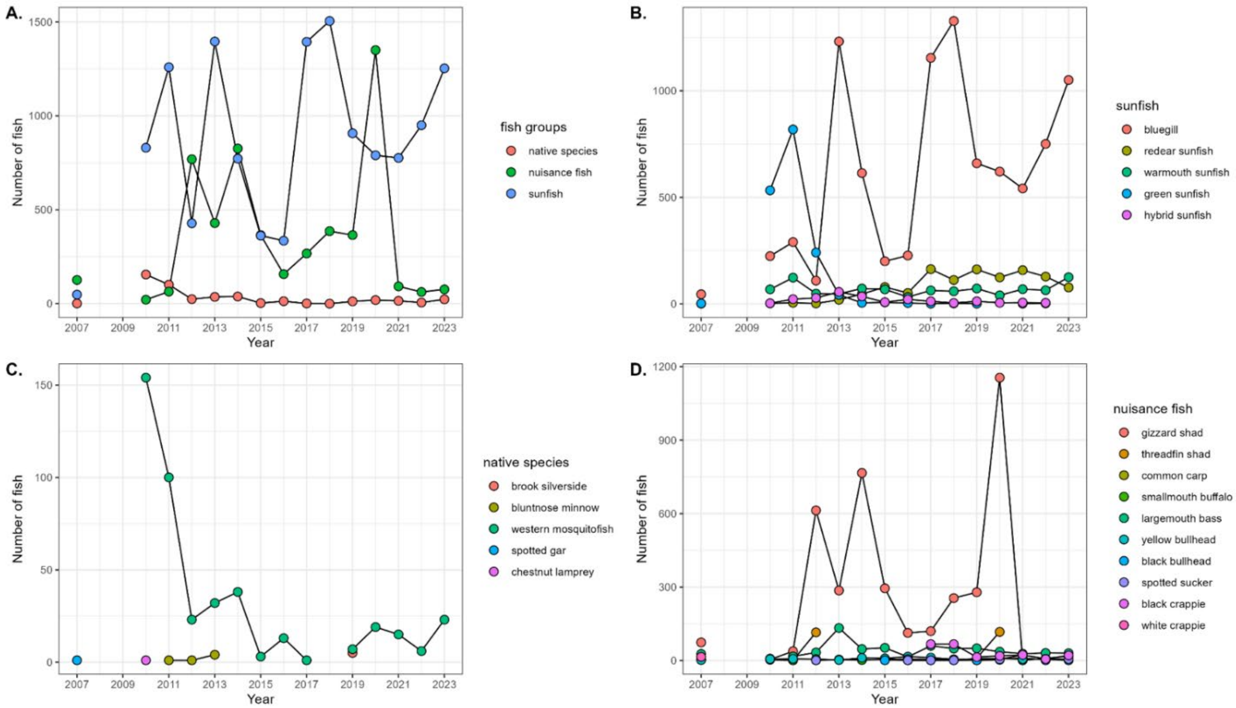


Figure 3.51. Changes in the K-1007-P1 Pond fish community from 2007–2023

EMWMF only receives low-level radioactive and hazardous waste meeting specific criteria. The waste is mostly soil and building debris. In FY 2023, EMWMF received 5,211 waste shipments from cleanup projects at ETTP, ORNL, and Y-12, plus 84 clean fill shipments for the enhanced operational cover expansion and constructing access roads and dump ramps. The EMWMF landfill has a design capacity of 2.331 million yd^3 and is now over 85 percent filled.

EMWMF generated 14.71 million gal of wastewater in FY 2023. Approximately 3.53 million gal of leachate (water that enters the leachate collection system) was transported by tanker to the ORNL Liquid and Gaseous Waste Operations for treatment and release. Approximately 11.18 million gal of contact water (water that contacts waste but does not enter the leachate collection system) was released to Bear Creek after laboratory analysis verified it met all regulatory limits and discharge standards. ORRL accepts sanitary/industrial waste and construction/demolition debris. In FY 2023, these three active landfills received 6,629 waste shipments, totaling 92,911 yd^3 of waste.

ORRL also manages non-regulated leachate. In FY 2023, ORRL compliantly discharged 3.7 million gal of leachate from the three active landfills to the Y-12 sanitary sewer system.

Work continued with regulatory agencies on seep mitigations for Sanitary Landfill II (a closed landfill) and active Landfill VII. Repairs at Landfill VII included developing and implementing a minor modification approved by the regulators that allowed landfill operations to remove approximately 1,164,000 gal of leachate trapped inside of Landfill VII for an extended period of time. This water was transferred to the Landfill V leachate facility for discharge.

In FY 2023, ORRL continued improvements for all sediment and erosion controls. These measures included upgrading drainage features, which significantly reduces the amount of sediment released from these landfills. TDEC inspections in FY 2023 noted excellent sediment and erosion controls with no areas of concern or violations.

Expansion of Construction/Demolition Landfill (CDL)-V area 5 expansion was constructed to a 95 percent completion level during this fiscal year.

EMWMF will reach capacity before OREM completes its cleanup at Y-12 and ORNL. Planning continued in FY 2023 for another disposal facility, the EMDF, to provide the capacity required to complete Oak Ridge's cleanup mission.

A groundbreaking ceremony for the EMDF was held on August 2, 2023. Attendees included U.S. Congressman Chuck Fleischmann, OREM Manager Jay Mullis, UCOR President and CEO Ken Rueter, contractor executives, other local elected officials, senior leadership from EPA and TDEC, and representatives from the U.S. laborers and operators unions.

Fieldwork for the early site preparation activities began after the groundbreaking. This work included rerouting portions of Bear Creek Road and the Haul Road, and development of other support areas.

OREM continues to work with EPA and TDEC on regulatory documents for the EMDF landfill. The Early Site Preparation Remedial Design Report/Remedial Action Work Plan was approved in June 2023 and the Groundwater Field Demonstration Remedial Design Work Plan/Remedial Action Work Plan was prepared and reviewed in 2023 with approval in October 2023.

OREM continued to monitor 31 groundwater wells at the selected site for the disposal facility, measuring and recording water levels and groundwater characteristic data for the entire year.

The Transuranic (TRU) Waste Processing Center (TWPC) continued processing and shipping TRU, mixed low-level waste (MLLW), and low-level waste in FY 2023. The facility has completed processing of 99 percent of the contact-handled (CH) TRU and 98 percent of the remote-handled (RH) TRU legacy wastes within the processing milestones of the Site Treatment Plan for Mixed Wastes on the DOE Oak Ridge Reservation.

TWPC's operational focus in FY 2023 was on processing the legacy Nuclear Fuel Services waste (1.9 cubic meters [m^3]) and TRU waste processing by-product wastes (12.8 m^3). TWPC completed limited processing operations for 1 m^3 of legacy CH TRU waste. TWPC completed certification and shipment of 159 m^3 of TRU waste for disposal at WIPP, 72.5 m^3 of LLW for disposal at Nevada National Security Site, and 1.8 m^3 of hazardous/universal waste for treatment and disposal, eliminating 855 containers of the stored inventory.

3.8.2. Environmental Remediation Activities

Several years of characterization, data analysis, delineation, and modeling have resulted in the identification of numerous contaminated areas at ETTP that are now in the final stages of cleanup. Remediation efforts are being performed to eliminate hazards at the site and pave the way for future industrial use.

The site is divided into two cleanup regions: Zone 1, a 1,300-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 EUs that vary in size from 6 to 38 acres. Remediation efforts are designed to protect groundwater, wildlife, and the future workforce.

Highlights of this effort are given below. For details, please see the *2023 Cleanup Progress—Annual Report to the Oak Ridge Regional Community* (UCOR 2024, OREM-23-7637).

3.8.2.1. Soil Remediation

Soil remediation at ETTP is nearing completion. Regulatory agencies have identified and approved all required remedial actions necessary to address soil cleanup. A revised Final Record of Decision for Zone 1 Soils was submitted to the regulatory agencies, which recommended no further action. Remediation activities include removal of facilities, excavation of soil, and land use covenants. To support the treatment of water that could accumulate within the excavation areas, an onsite treatment system was used to remove contaminants from the water prior to discharge to the Clinch River. Highlights for 2023 include the following activities:

- OREM completed soil and concrete remedial actions at EU-13 associated with a radiologically contaminated release from a tie line adjacent to the former K-631 Surge and Waste Facility. Site restoration activities included placing clean fill topped with gravel to stabilize the site.
- Soil remedial actions were completed at EU-16 at the former K-1064 Salvage Material Yard, the K-1064-H area, and a radiologically contaminated hot spot. Site restoration activities included placing soil fill and hydroseeding the area to stabilize the site. Crews also completed a remedial action to remove historical waste materials and contaminated soil at the former K-1064 North Trash Slope located along the bank of Poplar Creek. Site restoration activities included placing large stone (riprap) fill to stabilize the site.
- At EU-17, a remedial action was completed to remove exposed transite pieces (material made using asbestos) that were historically disposed and located along the banks of Poplar Creek. Site restoration activities included placing large stone fill to stabilize the site.
- A soil remedial action was completed in EU-38 at the former K-1417-B Drum Storage Yard. Site restoration activities included placing clean fill topped with gravel to stabilize the site. Crews also started a remedial action to remove sediment from sumps at the K-1417-A Concrete Block Casting Facility.
- A remedial action was started at EU-39 to remove contaminated soil from the footprint of the K-1420 Equipment Decontamination Facilities.
- Crews continue to remediate TCE-contaminated soil at the EU-21 project. EU-21 encompasses the area within the U-shaped footprint of the former K-25 Building. Since July 2021, more than 61,600 yd^3 of contaminated soil was removed and taken to the local disposal facilities. During this excavation, approximately 3,100 yd^3 of RCRA F-listed soil was encountered, which was contaminated with waste from manufacturing and industrial processes considered hazardous. UCOR partnered with Perma-Fix Environmental Services, Inc. for this disposal project, which transported the soil by rail for disposal at an offsite facility.
- In February 2023, UCOR completed a Time-Critical Removal Action of contaminated soils at the EU-19 mudflat. The mudflat was located at the end of a ditch that empties into Poplar Creek and had been impacted by past site operations. Sevenson Environmental Services teamed with UCOR to remove 8,000 yd^3 from a floating work platform positioned in the creek (Figure 3.52). An onshore 125-ton crane was used to move the containers of excavated soil from the work platform for characterization and disposal.

Figure 3.52. Workers excavate soil from the EU-19 mudflat to load on the floating platform

3.8.2.2. Groundwater Protection

With crews set to finish excavating and removing contaminated soil from the site in 2024, the spotlight is turning to groundwater.

ETTP is divided into three sections for groundwater remediation planning. One section is the Main Plant Area, which encompasses most of the operations area at the former enrichment complex.

Another section is the area where the large K-31 and K-33 uranium enrichment buildings once stood. The third section encompasses Zone 1, the area immediately surrounding the Main Plant and K-31/ K-33 area.

Planning took a major step forward recently when the EPA and TDEC approved OREM's proposed plans for addressing groundwater in the Main Plant and K-31 and K-33 areas.

OREM hosted two public meetings in 2023 to discuss the preferred approach for groundwater remediation at ETTP. The meetings provided an opportunity to explain the planned work at the site and for attendees to share comments.

The preferred approach for groundwater remediation in the Main Plant Area is a process called enhanced in situ bioremediation. A widely used technology for treating contaminated waste, it involves injecting microorganisms and a carbon source, such as vegetable oil, into the ground. The microorganisms reduce or detoxify the contaminants.

For the K-31/K-33 area, OREM is proposing a process called monitored natural attenuation along with land use controls. Monitored natural attenuation relies on natural processes that reduce contaminant concentrations in groundwater. Using this process as the remedial action involves monitoring groundwater conditions with land use controls, limiting potential exposures.

Groundwater remediation is being addressed in part in an interim ROD for the Main Plant Area and a ROD for the K-31/K-33 area, discussed previously in Section 3.6.4 (DOE 2023b, DOE 2023c). A future ROD will address the Zone 1 groundwater plumes.

3.8.3. Reindustrialization

The Reindustrialization Program maintained progress in 2023 by continuing partnerships and planning for the transfer of remediated land and remaining infrastructure at ETTP to public or private ownership for the economic benefit of the community. The former DOE K-25 uranium enrichment complex is currently in conversion to a multi-use industrial park that includes manufacturing, clean energy, national historic preservation, and conservation with public access to natural areas. Accounting for committed land transfers to date, only a few hundred acres of the approximately 2,200 original acres remain for final transfer. The vision for the park continues to be realized (Figure 3.53).

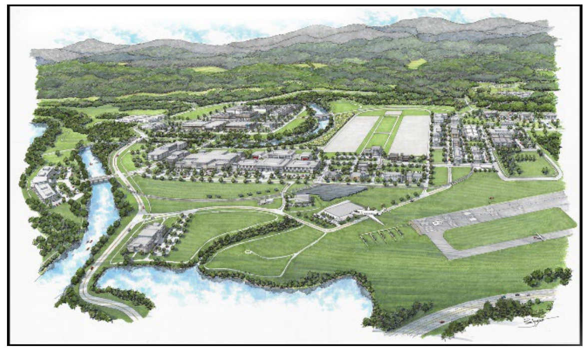


Figure 3.53. Artist's rendering of ETTP as a multi-use industrial park

During FY 2023, the Reindustrialization team advanced the regulatory review of almost 500 acres of remediated land in transfer packages. This land includes the former K-1037 Steam Plant and Toxic Substances Control Act Incinerator package, the former Old Powerhouse Area, the former K-732 Switchyard, and multiple parcels intended for development of a new municipal airport. Upon regulatory approval, transfer packages are submitted for department and congressional approvals, which finalizes the process to release the land for new businesses and economic growth opportunities. The Oak Ridge community continues to develop a reputation as an area known for clean energy and next-generation nuclear power industries. In 2023, Tennessee Governor Bill Lee issued an Executive Order to Advance Nuclear Energy Innovation and Investment, thereby positioning Tennessee as a national leader, and created the Nuclear Energy Advisory Council to formalize an implementation strategy that could build upon recent progress in Oak Ridge and Knoxville.

Members include prominent Oak Ridge scientists, policy makers, and business professionals working together to evaluate future possibilities. Clean energy and new nuclear businesses currently developing in the area include TRISO-X, Ultra Safe Nuclear Corporation, Kairos Power, and the Tennessee Valley Authority. The area is expected to attract additional companies needed to support these industries.

The national historical preservation activities continued with the groundbreaking for a viewing platform. This new facility will be adjacent to the K-25 History Center and is positioned to overlook the former K-25 Building footprint.

Public Involvement

Since 2011, UCOR has provided environmental management, remediation, and cleanup services to DOE's Oak Ridge Office of Environmental Management to move forward the site's transformation to a multi-use industrial center, national park, and recreational area.

OREM and UCOR continued to share progress and lessons learned with the community and stakeholders through a variety of outlets. Two public meetings were held in FY 2023 regarding groundwater remediation at ETTP, where OREM presented information on the proposed plans for remedial actions for the ETTP Main Plant Area and for the K-31/K-33 area. In 2023, the Oak Ridge Site Specific Advisory Board (ORSSAB) issued a recommendation on the site's budget request and a recommendation on groundwater remedies for ETTP. ORSSAB has also been conducting public information sessions about the expansion of ORR waste disposal capacity through ongoing development of the planned new onsite waste disposal facility, the EMDF. These activities helped describe the remaining scope of work and provided an update on how the site is being transformed into a valuable community asset.

3.9. References

DOE 1992. *Federal Facility Agreement for the Oak Ridge Reservation*. FFA-PM/18-011, DOE/OR-014, January 1, 1992, or latest revision, US Environmental Protection Agency Region IV, US Department of Energy, and Tennessee Department of Environment and Conservation, Oak Ridge, Tennessee. Retrieved April 20, 2023, from https://www.energy.gov/sites/prod/files/em/2001_Agreements/ORR_FFA_1-1-92.pdf.

DOE 1993a. *Radiation Protection of the Public and the Environment,* DOE Order 5400.5, Chg. 2. Approved January 7, 1993. US Department of Energy, Washington, DC.

DOE 1993b. *Record of Decision for the K-1407-B/C Ponds at the Oak Ridge K-25 Site, Oak Ridge, Tennessee*. DOE/OR/02-1125&D3, September 1, 1993, US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee.

DOE 1995. *Remedial Action Report for the K-1407-B Holding Pond and the K-1407-C Retention Basin*. DOE/OR/01-1371&D1, August 3, 1995, US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee.

DOE 1997. *Record of Decision for the K-1070-C/D Operable Unit, East Tennessee Technology Park, Oak Ridge, Tennessee*. DOE/OR/02-1486&D4, November 1997. US Department of Energy, Washington, DC.

DOE 2011a. *Departmental Sustainability*. DOE Order 436.1. Approved May 2, 2011. US Department of Energy, Washington, DC.

DOE 2011b. *Radiation Protection of the Public and the Environment*. DOE Order 458.1. Approved February 11, 2011. US Department of Energy, Washington, DC.

DOE 2012. *Memorandum of Agreement Among the U.S. Department of Energy Oak Ridge Office of Environmental Management, Department of Energy Federal Preservation Officer, the Tennessee State Historic Preservation Office, the Advisory Council on Historic Preservation, the City of Oak Ridge, Tennessee, and the East Tennessee Preservation Alliance, Pursuant to 36 CFR Part 800.6(B)(2) For Decommissioning And Demolition of the K-25 Site and Interpretation of the East Tennessee Technology Park, on the Oak Ridge Reservation, Roane County, Tennessee*, August 6, 2012, US Department of Energy, Oak Ridge Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2018. *Oak Ridge Reservation Polychlorinated Biphenyl Federal Facilities Compliance Agreement*. ORR-PCB-FFCA, Revision 6. US Department of Environmental Protection Agency, US Department of Energy, Oak Ridge Field Office, Oak Ridge, Tennessee. Retrieved April 20, 2023, from: http://ucor.com/wp-content/uploads/2021/07/PCB_FFCA.pdf.

DOE 2020a. *Compliance Plan National Emission Standards for Hazardous Air Pollutants for Airborne Radionuclides on the Oak Ridge Reservation, Oak Ridge, Tennessee.* DOE/ORO/2196, Rev. 2, May 1, 2020, US Department of Energy, Oak Ridge Office, Oak Ridge, Tennessee.

DOE 2020b. *East Tennessee Technology Park Administrative Watershed Remedial Action Report Comprehensive Monitoring Plan, Oak Ridge, Tennessee*. DOE/OR/01-2477&D4, 2020, US Department of Energy, Oak Ridge Office, Oak Ridge, Tennessee.

DOE 2022a. *Derived Concentration Technical Standard*. DOE-STD-1196-2022, December 2022, US Department of Energy, Washington, DC.

DOE 2022b. *East Tennessee Technology Park Main Plant Groundwater Focused Feasibility Study, Oak Ridge, Tennessee*. DOE/OR/01-2894&D2, February 2022, US Department of Energy, Oak Ridge Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2022c. *Remedial Investigation/Feasibility Study Report for the K-31/K-33 Area at the East Tennessee Technology Park, Oak Ridge, Tennessee.* DOE/OR/01-2893&D2, July 2022, US Department of Energy, Oak Ridge Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2023a. *2022 Oak Ridge Reservation Annual Site Environmental Report*. DOE-SC-OSO/RM-2023-01, September 2023, US Department of Energy, Oak Ridge Office of Environmental Management*, Oak Ridge, Tennessee.*

DOE 2023b. *Interim Record of Decision for Groundwater in the Main Plant Area at the East Tennessee Technology Park, Oak Ridge, Tennessee*. DOE/OR/01-2949&D1, July 24, 2023, US Department of Energy, Oak Ridge Office, Oak Ridge, Tennessee.

DOE 2023c. *Record of Decision for Groundwater in the K-31/K-33 Area at the East Tennessee Technology Park, Oak Ridge, Tennessee.* DOE/OR/01-2950&D1, July 20, 2023, US Department of Energy, Oak Ridge Office, Oak Ridge, Tennessee.

DOE 2023d. *Proposed Plan for an Interim Record of Decision for Groundwater in Main Plant Area at East Tennessee Technology Park, Oak Ridge, Tennessee.* DOE/OR/01-2921&D2, January 2023, US Department of Energy, Oak Ridge Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2023e. *Proposed Plan for the Record of Decision for Groundwater in the K-31/K-33 Area at the East Tennessee Technology Park, Oak Ridge, Tennessee.* DOE/OR/01-2922&D2, January 2023, US Department of Energy, Oak Ridge Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2023f. *Zone 1 Groundwater Plumes Remedial Investigation Work Plan, East Tennessee Technology Park, Oak Ridge Tennessee*. DOE/OR/01-2903&D2/A1, April 1, 2023, US Department of Energy, Oak Ridge Office of Environmental Management, Tennessee.

DOI 2015. *Interior and Energy Departments Formally Establish the Manhattan Project National Historical Park.* Retrieved July 6, 2023, from https://www.doi.gov/pressreleases/interior-and-energy-departments-formally-establish-manhattan-project-national.

EO 13514. *Federal Leadership in Environmental, Energy, and Economic Performance*, October 8, 2009, Federal Register, Vol. 74(194).

EO 13693. *Planning for Federal Sustainability in the Next Decade*, March 25, 2015, Federal Register, Vol. 80(57).

EO 13834. *Efficient Federal Operations*, May 22, 2018, Federal Register, Vol. 83 (99).

EO 14008. Justice40 Initiative. EO 14008. Justice40 Initiative, *Tackling the Climate Crisis at Home and Abroad*, January 27, 2021, Federal Register, Vol. 86 (19).

EO 14057. *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability*, December 8, 2021, Federal Register, Vol. 86 (236).

EPA 1975. *National Primary Drinking Water Regulations*. December 24, 1975, 40 CFR Part 141, Subparts B and G. US Environmental Protection Agency, Washington, DC.

EPA 1978. *Terminology and Index*, "Categorical exclusion." November 29, 1978, 40 CFR Part 1508.4. US Environmental Protection Agency, Washington, DC.

EPA 1979. *Polychlorinated Biphenyls (PCBS) Manufacturing, Processing, Distribution in Commerce, And Use Prohibitions*. May 31, 1979, 40 CFR Part 761. US Environmental Protection Agency, Washington, DC.

EPA 1984. *National Emission Standards for Hazardous Air Pollutants*, "National Emission Standard for Asbestos," April 5, 1984, 40 CFR Part 61, Subpart M. US Environmental Protection Agency, Washington, DC.

EPA 1989. *National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities.* 40 CFR Part 61.93(b)(1)(iii), Emission monitoring and test procedures; appendix B, Method 114, EPA 1989; updated Sept 9, 2002. US Environmental Protection Agency, Washington, DC.

EPA 1990. *National Emission Standards for Hazardous Air Pollutants*, Subpart M—National Emission Standard for Asbestos, Standard for demolition and renovation, Notification requirements. November 20, 1990, 40 CFR Part 61.145(b). US Environmental Protection Agency, Washington, DC.

EPA 1993. *Protection of Stratospheric Ozone*, Subpart F—Recycling and Emissions Reduction. May 14, 1993, 40 CFR Part 82, US Environmental Protection Agency, Washington, DC.

EPA 1994. *Chemical Accident Prevention Provisions*. January 31, 1994, 40 CFR Part 68. US Environmental Protection Agency, Washington, DC.

EPA 2009. *Mandatory Greenhouse Gas Reporting*. October 30, 2009, 40 CFR Part 98. US Environmental Protection Agency, Washington, DC.

ISO 2004. *Environmental management systems—Requirements with guidance for use*. ISO 14001:2004. November, International Organization for Standardization, Geneva, Switzerland.

K-25 Virtual Museum 2015. United Cleanup Oak Ridge LLC, US Department of Energy, Oak Ridge, Tennessee. Retrieved April 19, 2023, from http://k-25virtualmuseum.org/.

Souza et al. 2001. Souza, Peter A., Glyn D. DuVall, and Melisa J. Hart, *Cultural Resource Management Plan, DOE Oak Ridge Reservation, Anderson and Roane Counties, Tennessee*. DOE/ORO/2085, US Department of Energy, Washington, DC.

TDEC 2017a. *Quality System Standard Operating Procedures for Macroinvertebrate Stream Surveys*, August 2018, DWR-PAS-P-01-QSSOP-081117, TDEC Division of Water Pollution Control, Nashville, Tennessee. Retrieved on April 20, 2023, at https://www.tn.gov/content/dam/tn/environment/water/documents/DWR-PAS-P-01-Quality_System_SOP_for_Macroinvertebrate_Stream_Surveys-081117.pdf.

TDEC 2017b. Construction and Operating Permits, Permits-by-Rule. TDEC Rule 1200-03-09-.07, August 2017 revised. Tennessee Department of Environment and Conservation, Nashville, Tennessee.

TDEC 2018. *Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities*. TDEC Rule 1200-03-11-.08, September 2018 revised (1996). Tennessee Department of Environment & Conservation, Nashville, Tennessee.

TDEC 2019. *General Water Quality Criteria, Criteria for Water Uses.* TDEC Rule 0400-40-03-.03, September 2019. Tennessee Department of Environment & Conservation, Nashville, Tennessee.

UCOR 2018. *Quality Assurance Program Plan for Compliance with Radionuclide National Emission Standards for Hazardous Air Pollutants, East Tennessee Technology Park, Oak Ridge, Tennessee*. UCOR-4257/R2, September, URS | CH2M Oak Ridge LLC, Oak Ridge, Tennessee. (Not available for public release.)

UCOR 2020a. *Disposition of Personal Property.* PROC-PR-2032, Rev. 10, United Cleanup Oak Ridge LLC, Oak Ridge, Tennessee. (Not available for public release.)

UCOR 2020b. *Environmental Management and Protection*. POL-UCOR-007, Rev. 7, United Cleanup Oak Ridge LLC, Oak Ridge, Tennessee. (Not available for public release.)

UCOR 2022a. *Pollution Prevention and Waste Minimization Program Plan for the East Tennessee Technology Park, Oak Ridge, Tennessee.* UCOR-4127/R10, February, United Cleanup Oak Ridge LLC , Oak Ridge, Tennessee. (Available for public release by request.)

UCOR 2023a. Pollution Prevention and Waste Minimization Program Plan for the East Tennessee Technology Park, Oak Ridge, Tennessee. UCOR-4127/R11, September, United Cleanup Oak Ridge LLC, Oak Ridge, Tennessee. (Available for public release by request.)

UCOR 2023b. *East Tennessee Technology Park Storm Water Pollution Prevention Program Sampling and Analysis Plan, Oak Ridge, Tennessee*. UCOR-4028/R14, August, United Cleanup Oak Ridge LLC, Oak Ridge, Tennessee. (Available for public release.)

UCOR 2024. *2023 Cleanup Progress—Annual Report to the Oak Ridge Regional Community*. OREM-23-7637, United Cleanup Oak Ridge LLC, Oak Ridge, Tennessee. Retrieved April 18, 2024, from https://www.energy.gov/sites/default/files/202301/Cleanup%20Progress%202022_FINAL.pdf.

Y-12 is a one-of-a-kind manufacturing complex that plays an important role in United States national security. Through Life Extension Program activities, Y-12 produces refurbished, replaced, and upgraded weapons components to modernize the enduring stockpile.

4

The Y-12 National Security Complex

Y-12, a premier manufacturing facility managed and 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 75 years of manufacturing excellence, Y-12 helps ensure a safe and reliable United States nuclear weapons deterrent.

Y-12 has three primary missions—maintain the safety, security, and effectiveness of the U.S. nuclear weapons stockpile; reduce the global threat posed by nuclear proliferation and terrorism; and provide feedstock to fuel the U.S. Nuclear Navy.

Today's environment requires Y-12 to have 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.

4.1. Description of Site and Operations

4.1.1. Mission

Charged with maintaining the safety, security, and effectiveness of the US nuclear weapons stockpile, Y-12 is a one-of-a-kind manufacturing facility that has a core mission to ensure a safe, secure, and reliable nuclear deterrent. Every weapon in the 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 nonexplosive, peaceful uses.

Y-12 secures and stores highly enriched uranium, and makes uranium available for non-weapon uses (e.g., in research reactors that produce cancer-fighting medical isotopes and for other research reactor purposes). Y-12 also processes highly enriched uranium from weapons removed from the 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, the site covers more than 3,024 acres including 810 acres in the Bear Creek Valley, stretching 2.5 mi (4.0 km) in length down the valley and nearly 1.5 mi (2.4 km) in width across it. Additional NNSA-related facilities located off-site include the Central Training Facility, Alternate Emergency Operations Center, Oak Ridge Enhanced Technology and Training Center, Uranium Processing Facility (UPF) project laydown storage and offices, Y-12 Material Acquisition and Control Facilities, John M. Googin Technology Development Facility, Test and Demonstration Facility, Commerce Park Office Complex, and Union Valley Sample Preparation Facility.

4.1.2. Modernization

Y-12 directly supports four NNSA capabilities—uranium, lithium, weapons assembly and disassembly, and safe and secure storage of strategic materials. The Y-12 strategic vision is driven by the overarching objectives that, by 2040, Y-12 will be capable of reliably fabricating any component, building any weapon, and qualifying any system on any day, as well as executing a digital transformation strategy that enables smart, real-time, data-driven operations. Today, Y-12 is not well suited to deliver this type of responsive capability. Following the end of the Cold War, operations were scaled back, and many once-reliable processes have since atrophied.

The ability to deliver a nuclear weapon without reusing components from legacy weapons or relying heavily on aging infrastructure does not exist. Additionally, Y-12 faces a unique need to reestablish capabilities and two material streams—binary and special materials—associated with the NNSA mission. Accelerated planning and improvements to site infrastructure, including the following, are key to reestablishing these capabilities:

- New production facilities
- New capability and operational support facilities
- Capability bridging until new facilities are in place

Planning for the future site ensures that Y-12 will continue to provide the infrastructure needed to support the primary capabilities and materials missions with new facilities and associated technologies. In addition to new and revitalized facilities, the security posture will be strengthened by a reduced protected area footprint and revitalized security infrastructure and systems. The envisioned future Y-12 site includes the following elements:

- Major supply chains, including uranium (enriched uranium, depleted uranium, and low enriched uranium) and lithium, are reestablished and/or transformed.
- The UPF, Lithium Processing Facility (LPF), Enriched Uranium Manufacturing Center, Assembly and Disassembly Center, and Depleted Uranium Manufacturing Capability are constructed.
- The security posture is sustained and improved through recapitalized and transformed footprint and security systems.
- The Mercury Treatment Facility and Environmental Management Disposal Facility are constructed, enabling approximately 2.8 million gross square feet (gsf) of excess facility demolition and legacy environmental threats to be remediated.
- Public tours of Y-12 historic facilities and participation in the Manhattan Project National Historic Park are implemented, to the extent possible.

Sixty-five percent of Y-12's facility footprint is more than 60 years old and accounts for 18 percent of Y-12's buildings, as shown in

Figure 4.1. To address this situation, Y-12 has been consolidating operations, modernizing facilities and infrastructure, and reducing the legacy footprint. These actions support NNSA overall transformation planning.

Through continued infrastructure projects, new construction, and the disposition of excess facilities, Y-12 continues to become more responsive and sustainable.

Replacement and revitalization are key elements to modernizing Y-12. A significant number of facilities are at or beyond design life. Currently, construction activities include the UPF, LPF, and the West End Protected Area Reduction project.

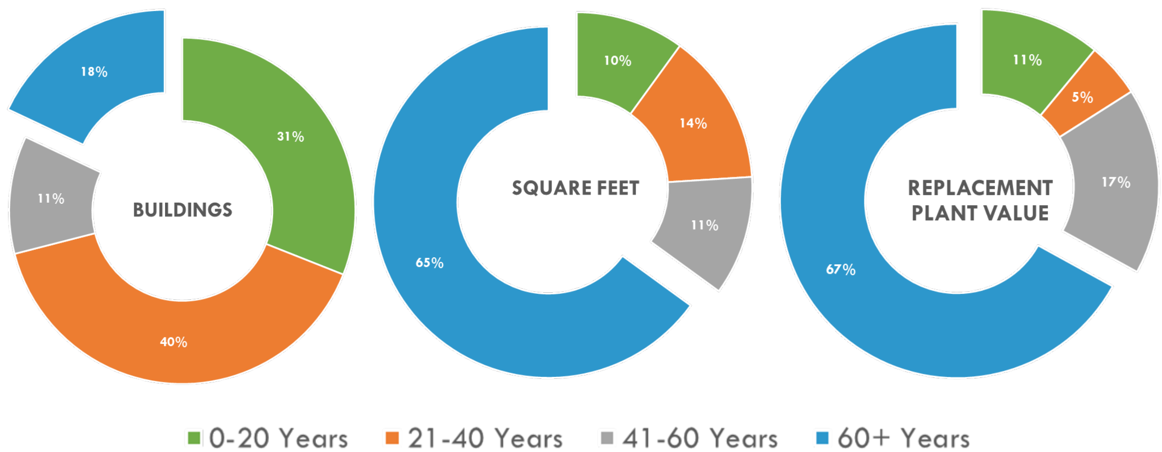


Figure 4.1. Age of facilities at Y-12 as of 2023

4.1.3. Production Operations

Y-12's core manufacturing and processing operations are housed in decades-old buildings near or past the end of their expected life spans. The UPF, which is an integral part of Y-12's transformation, is being constructed as one of two main facilities in which enriched uranium will be stored and processed in a more centralized area.

The major production capabilities and associated facilities at Y-12 include the following:

- **Enriched uranium.** Buildings 9212, 9215, and UPF
- **Depleted uranium.** Buildings 9215, 9201-05N, 9201-05W, 9996, and 9998
- **Lithium.** Buildings 9204-02, 9202, and LPF
- **General manufacturing and fabrication.** Building 9201-01
- **Assembly and disassembly.** Building 9204-02E
- **Special materials.** Buildings 9225-03 (2025) and 9990-03
- **Storage:** Buildings 9720-82, 9720-05, 9720-26, 9720-32, 9720-33, 9720-59, and 9811-01

The following planned major construction activities are replacing key production operations currently in aging, oversized facilities. Dates of the construction activities are tentative and subject to change.

- Building 9212 functions are to be replaced by the UPF in 2028, with some Building 9212 processes relocated to Buildings 9215 and 9204-2E.
- Building 9215 enriched uranium functions are to be replaced by the Enriched Uranium Manufacturing Center by 2050.
- Building 9204-02E functions are to be replaced by the Assembly and Disassembly Center by 2055.
- Building 9204-02 lithium functions are to be replaced by the LPF by 2031.
- Depleted uranium fabricating and manufacturing functions from the Building 9215 Complex, Building 9201-05N, and Building 9201-05W are to be replaced by phased line item construction, with the first phase—the Depleted Uranium Complex—by 2035.
- General manufacturing and fabrication functions from Building 9201-01 are to be replaced by the General Manufacturing Capability by 2043.

4.1.4. Support Facilities

Organization and facilities that support operations ensure Y-12 mission-critical work is completed. The primary missions of the operations support infrastructure are to protect vital national security assets and people and enable site missions. Operations support includes the following:

- Security
- Emergency Services
- Development
- Analytical Chemistry
- General Storage and Warehousing
- Cybersecurity and Information Technology
- Global Security and Strategic Partnerships
- Waste Management
- Sustainability and Stewardship
- Oak Ridge Enhanced Technology and Training Center

The following planned major construction activities are replacing key operations support facilities:

- Complete the West End Protected Area Reduction project, including a new Entry Control Facility, by 2025.
- Relocate bench-scale laboratory development functions from Buildings 9202 and 9203 to the off-site John M. Googin Technology Development Facility, located at 103 Palladium Way, by 2027. Construct a phased line item construction development campus, with the first phase—the Applied Technologies Laboratory—by 2037.
- Implement the Security Infrastructure Revitalization Program to upgrade and replace the legacy Perimeter Intrusion Detection and Assessment System.
- Explore new construction for replacement facilities to support Analytical Chemistry operations, including phased campus construction, beginning in 2026, and a future line item construction project—the Analytical Chemistry Laboratory—in 2033.
- Construct the Oak Ridge Institute for Global Nuclear Security at the new Oak Ridge Enhanced Technology and Training Center campus.
- Construct a new maintenance complex through phased line item construction, with the first phase to replace the 78-year-old Building 9201-03 and other aging maintenance facilities.
- Construct a new waste management complex to replace the aging West End Treatment Facilities.
- Implement a digital transformation and cybersecurity strategy.

- Construct a new security complex to accommodate growing requirements.

4.1.5. Excess Facility Disposition

Currently, there are 70 excess facilities at Y-12, with another 59 buildings and trailers to be excessed within the next 10 years. The major excess process-contaminated facilities, including Building 9201-05, Building 9204-04, and Building 9206, will be transitioned to the DOE Office of Environmental Management (EM) for disposition. The smaller, process-contaminated, ancillary facilities associated with Buildings 9201-05, 9204-04, and 9206; Building 9212-associated facilities; and the Building 9401-03 Complex (Steam Plant) are planned to be dispositioned by NNSA.

Process-contaminated facilities contain radiological and/or chemical contamination resulting from mission operations during the Manhattan Project or Cold War eras. Excess process-contaminated facilities are expected to be sufficiently managed until facility conditions meet criteria for transition to EM. Excess non-process-contaminated facilities are generally expected to be demolished by NNSA; however, some excess non-process-contaminated facilities may be demolished by EM depending on their complexity and/or proximity to process-contaminated facilities.

The Mercury Treatment Facility and the Environmental Management Disposal Facility will be constructed before any mercury-contaminated facilities can be demolished. Surveillance and maintenance activities, along with utility reroutes, unneeded material cleanout, and fluid and oil disposition, continue while these new facilities are being built.

4.2. Environmental Management System

DOE Order 436.1A, *Departmental Sustainability* (DOE 2023a), requires federal facilities to use a certified or conforming environmental management system (EMS) as a management framework to implement programs that meet sustainability goals and support the fulfillment of environmental compliance obligations.

The DOE Order also requires that EMSs, covering all site activities, are certified to or conform to the International Organization for Standardization's (ISO) 14001, *Environmental management systems—Requirements with guidance for use* (ISO 2015).

In September 2021, the Y-12 EMS was declared to be in conformance with ISO 14001. The audit team from The University of Tennessee Center for Industrial Services noted in the report that the Y-12 management and operating contract requires conforming to the 2004 version of the standard. The team audited the site to the 2015 version of the standard in anticipation that the requirement will change with the next Y-12 contract.

The EMS applies to site activities and operations managed by CNS as described in Section 4.1. By design, the "plan-do-check-act" approach of the ISO 14001 standard improves environmental performance, which supports Y-12's overall mission effectiveness.

The Y-12 EMS has two areas of focus—environmental compliance and environmental sustainability. Environmental compliance consists of regulatory compliance and monitoring programs that implement federal, state, and local requirements, agreements, and permits. Environmental sustainability promotes and integrates initiatives such as energy and natural resource conservation, air pollutant emission minimization, waste minimization, and the use of sustainable products and services.

4.2.1. Integrating 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, workers, or the environment. Elements of the ISO 14001 EMS are incorporated in ISMS to achieve environmental compliance, pollution prevention, waste minimization, resource conservation, and sustainability. Both 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 ISMS and the integrated EMS.

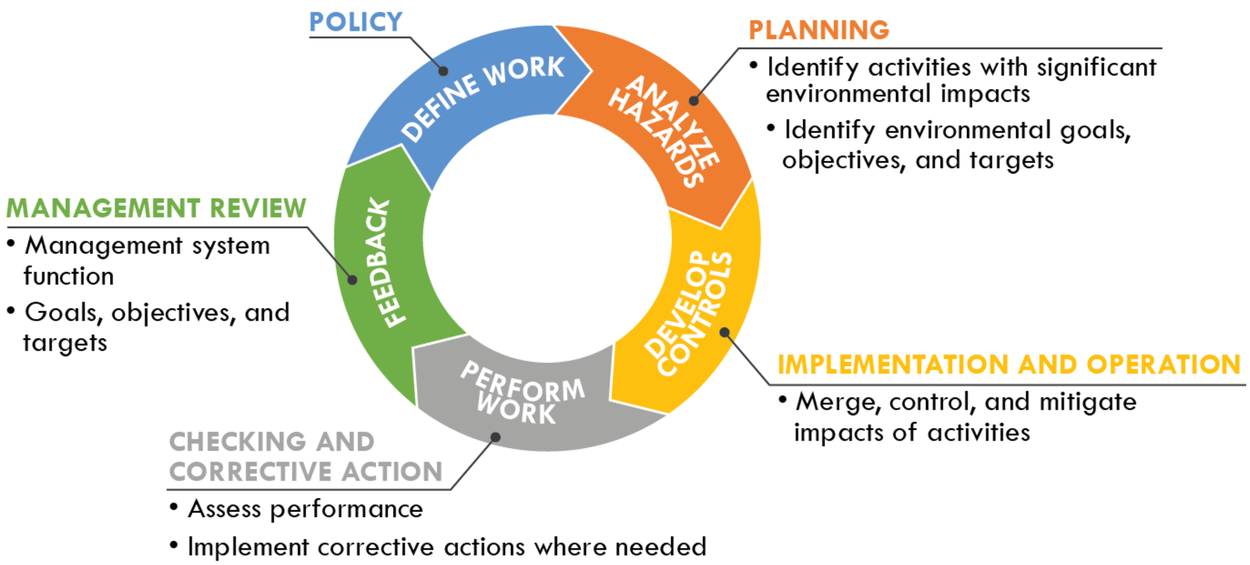


Figure 4.2. The "plan-do-check-act" cycle of continual improvement

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 senior management, and have been made available to the public via company-sponsored forums and public documents. Y-12's ES&H policy is provided in Figure 4.3.

In addition to Y-12's ES&H policy, CNS has issued an environmental policy that is a significant component of its corporate ISMS and contributes to sustaining safe and secure operations. The Y-12 ES&H policy and the CNS environmental policy are incorporated into mandatory training for every employee and subcontractor. 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 they relate to work activities. Communication of Y-12's environmental policy and other EMS training and awareness activities foster a greater understanding of environmental issues and empowers employees to contribute to improving Y-12's environmental footprint.

4.2.3. Planning

The following sections describe planning activities conducted as part of the Y-12 EMS.

4.2.3.1. Y-12 Environmental Aspects

Environmental aspects may be thought of as potential environmental hazards associated with a facility operation, maintenance job, or work activity. Environmental aspects and their impacts (i.e., potential risks to and 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 ensures 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 2023:

- Storm water (runoff from roofs and outdoor storage areas)
- Groundwater
- Surface water (process water and dike emissions to creek)
- Wastewater (sanitary sewer and process water treated and disposed)
- Radiological waste
- Hazardous or mixed waste
- Excess facilities and unneeded materials and chemicals
- Aging infrastructure and equipment
- Legacy contamination and disturbance

Y-12 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 process.
- Continuously improving our process 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 operating expression of ES&H concerns.

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

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 discussed in Section 4.3.

4.2.3.3. Objectives, Targets, and Environmental Action Plans

Y-12 pursues sustainability initiatives by establishing and maintaining environmental commitments, goals, targets, and action plans. Goals and commitments are established annually and consider the site'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 2023 environmental achievements are presented in Section 4.2.6.1.

4.2.3.4. Programs

NNSA has developed and funded several 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 provides environmental technical support services and oversees 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 orders, environmental laws, and regulations; and consistent with CNS environmental policy and Y-12 site procedures. The department serves as the 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 the EPA. Environmental Compliance staff members administer 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.

The organization also maintains and ensures implementation of the Y-12 EMS and spearheads initiatives to 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 the site. While ensuring compliance with federal and state regulations, DOE orders, Waste Acceptance Criteria, and Y-12 procedures and policies, the 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 and disposal. The program also provides technical support to Y-12 Operations for waste planning, characterizing, packaging, tracking, reporting, and managing waste treatment and disposal subcontracts.

Sustainability and Stewardship

The Sustainability and Stewardship Program has two major missions. The first is to establish and maintain programs and services to support sustainable material management operations. These sustainable operations include pollution prevention and recycling programs, excess materials programs, the PrYde Program for facility cleanliness, generator services programs, sanitary waste and landfill coordination, and Destruction and Recycle Facility operations.

Y-12 has implemented continuous improvement activities, such as an Items Available for Reuse section on the site Property Accountability Tracking System and a central telephone number (574-JUNK) to provide employees with easy access to information and assistance related to the proper methods for disposing excess materials.

The second mission is managing stewardship practices—the programs that address legacy issues and assist in preventing development of new problematic issues. Stewardship programs include Clean Sweep, Unneeded Materials and Chemicals, and Targeted Excess Materials.

The Clean Sweep Program provides turnkey services to material generators, including segregation, staging, and materials pickup for excess, recycle, or 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.

Unneeded materials at Y-12 are not automatically assumed to be wastes requiring disposal. Y-12 uses a systematic disposition evaluation process. The first step in the 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 Executive Orders, DOE orders, federal and state regulations, and NNSA expectations, as well as eliminates duplication of efforts, while providing an overall improved appearance at Y-12.

Additionally, implementing these programs supports EMS objectives to disposition unneeded materials and chemicals; continually improves recycle programs by adding new recycle streams as applicable; improves sustainable acquisition (i.e., promotes the purchase of products made with recycled content and bio-based products); meets sustainable design requirements; and adheres to pollution prevention reporting requirements.

Energy Management

The Y-12 Energy Management Program incorporates energy efficient technologies across the site and positions Y-12 to meet NNSA energy requirement needs and reduction requirements as set forth by DOE. The program identifies improvements in energy efficiency in facilities, coordinates energy-related efforts across the site, is involved with energy savings and performance contracts, and promotes employee awareness of energy conservation programs and opportunities.

4.2.4. Implementing and Operating

The following sections describe activities conducted as part of the Y-12 EMS to establish, implement, and maintain good environmental practices and procedures.

4.2.4.1. Roles, Responsibility, and Authority

Safe, secure, efficient, and environmentally responsible operation of Y-12 requires the commitment of all personnel. Environmental and Waste Management technical support personnel assist line organizations with identifying and carrying out their environmental responsibilities. Additionally, the Environmental Officer Program helps to communicate environmental regulatory requirements and promotes EMS as a tool to drive continual environmental improvement. Environmental officers coordinate their organizations' efforts to maintain environmental regulatory compliance and promote other improvement activities.

4.2.4.2. Community and Community Involvement

NNSA and CNS are committed to keeping the community informed on operations, environmental concerns, safety, and emergency preparedness. CNS is a member of Oak Ridge and East Tennessee economic development and business development agencies including the East Tennessee Economic Council, the Oak Ridge Chamber of Commerce, and the Anderson County Chamber of Commerce. CNS is also engaged in Anderson County and Oak Ridge's Leadership programs through its support of the Center for Leadership and Community Development.

Local charities receive donations from funds generated from the sale of aluminum beverage cans through the Employee Aluminum Can Recycling Program. Since the program began, more than $96,200 has been donated to local charities that were nominated by Y-12 employees and voted on by an employee committee.

Y-12 continues to promote sustainable behaviors for environmental improvements at the site and within the community. A United way coat and toiletries drive is held to provide coats and other needed items for the homeless who are served by the Volunteer Ministry Center. These activities reflect Y-12 employees' commitment to reduce landfill waste and to support community outreach.

4.2.4.3. Environmental Justice

CNS endorses and implements the core value of environmental justice through charitable and educational outreach to disadvantaged communities that are located in the counties that surround the Y-12 site. These counties include Anderson, Blount, Knox, Morgan, Roane, Hamblen, and Loudon.

In 2023, the CNS Community Investment Fund awarded grants totaling $180,000 to 24 nonprofits across East Tennessee. The fund is managed by the East Tennessee Foundation and directed by a committee of Y-12 volunteer employees. The fund passed the $1 million mark in grant distributions in 2022.

CNS is also a major supporter of United Way of Anderson County and the United Way of Greater Knoxville, with corporate and employee contributions totaling hundreds of thousands of dollars.

CNS continued its efforts to build relationships with K-12 teachers, community colleges, and technical schools. CNS provided volunteers for classroom outreach and community service projects and also provided leaders who served on local committees, nonprofit boards, and area business and professional organizations. CNS continued to fund educational scholarships to residents of the Scarboro community, located in Oak Ridge. Introduce a Girl to Engineering hosted hundreds of young girls toward an engineering career with in-person events early in 2023.

Additional organizations that CNS supports through charitable and educational outreach include the following:

- Aid to Distressed Families of Appalachian Counties
- American Museum of Science and Energy
- Angel Tree
- Big Brothers Big Sisters
- Casting for Recovery
- Children's Museum of Oak Ridge
- Covenant Health
- East Tennessee Children's Hospital
- Emory Valley Center
- Free Medical Clinic
- Helen Ross McNabb Center
- Junior Achievement
- Oak Ridge Breakfast Rotary Club Foundation
- Leukemia & Lymphoma Society
- March of Dimes
- McNabb Center
- Methodist Medical Center of Oak Ridge

4.2.4.4. Emergency Preparedness and Response

Local, state, and federal emergency response organizations are 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.

The exercises, performance drills, and training drills conducted at Y-12 during FY 2023 focused on topics such as responding to a severe weather event with a chemical release and a change in the site's Security Condition. Building evacuation and accountability drills were also conducted.

4.2.5. Checking

The following sections describe Y-12 EMS activities to review, assess, and monitor operations to maintain environmentally safe and compliant practices and continually improve environmental performance.

4.2.5.1. Monitoring and Measuring

Y-12 maintains procedures to monitor overall environmental performance 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 2023 program activities are described throughout this chapter. Progress in achieving environmental goals is reported as a monthly metric on PerformanceTrack, 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) [Note: NPO was replaced by the new Y-12 Field Office (YFO) in April 2024].

4.2.5.2. Environmental Management System Assessments

To periodically verify that the 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 conducts 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 to adhere to requirements in DOE Order 436.1a, the EMS must be audited at least every 3 years by a qualified party outside of the control or scope of the EMS. In 2021, an audit team from The University of Tennessee Center for Industrial Services found that the Y-12 EMS fully conformed, and no issues were identified. The next external verification audit is scheduled for summer 2024.

4.2.6. Performance

This section discusses EMS objectives, targets, other plans, initiatives, and successes that work together to accomplish DOE goals, reduce environmental impacts and risks, and improve effectiveness in overall mission. To report performance, Y-12 uses the Federal Automotive Statistical Tool, which collects fleet inventory and fuel use, and 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.

Y-12 was given an EMS scorecard rating of "green" for FY 2023, indicating full and effective implementation of EMS requirements after submitting its annual compliance report via the DOE EMS Site Information Database.

4.2.6.1. Environmental Management System Objectives and Targets

At the end of 2023, Y-12 had achieved nine of 12 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 completed a project to seal the Stack 11 basin and identified improved mission operations and improvements to air emissions.
- **Energy efficiency.** Y-12 completed chiller plant improvements in three locations after obtaining a utility energy service contract and funding approval.
- **Hazardous materials.** A project to disposition and ship legacy mixed waste according to the site treatment plan continued with five items shipped in FY 2023 to meet plan milestones. Unneeded materials and equipment were dispositioned from Building 9998 and two tanker trailers in FY 2023. Y-12 improved waste characterization processes and implemented real-time radiography to improve control and management of low-level radioactive waste.
- **Land, water, and natural resources.** Y-12 upgraded sanitary sewer networks in two areas as part of a project to protect the sanitary sewer lines from infill and infiltration. Y-12 also completed tank assessments on six aboveground inactive tanks and dikes in FY 2023.

4.2.6.2. Sustainability and Stewardship

Numerous efforts, including increased use of environmentally friendly products and processes and reductions in waste and emissions, have reduced Y-12's impact on the environment. These efforts have been recognized by NNSA, the community, and other stakeholders. Pollution prevention efforts at Y 12 have not only benefited the environment but have also resulted in cost avoidances (Figure 4.4).

In FY 2023, Y-12 implemented 105 pollution prevention initiatives (Figure 4.5), with a reduction of more than 17.8 million lb of waste and projected cost avoidances of more than $3.4 million.

Pollution Prevention and Source Reduction

Across Y-12, sustainable initiatives reduce the impact of pollution on the environment and to increase operational efficiency. Many of these sustainable initiatives have pollution prevention benefits or targets eliminating the source of pollution, including the 2023 activities highlighted in this section.

Sustainable Acquisition—Environmentally Preferable Purchasing

Sustainable products, including recycled content materials, are purchased for use across the site. In 2023, Y-12 bought more than $11.98 million of materials with recycled content.

Solid Waste Reduction

Y-12 reduces the amount of solid waste generated, often by diverting waste through source reduction, reuse, and recycling. In 2023, Y-12 diverted 56.8 percent of municipal and 32 percent of construction and demolition waste from landfill disposal through reuse and recycle. More than 4.1 million lb of municipal materials from landfill disposal were diverted through source reduction, reuse, and recycling, and more than 13.2 million lb of construction and demolition materials were diverted from landfill disposal.

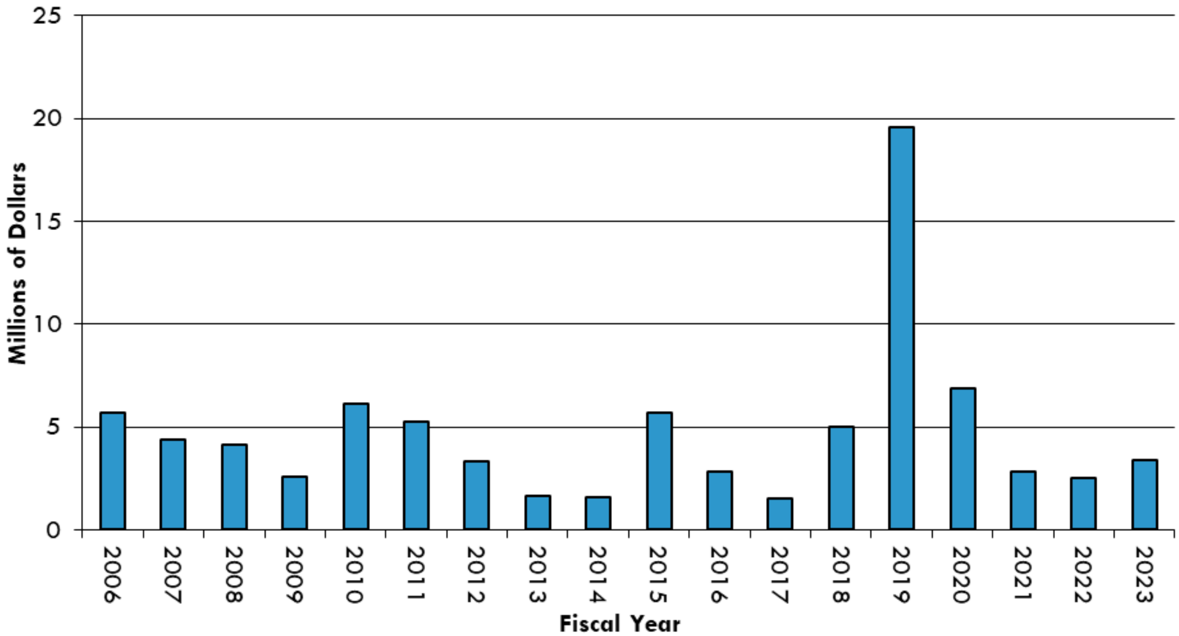


Figure 4.4. Cost avoidances from Y-12 pollution prevention activities, 2006–2023

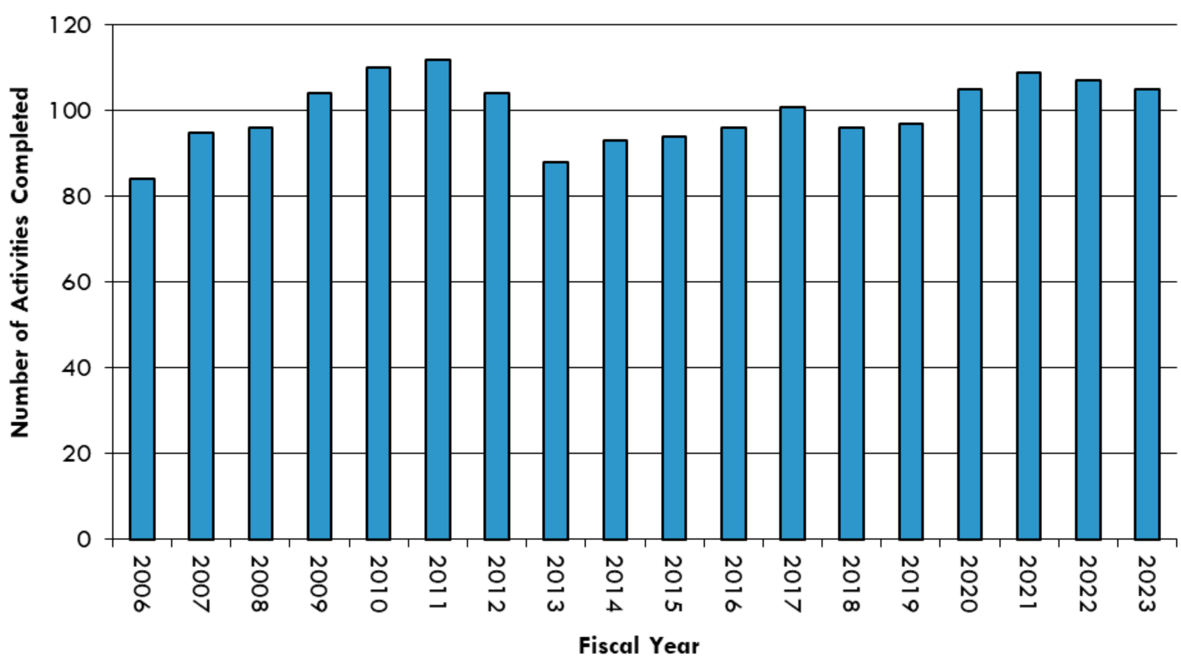


Figure 4.5. Y-12 pollution prevention initiatives, 2006–2023

Hazardous Chemical Minimization

The Generator Services group provides material disposition management services for waste generators at Y-12, including technical support to assist generators with determining whether the materials can be recycled, excessed, or reused. The Generator Services group can be used by any organization or generator at Y-12. During FY 2023, Generator Services personnel reused, or disseminated to other Y-12 organizations for reuse, more than 800 lb of various excess materials and chemicals. The Legacy Facilities group continued to produce hypochlorous acid, a safe, environmentally friendly, sustainable, and effective disinfectant. Producing hypochlorous acid on-site has reduced the need to purchase commercial disinfectants. Refillable containers are used to reduce the associated packaging waste materials from disinfectants.

Recycling

Y-12 has a well-established recycling program. The site 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 5.8 million lb of materials were diverted from landfills and into viable recycle processes during 2023. Currently, recycled materials range from office-related items 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 Recycle Program was expanded in FY 2023 to include painted pallets to broaden waste diversion efforts.

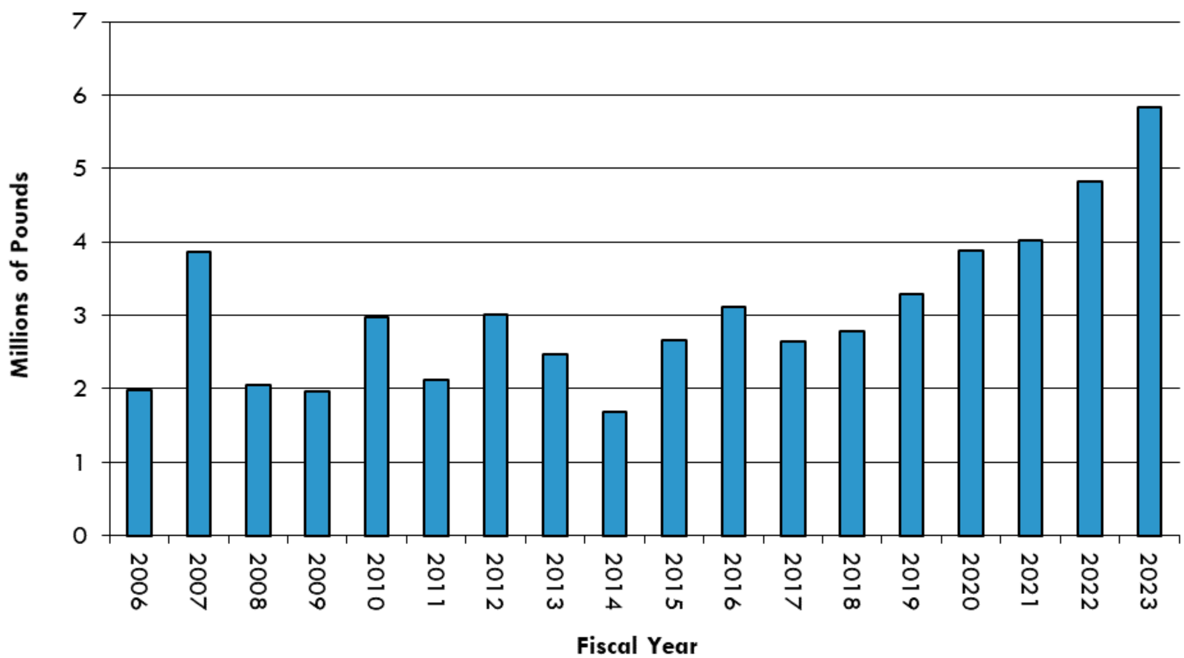
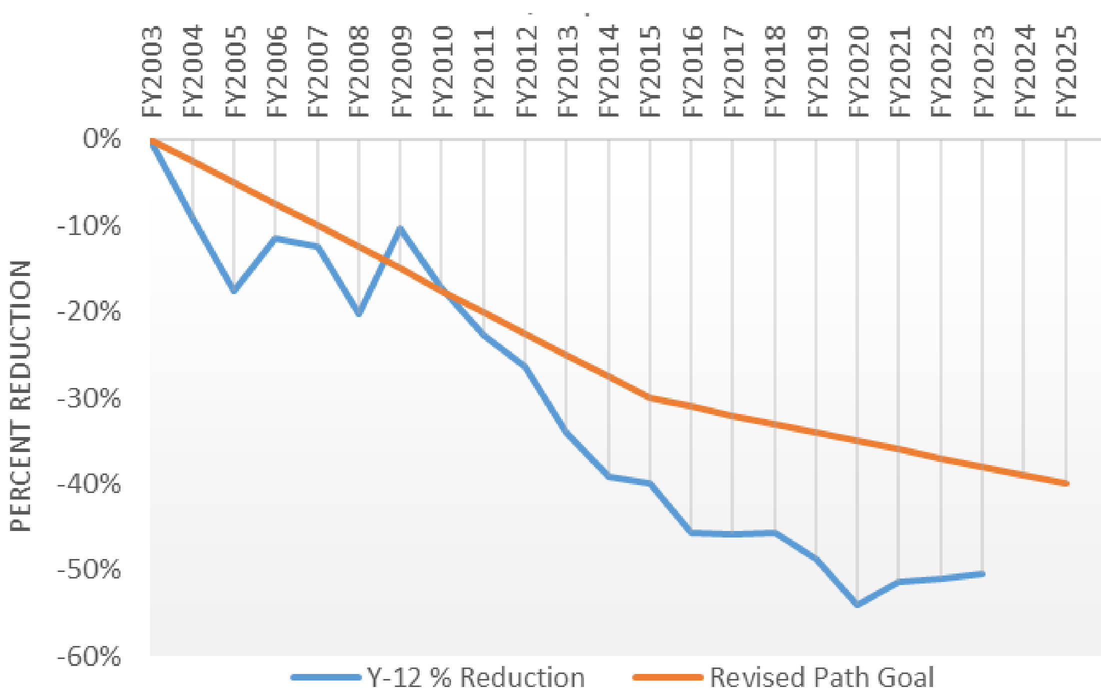


Figure 4.6. Y-12 recycling results, 2006–2023

4.2.6.3. Energy Management

The Energy Sustainability organization performs energy management activities. Energy usage and intensity, Energy Independence and Security Act of 2007 (EISA, EISA 2007) benchmarking and evaluations, facility metering and monitoring in accordance with the Energy Act of 2020 (EA 2020), and non-fleet vehicles and equipment are components of energy management reporting activities.

Y-12 exceeded the goal of a 30 percent energy intensity (Btu/gsf) reduction in goal-subject buildings by FY 2015 (from a FY 2003 baseline and 1 percent year-to-year reduction thereafter). During FY 2023, energy intensity was 207,645 Btu/gsf, a little over a half of a percentage above the prior year's 205,343 Btu/gsf. After the COVID-19 pandemic, rates have been rising slightly, especially compared to pandemic years 2020 and 2021, as the site's maximum teleworking policy expired and the site's population increased with newly hired employees. Continuing and new construction projects also contribute to the slightly increased energy intensity. Compared to the FY 2003 baseline year, Y-12 has seen an overall energy intensity reduction of 50.38 percent. Energy intensity through 2023 is shown in Figure 4.7.



Acronym: *FY = fiscal year*

Figure 4.7. Y-12 energy intensity (Btu per gross square foot) versus 2003 baseline goal

4.2.6.4. Sustainable Goals and Performance

DOE is required to meet sustainability goals mandated by statute and related Executive Orders, including goals for GHG emissions, energy and water use, fleet optimization, green buildings, and renewable energy. In 2023, the DOE Sustainability Performance Office used its web-based sustainability dashboard to collect and consolidate data from all DOE sites. The dashboard focuses on specific DOE sustainability goals, and site sustainability plans are completed within the dashboard. These goals, along with the current Y-12 performance ratings, are listed in Table 4.1.

Table 4.1. Sustainability goals and performance, 2023

DOE Goal	Current Status
Energy Management	
Reduce energy use intensity (Btu per gross square foot) in goal-subject buildings.	Goal Met: Y-12 exceeded the goal of meeting a 30 percent energy intensity reduction in goal-subject buildings by FY 2015 from an FY 2003 baseline and 1 percent year-to-year reduction thereafter. While energy reductions were met this year, as Y-12 site population increases every year and the site transforms to meet increased scope in the outyears, energy reductions compared to baseline will not be possible.
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 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. Efforts are underway to fully implement sitewide metering.
Achieve a net-zero emissions building portfolio by 2045 through building electrification and other efforts.	Goal Not Met: Y-12 does not have a complete net-zero emissions portfolio at this time. Initial efforts are underway to begin net-zero planning for the site.
Water Management	
Reduce potable water use intensity (gal per gross square foot).	Goal Met: Y-12 exceeded the goal of reducing water intensity by 36% by FY 2025 relative to FY 2007.
Reduce non-potable freshwater consumption (gal) for industrial, landscaping, and agricultural.	Goal Not Applicable. Y-12 does not use industrial, landscaping, or agricultural water.
Waste Management	
Reduce nonhazardous solid waste sent to treatment and disposal facilities.	Goal Met: 56.5% (1,880.3 metric tons/3,329.8 metric tons) of nonhazardous waste diverted from the landfill.
Reduce construction and demolition materials and debris sent to treatment and disposal facilities by 50%.	Goal Not Met: 32% (2,164.9 metric tons/28,888 metric tons) of construction and demolition materials were diverted from the landfill in FY 2023.
Fleet Management	
Reduce petroleum consumption.	Goal Not Met: Y-12 did not meet the interim target of 20% reduction in fleet petroleum consumption. There was an 11.6% increase from the FY 2005 baseline.
Increase alternative fuel consumption.	Goal Not Applicable: Y-12 does not have access to alternative fuels.
Achieve 100 percent zero-emission vehicle acquisitions by 2035, including 100 percent zero-emission light-duty vehicle acquisitions by 2027.	Goal Not Met: Y-12 ordered 42 vehicles with zero-emission capabilities when available in FY 2023. While 100 percent zero-emission vehicle acquisitions have not been met, Y-12 is working toward the goals for 2035 and 2037.
Clean & Renewable Energy	
Achieve 100 percent carbon pollution-free electricity on a net annual basis by 2030, including 50 percent 24/7 carbon pollution-free electricity.	Goal Not Met: Y-12 has not fully achieved these goals but is working on a decarbonization plan.
Increase consumption of clean and renewable non-electric thermal energy.	Goal Not Met: Y-12 had a 5.4% decrease in natural gas use for FY 2023.

Table 4.1. Sustainability goals and performance, 2023 (continued)

DOE Goal	Current Status
Sustainable Buildings	
Increase the number of owned buildings that are compliant with the Guiding Principles for Sustainable Buildings.	Goal Met: Two buildings were certified as High Performance and Sustainable Buildings in FY 2023.
Acquisition & Procurement	
Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring all sustainability clauses are included as appropriate.	Goal Met: All eligible contracts after Oct. 1, 2013, contain the sustainable acquisition requirements. The CNS Sustainable Acquisition Program is working with Contracts and Procurement to review the current $150,000 contract threshold for sustainable acquisition requirements to be included in subcontract languages so that future appropriate contracts will have the requirements to purchase sustainably.
Investments: Improvement Measures, Workforce, & Community	
Implement life-cycle cost-effective efficiency and conservation measures with appropriated funds and/or performance contracts.	Goal Met: Y-12 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 & Data Centers	
Promote electronics stewardship from acquisition, to operations, to end of life.	Goal Not Met: Y-12 did not meet the goal of purchasing 95% of eligible electronics as Electronic Product Environmental Assessment Tool registered products. Current performance for FY 2023 is at 89.5%. Y-12 power manages all mission-critical electronics, and current automatic duplexing is at 91.2%. Y-12's electronics recycling vendor maintained Responsible Recycling certification; therefore, all FY 2023 shipments were made to a certified recycler. Electronics that were not recycled were those that could not be radiologically cleared for release. Therefore, 100% of eligible electronics were recycled to a Responsible Recycling certified recycler or were donated for reuse.
Increase energy and water efficiency in high performance computing and data centers.	Goal Not Met: While data centers have been consolidated at Y-12, which has saved energy and water, they are not fully metered. Current power usage effectiveness is estimated to be 2.4. As the site moves to modernized data centers, the overall energy and water efficiencies will continue to increase.
Adaptation & Resilience	
Implement climate adaptation and resilience measures.	Goal Met: Y-12 issued a severe event emergency response plan that addresses severe natural phenomena events, extended loss of power events, and events that result in the loss of mutual aid. Additionally, the site updated its vulnerability assessment and resilience plan, along with identified resilience solutions, which include increasing on-site renewable energy generation; solar powered equipment; new facilities; roof repairs and replacement; chiller upgrades; and heating, ventilation, and air conditioning system repairs and replacements.

Table 4.1. Sustainability goals and performance, 2023 (continued)

DOE Goal	Current Status
Multiple Categories	
Reduce Scope 1 and 2 greenhouse gas emissions.	Goal Met: Site Scope 1 and 2 emissions were reduced by 62.6% from the FY 2008 baseline. Most of this can be attributed to infrastructure improvements through energy savings performance contract projects.
Reduce Scope 3 greenhouse gas emissions.	Goal Not Met: Site Scope 3 emissions increased by 13.1% from FY 2022 (43,493.2 $MtCO_2e$) to FY 2023 (49,186.7 $MtCO_2e$). Overall Scope 3 emissions have increased by 54.2% since the FY 2008 baseline (31,894.5 $MtCO_2e$). The increase in Scope 3 emissions in FY 2023 is primarily due to the site's expiration of the teleworking policy and an increase in the on-site population.

Acronyms:

CNS = Consolidated Nuclear Security

EISA = Energy Independence and Security Act

FY = fiscal year

NNSA = National Nuclear Security Administration

4.2.6.5. Water Management

The current DOE water intensity goal is a 20 percent reduction from a FY 2007 baseline by FY 2015 and year to-year reductions of 0.5 percent thereafter. In FY 2023, Y-12's water intensity rating was 66.80 gal/ft^2, which is an 8.005 percent decrease from the previous year and a 68.27 percent reduction from the 2007 baseline. During the pandemic years (FYs 2020 and 2021), water intensity decreased significantly, as on-site personnel and processes were reduced and is not representative of Y-12's water intensity trend. An overview of water intensity performance is shown in Figure 4.8.

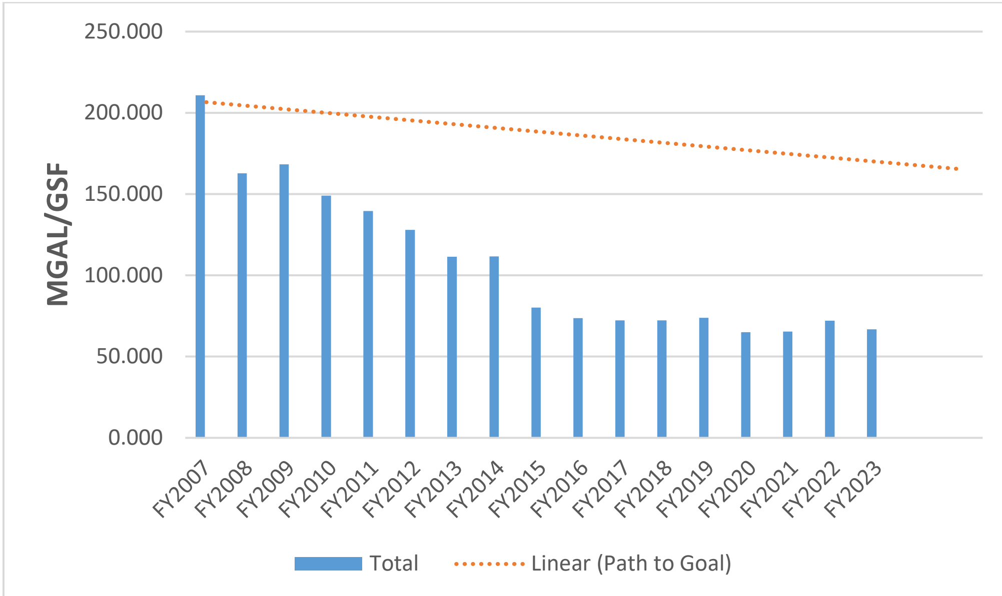
The following actions have contributed to the overall reduction in potable water use:

- 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
- Steam replacements to natural gas when possible

Internal EISA audits are conducted on covered facilities on a 4-year rotating schedule. Additionally, Y-12 completed the FY 2022 water assessment of the site, which 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 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 system with air-cooled equivalents
- Installing advanced potable water meters



Acronyms:
FY = fiscal year
GSF = gross square feet
Mgal = millions of gallons

Figure 4.8. Water intensity graph from baseline 2007 through FY 2023

4.2.6.6. Fleet Management

There are 638 vehicles in the Y-12 fleet, including 124 agency-owned units, 502 leased from General Services Administration (GSA), and 12 commercially leased special purpose vehicles. The inventory consists of sedans; light-duty trucks, vans, and sport utility vehicles; medium-duty trucks, vans, and sport utility vehicles; and heavy-duty trucks such as road tractors, dump trucks, box trucks, flatbeds, wreckers, and service trucks.

During 2023, Y-12 exchanged 42 older GSA-leased vehicles with new units and dispositioned 10 older E-tagged vehicles through Y-12 Property Sales. The new GSA replacements were ordered with alternative fuel or zero-emission capabilities when available, and these new vehicles have better fuel consumption and GHG emission figures than the older vehicles, which ranged from 7 to 12 years of age.

Vehicle availability (replacements as well as additions) was again a struggle during FY 2023, as only 34% of the GSA vehicle replacement order was actually filled. Normally, the majority of replacement orders placed with GSA in the November timeframe would be delivered by September, but manufacturer shortages and cancellations had a major impact in the actual vehicle delivery cycle during FY 2023. Additional vehicles will be required in the near future to support Y-12 construction projects.

The Y-12 taxi service and UPF bus service were major modes of transportation for the more than 6,500 employees. This service also helps reduce the number of overall vehicles needed, fuel consumption, and GHG emissions. The taxi service is an important asset to the overall transportation needs of the Y-12 workforce.

The Y-12 vehicle fleet achieved a 98.3 percent vehicle utilization rate for FY 2023 compared to 97.3 percent in FY 2022. Of those 11 vehicles that failed the utilization rate, eight achieved

80 percent or greater utilization scores. Vehicle reassignments were made multiple times throughout the year to help meet utilization goals.

FY 2023 fuel consumption at Y-12 (diesel and gasoline) decreased by 6.8 percent compared with FY 2022, while miles traveled for those same vehicles was down by 2.6 percent compared to the previous year.

Y-12 continues to use a mobile fuel tanker to dispense gasoline and diesel for vehicles because the site lacks a new fuel station, although plans are in place to build one just southwest of the existing Y-12 garage at the east end of the plant. Y-12 does not use alternative fuel (E85) because it is not available in the area. Because of this, an Epact 701 waiver (5 miles or 15 minutes away) was granted to Y-12.

4.2.6.7. Electronic Stewardship

Y-12 has various electronic stewardship activities, including virtualizing servers, creating virtual desktop infrastructure, procuring energy efficient computing equipment, reusing and recycling computing equipment, replacing aging computing equipment with more energy efficient equipment, and reconfiguring data centers to achieve more energy efficient operations. More than 89 percent of the desktop computers, laptops, monitors, and thin clients purchased or leased during FY 2023 were registered Electronic Product Environmental Assessment Tool products. Y-12's standard desktop configuration specifies the procurement of Electronic Product Environmental Assessment Tool registered and Energy Star-qualified products.

4.2.6.8. Greenhouse Gases

Compared to the FY 2008 baseline, Y-12 Scope 1 (on-site fuel burning) and Scope 2 (purchased electricity) GHG emissions have been reduced. Emission reductions can be attributed primarily to decreased Scope 1 emissions due to more efficient steam generation and decreased Scope 2 emissions due to energy efficiency projects.

Purchased electricity is by far the biggest contributor to Y-12's GHG footprint. Energy reduction initiatives involving production facilities and utility infrastructure have been completed through energy savings performance contract projects.

4.2.6.9. Storm Water Management and the Energy Independence and Security Act

Section 438 of the EISA requires federal agencies reduce storm water runoff from development and redevelopment projects to protect water resources. Y-12 complies with these requirements by using a variety of storm water management practices, often referred to as green infrastructure or low impact development practices. Several green infrastructure initiatives have been implemented to reduce the size and number of impervious surfaces through sustainable vegetative practices and porous pavements. During 2022, the Emergency Operation Center and Fire Station projects contributed to the overall prevention of storm water runoff by installing bioretention infiltration areas on the project sites. No new green storm water management practices were initiated in 2023.

4.3. Compliance Status

During 2023, Y-12 operations were conducted to comply with contractual and regulatory environmental requirements. Table 4.2 presents a summary of environmental audits conducted at Y-12 in 2023. The following sections summarize the major environmental programs and activities at the site and provide an overview of the compliance status for the year.

4.3.1. Environmental Permits

Table 4.3 lists environmental permits in force at Y-12.

Table 4.2. Summary of external regulatory audits and reviews, 2023

Date	Reviewer	Subject
February 23	TDEC	Quarterly ORR Landfill Inspection ILF-V, ILF-IV, and CDL-VII
March 6	COR	Sanitary Sewer Inspection
March 7	TDEC	Annual RCRA Hazardous Waste Compliance Inspection (ORR Landfill)
March 24	TDEC	Air Quality Inspection
May 11	TDEC	ILF-V Area 5 Construction Inspection
May 30	TDEC	ILF-V Area 5 Construction Inspection
May 31	TDEC	Quarterly ORR Landfill Inspection ILF-II, ILF-V, and CDL-VII
June 29	TDEC	Quarterly ORR Landfill Inspection ILF-IV
July 10	TDEC	ILF-V Area 5 Construction Inspection
August 2	COR	Sanitary Sewer Inspection
August 21	TDEC	ILF-V Area 5 Construction Inspection
August 29	TDEC	ILF-V Area 5 Construction Inspection
August 31	TDEC	Quarterly ORR Landfill Inspection of ILF-V and CDL-VII; Second Semi-Annual Inspection of Closed ILF-II
September 6	TDEC	NPDES Compliance Evaluation Inspection
September 7	TDEC	Quarterly ORR Landfill Inspection ILF-IV
September 5	TDEC	ILF-V Area 5 Construction Inspection
November 22	TDEC	Quarterly ORR Landfill Inspection of ILF-IV, V, and CDL-VII

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

Table 4.3. Y-12 environmental permits, 2023

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
CAA	Title V Major Source Operating Permit	571832	12/01/17	11/30/22[a]	DOE	DOE	CNS
CWA	Industrial and Commercial User Wastewater Discharge (Sanitary Sewer) Permit	1-91	07/20/21	03/31/26	DOE	DOE	CNS
CWA	NPDES Permit	TN0002968	08/05/22	09/30/27[b]	DOE	DOE	CNS
CWA	UPF General Storm Water Permit Y-12 (41.7 ha/103 acres)	TNR 134022	10/27/11	09/30/26	DOE	CNS	CNS
CWA	UPF NPDES General Permit for Construction Storm Water	TNR135568	08/06/18	09/30/26	DOE	BNI	BNI
CWA	Central Training Facility Berm Reinvestment Project NPDES Construction General Permit	TNR 135924	10/01/19	09/30/26	DOE	DOE	CNS
CWA	UCOR ILF-II General Storm Water Permit Y-12 (8.2 acres)	TNR 136478	08/03/21	Upon Notice of Termination	DOE	UCOR	UCOR
CWA	Y-12 Outfall 014 Repair Aquatic Resource Alteration Permit	NR1903.116	06/21/19	04/05/25	DOE	DOE	CNS
CWA	Central Training Facility Berm Aquatic Resource Alteration Permit	NR1903.096	05/15/19	04/05/25	DOE	DOE	CNS
CWA	Security Infrastructure Revitalization Program NPDES General Construction Permit	TNR 136604	11/30/21	Upon Notice of Termination	DOE	DOE	CNS
CWA	No Discharge Portal 20 Pump and Haul Permit	SOP-17014	06/24/22	06/30/27	DOE	DOE	CNS
CWA	No Discharge Portal 23 Pump and Haul Permit	SOP-17015	06/20/22	07/30/27	DOE	DOE	CNS
CWA	No Discharge Portal 19 Pump and Haul Permit	SOP-13031	07/01/23	06/30/28	DOE	DOE	CNS
CWA	No Discharge Environmental Management Waste Management Facility Pump and Haul Permit	SOP-01043	09/01/22	08/31/27	DOE	UCOR	UCOR
CWA	Oak Ridge Institute for Global Nuclear Security Aquatic Resource Alteration Permit	NR2003.249	01/14/21	Upon Notice of Termination	DOE	DOE	CNS
CWA	Oak Ridge Institute for Global Nuclear Security NPDES General Construction Permit	TNR136307	04/26/21	09/30/26	DOE	DOE	CNS
CWA	Y-12 National Security Complex LPF Permit	TNR13724	07/21/23	Upon Notice of Termination	DOE	DOE	CNS
CWA	West End Protected Area Reduction NPDES General Construction Permit	TNR136382	04/26/21	09/30/26	DOE	DOE	CNS

Table 4.3. Y-12 environmental permits, 2023 (continued)

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
CWA	Monitoring Station 8 and Outfalls 051 and 099 Access Improvements Aquatic Resource Alteration Permit	NR2103.288	11/08/21	04/07/25	DOE	DOE	CNS
RCRA	Hazardous Waste Transporter Permit	TN3890090001	12/05/22	01/31/24	DOE	DOE	CNS
RCRA	Hazardous Waste Corrective Action Permit	TNHW-164	09/15/15	09/15/25	DOE	DOE, NNSA, and all ORR co-operators of hazardous waste permits	UCOR
RCRA	Hazardous Waste Container Storage Units	TNHW-184	03/05/21	03/05/31	DOE	DOE/CNS	CNS/LATS co-operator
RCRA	Hazardous Waste Container Storage and Treatment Units	TNHW-191	09/21/23	09/21/33[c]	DOE	DOE/CNS	CNS co-operator
Solid Waste	Industrial Landfill IV (operating, Class II)	IDL-01-000-0075	Permitted in 1988. Most recent modification approved 06/20/19	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Industrial Landfill V (operating, Class II)	IDL-01-000-0083	Permitted in 1993. Most recent modification approved 08/04/22	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Construction and Demolition Landfill (overfilled, Class IV subject to CERCLA Record of Decision)	DML-01-000-0012	Initial permit 01/15/86	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Construction and Demolition Landfill VI (post-closure care and maintenance)	DML-01-000-0036	Permit terminated by TDEC 03/15/07	N/A	DOE	DOE/UCOR	UCOR

Table 4.3. Y-12 environmental permits, 2023 (continued)

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
Solid Waste	Construction and Demolition Landfill VII (operating, Class IV)	DML-01-000-0045	Permitted in 1993. Most recent modification approved 08/31/22	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Centralized Industrial Landfill II (post-closure care and maintenance)	IDL-01-000-0189	Most recent modification approved 05/08/92	N/A	DOE	DOE/UCOR	UCOR
Safe Drinking Water Act	Underground Injection Control Class V Injection Well Permit	Permit by Rule, TDEC Rule 0400-45-06 and -00041	N/A	N/A	DOE	DOE	CNS

[a] *The Title V air permit renewal is still in the review process by TDEC.*

[b] *Some aspects of the current NPDES permit are currently under appeal by NNSA.*

Acronyms:

BNI = Bechtel National Inc.
CAA = Clean Air Act
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CNS = Consolidated Nuclear Security, LLC
CWA = Clean Water Act
LATS = LATA-Atkins Technical Services, LLC
LPF = Lithium Processing Facility
N/A = not applicable
NNSA = National Nuclear Security Administration
NPDES = National Pollutant Discharge Elimination System
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation
UPF = Uranium Processing Facility

4.3.2. National Environmental Policy Act

As federal agencies, DOE and NNSA comply with National Environmental Policy Act (NEPA) requirements as outlined in 10 CFR 1021, *National Environmental Policy Act Implementing Procedures*. NEPA requires reviews of all federal actions to identify any environmental or public consequences associated with that action. NEPA does not require that certain decisions be made or activities be rejected—it just makes sure that federal agencies evaluate environmental and related social and economic impacts in the decision-making process. This evaluation helps Y-12 and NNSA stay in compliance with many federal and state laws, regulations, and permits. Many of the NEPA documents for Y-12 can be found on the Y-12 publicly accessible website at www.y12.doe.gov.

The broadest and most complex NEPA document for Y-12 is DOE/EIS-0387, *Final Site-Wide Environmental Impact Statement (EIS) for the Y-12 National Security Complex* (DOE 2011a). This document takes into account the myriad activities planned for Y-12 in the foreseeable future. As changes in plans are identified or additional information becomes available, the sitewide document is updated with various supplement analyses. Following the 2011 sitewide EIS, supplement analyses were issued in 2016, 2018, and 2020 (NNSA 2016, NNSA 2018, NNSA 2020). NNSA plans to pursue a contract for a new supplement analysis in 2024.

NEPA environmental assessments are prepared for larger projects that may not have been covered in the EIS or supplement analysis.

The lowest level of NEPA documentation is a Categorical Exclusion (CX). These documents are used for smaller projects that have fewer environmental impacts and less cost than the types of activities covered by an EIS or environmental assessment.

There were 50 CX reviews in 2023, with 10 of those being federal CX documents requiring approval by the NNSA NEPA Compliance Officer. Some of these CX documents were for new projects, and others may be revisions to older project documents based on new information or small changes in project scope.

The EIS, supplement analyses, environmental assessments, and federal CXs documents are available at the Y-12 publicly accessible website on the Environment, Safety, and Health page under the About tab. Table 4.4 lists the 10 federal CX documents developed during 2023.

Table 4.4. National Nuclear Security Administration-approved Categorical Exclusions for 2023

Date issued	Title
2/2/2023	NEPA 5043 – Elza Switchyard Disposition
4/4/2023	NEPA 5056 – CRADA for CENTRUS UF6 Conversion Concept Development
4/11/2023	NEPA 5060 – Building 9983 Demolitions
5/24/2023	NEPA 4909 – Test and Demonstration Facility
8/24/2023	NEPA 5075 – Building 9713-14 Disposition
8/28/2023	Safety, Health, and Environmental Improvements for FY 2024 and FY 2025
8/30/2023	NEPA 5022 – Modular Salvage Operations
11/20/2023	NEPA 4818 Rev. 3 – Building 9215, DCM – Bottom Loading Furnaces
11/20/2023	NEPA 5079 – Building 9706-02 Complex Disposition
12/4/2023	NEPA 5087 – West End Production Change House

Acronyms:

CRADA = cooperative research and development agreement

DCM = Direct Chip Melt

NEPA = National Environmental Policy Act

4.3.3. National Historic Preservation Act

In accordance with the National Historic Preservation Act (NHPA, NHPA 1966), Y-12 is committed to identifying, preserving, enhancing, and protecting its cultural resources. Compliance activities in 2023 included completing Section 106 reviews of ongoing and new projects, coordinating with the Tennessee State Historic Preservation Office (SHPO) to update the cultural resource survey, and collecting and storing historic artifacts.

Y-12 is on approximately 3,500 acres within the northern portion of the 33,316 acres of the ORR. Archaeological surveys in 1992 and 1999 determined that the potential for preserved prehistoric or historic archaeological sites is virtually nonexistent due to the previous amount of disturbance during Manhattan Project-era and later construction. Y-12 continues to conduct archaeological surveys as necessary to comply with NHPA, although no surveys were needed during the 2023 time period.

The Y-12 guiding document for its historic preservation program, Y/TS-1983, *Y-12 National Security Complex National Historic Preservation Act Historic Preservation Plan* (BWXT 2003), is reviewed every 5 years to maintain its effectiveness. During the last review, it was determined that this document and the programmatic agreement needed to be updated to accurately reflect changes at Y-12 since the documents were completed in 2003.

Y-12 is updating its Section 110/cultural resource survey, which evaluates all site facilities constructed through 1992 to determine their eligibility for the National Register of Historic Places and inclusion within the redrawn boundaries of the Y-12 Historic District. This cultural resource survey is being developed in consultation with SHPO and will inform the strategies for the updated preservation plan and programmatic agreement. The proposed survey includes a total of 273 surveyed properties out of 352 extant properties at Y-12, including 119 properties assessed in the previous survey and 195 properties constructed after 1958, which is the end of the period of significance for the previous survey completed in 1999. The new proposed period of significance extends to 1992 to include Y-12's role in the Manhattan Project (1943-1945/1946), post-World War II (1945/1946-1950), the Cold War (1950-1992), and Peacetime Research and Development (1950-1992).

The NHPA program works through the NEPA process to ensure that the proper level of environmental review is performed before an irreversible commitment of resources is made. In 2023, 66 proposed projects were evaluated to determine whether any historic properties eligible for inclusion in the National Register of Historic Places would be adversely impacted. The SHPO was consulted twice for actions being taken toward minor heating and air modifications at Building 9731, the Manhattan Project-era facility included in the Manhattan Project National Historical Park. The SHPO agreed that the proposed modifications will have minimum adverse impact to the historical characteristics to the facility and will ultimately contribute to the future use and preservation of the facility.

4.3.4. Clean Air Compliance Status

The state of Tennessee issues permits as the primary means to impose 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 recordkeeping and annual and semiannual reports. More than 2,000 data points are obtained and reported each year. All reporting requirements were met during 2023, and there were no exceedances during the reporting period.

Ambient air monitoring, while not specifically required by any permit condition, is conducted at Y-12 to satisfy requirements in DOE Order 458.1, *Radiation Protection of the Public and the*

Environment (DOE 2011b), as a best management practice and to provide evidence of sufficient programmatic control of certain emissions. The 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 additional information about Clean Air Act (CAA) activities conducted at Y-12.

4.3.5. Clean Water Act Compliance Status

During 2023, Y-12 continued compliance with the National Pollutant Discharge Elimination System (NPDES) water discharge permit limits. 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 2023 was almost 100 percent.

Approximately 4,100 data points were obtained from sampling required by the NPDES permit. Y-12's new NPDES permit was issued on August 5, 2022, and became effective on October 1, 2022. The new permit is currently under appeal in part, and settlement negotiations are ongoing.

4.3.6. 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.

TDEC water resource regulation Chapter 0400-45-01, "Public Water Systems," (TDEC 2019), 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 Environmental Compliance organization, with oversight by a state-certified operator.

Y-12's potable water distribution system was last reviewed by TDEC in 2021 and 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. All total coliform samples collected during 2021 were analyzed by the state of Tennessee laboratory, and all results were negative. The 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 limits for the yearly average. Y-12's potable water system is sampled triennially for lead and copper. The system was last sampled in 2023. The results were below TDEC and Safe Drinking Water Act limits and met established requirements.

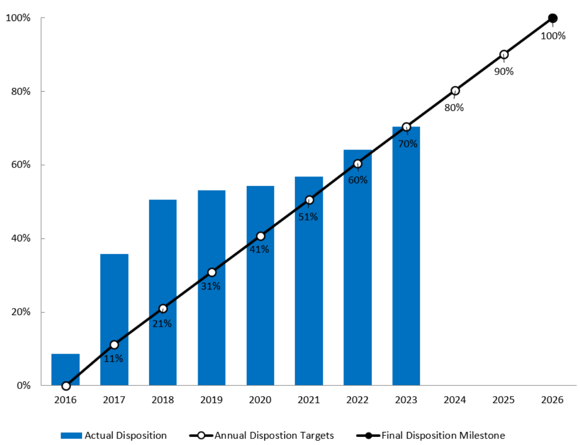
4.3.7. Resource Conservation and Recovery Act Compliance Status

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 off-site 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 Facility Compliance Act requires that DOE work with local regulators to develop a site treatment plan to manage mixed waste (FFCA 1992). 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 that cannot be treated and disposed of in strict compliance with RCRA time limits.

The *Site Treatment Plan for Mixed Wastes on the US Department of Energy Oak Ridge Reservation* (TDEC 2023) is updated annually and submitted to TDEC for review. The plan documents the mixed waste inventory and describes efforts 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 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 2016 through 2026, as shown in Figure 4.9. In FY 2023, Y-12 staff dispositioned 70 percent of the legacy mixed waste inventory listed in the ORR site treatment plan.



Note: *As part of the Oak Ridge Reservation Site Treatment Plan.*

Figure 4.9. Disposition of Y-12 legacy mixed waste inventory by fiscal year, 2016–2023

The quantity of hazardous and mixed wastes generated by Y-12 in 2023 decreased compared to the previous year, as shown in Figure 4.10. Y-12 is a state-permitted treatment, storage, and disposal facility. Under its permits, Y-12 received 5,064 kg of hazardous and mixed waste from off-site in 2023. The 5,064 kg of hazardous waste received at Y-12 was generated from CNS activities at the Union Valley Facility (UVF), Central Training Facility (CTF), and ETTP. Waste from all three facilities is shipped to Y-12, where it is aggregated to allow economical shipments to disposal facilities. The majority (97%) was generated as a result of analytical chemistry laboratory operations at UVF. It is typical for the majority of waste received to be from UVF; however, in 2023 there was a marked increase in waste from the facility due to some laboratory operations moving from Building 9995. In addition, there was a large cleanout activity that generated a number of expired and excess chemicals. Small amounts of hazardous waste were also generated from security activities at CTF and UPF project operations at ETTP.

In addition, 927,341 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.

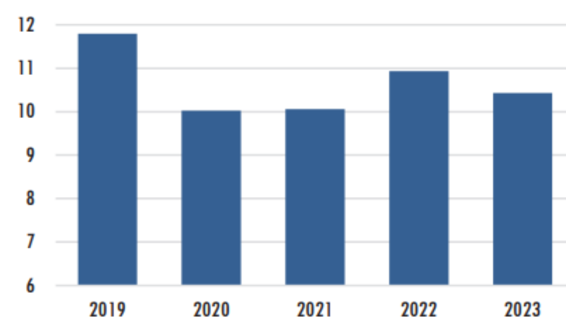


Figure 4.10. Y-12 hazardous waste generation (in million kg), 2019–2023

4.3.7.1. 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 Chapter 0400-18-01, “Underground Storage Tank Program” (TDEC 2018).

The last two petroleum USTs at Y-12 were closed and removed from the East End Fuel Station in August 2012. No petroleum USTs remain at Y-12.

4.3.7.2. Resource Conservation and Recovery Act Subtitle D Solid Waste

ORR landfills operated by DOE EM are located within the Y-12 boundary. 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 and feasibility study. A CERCLA Record of Decision for Spoil Area 1 was signed in 1997 (DOE 1997b). 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 4.3. Additional information about the operation of these landfills is provided in Section 4.8.2.

4.3.8. Resource Conservation and Recovery Act–Comprehensive Environmental Response, Compensation, and Liability Act Coordination

The ORR Federal Facility Agreement (DOE 2023c) is used to coordinate the corrective action processes of RCRA required under the ORR Corrective Action TNHW-164, which was renewed for a 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 2024 as an update of the previous year's activities.

4.3.9. Toxic Substances Control Act Compliance Status

Storage, handling, and use of polychlorinated biphenyls (PCBs) are regulated under the Toxic Substances Control Act (TSCA). Capacitors manufactured before 1970 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 22, 2023.

Given the widespread historical uses of PCBs at Y-12 and fissionable material requirements that must be met, EPA and DOE negotiated an agreement to assist ORR facilities in becoming compliant with TSCA regulations (DOE 2012). This agreement, known as the ORR PCB Federal Facility Compliance Agreement, addresses PCB compliance issues that are unique to these facilities. Y-12 operations involving TSCA-regulated materials were conducted in accordance with TSCA regulations and the agreement.

4.3.10. Emergency Planning and Community Right-to-Know Act Compliance Status

The Emergency Planning and Community Right-to-Know Act requires facilities to 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 (EPCRA 1986). Y-12 submitted reports for reporting year 2023 in accordance with requirements under Sections 303, 311, 312, and 313 of the Act.

Y-12 had no unplanned release of a hazardous substance that required notification of the regulatory agencies. (Section 4.3.11 provides additional information.) Three substances were over the threshold during 2023. 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 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 44 chemicals that were over Section 312 inventory thresholds in 2023.

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 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. Seven chemicals were reported for 2023 on the Toxic Release Inventory report. Table 4.5 lists the reported chemicals for Y-12 and its associated Central Training Facility for 2022 and 2023.

4.3.11. Spill Prevention, Control, and Countermeasures

Section 311 of the Clean Water Act regulates the discharge of oils or petroleum products to waters of the United States and requires spill prevention, control, and countermeasure plans be developed and implemented to minimize the potential for oil discharges (CWA 1972). The major requirements for plans are contained in 40 Part 112. These regulations require that these plans be reviewed, evaluated, and amended at least once every 5 years, or earlier if significant changes occur. The rule includes requirements for oil spill prevention, preparedness, and response to prevent oil discharges to navigable waters and adjoining shorelines. Specific facilities are required to prepare, amend, and implement spill prevention, control, and countermeasure plans.

Y/SUB/02-001091/8, *Spill Prevention, Control, and Countermeasure Plan for the U.S. Department of Energy Y-12 National Security Complex* (CNS 2022) was revised in October 2022 to update changing site infrastructure. This plan presents the requirements to be implemented by Y-12 to prevent spills of oil 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 Y-12 Operations Center. Spill response materials and equipment are stored near tanks, drum storage areas, and other strategic areas 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.

4.3.12. Unplanned Releases

Y-12 has procedures for notifying off-site authorities of 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, certain observable oil sheens on East Fork Poplar Creek (EFPC) must be reported to the EPA National Response Center, among others. 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 events and site conditions that could adversely affect public or worker health and safety, the environment, national security, DOE safeguards and security interests, DOE facilities functions, or DOE's reputation.

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.

During 2023, there were no reportable releases to the environment, including no reportable radiological air emission releases for Y-12.

Table 4.5. Emergency Planning and Community Right-to-Know Act Section 313 toxic chemical release and chemicals manufactured, processed, or otherwise used for Y-12 and the Central Training Facility

Report	Chemical/ Compound	2022 Manufactured (lb)	2022 Processed (lb)	2022 Otherwise Used (lb)	2023 Manufactured (lb)	2023 Processed (lb)	2023 Otherwise Used (lb)	Comments
Y-12	Chromium/ Chromium Compounds	0	124,787	62,990	0	169,521	17,475	2023 increased amount recycled and metal processed; decreased UPF construction materials otherwise used.
Y-12	Cobalt	0	29,718	6,928	0	40,072	2,912	2023 increased amount recycled and decreased UPF construction materials otherwise used.
Y-12	Copper	0	153,166	49,010	0	250,743	13,880	2023 increased amount recycled and decreased UPF construction materials otherwise used.
Y-12	Lead/Lead Compounds	0	66,122	8,389	0	91,984	35,435	2023 increased amount recycled and decreased construction materials otherwise used. CTF lead counts for ammunition are not included in the Y-12 report but in a standalone report for 2023. UCOR otherwise used and shipments increased for 2023.
Y-12	Manganese	0	84,755	21,514	0	117,437	9,172	2023 increased amount of recycled and metal processed; decreased UPF construction materials otherwise used.
Y-12	Methanol[a]	0	0	31,768	0	0	6,372	Not reportable under threshold for 2023. Building 9767-4 no longer in use for the brine system.
Y-12	Nickel	0	299,380	74,812	0	409,514	26,664	2023 increased amount recycled and metal processed and decreased UPF construction materials otherwise used.
CTF	Lead/Lead Compounds	0	0	1,094	0	0	1,109	2023 CTF is reported separately from Y-12 because the facility is not adjacent or adjoining the Y-12 site.

a Not reported during 2023

Acronyms:

CTF = Central Training Facility

UPF = Uranium Processing Facility

4.3.13. Audits and Oversight

In 2023, Y-12 was inspected by federal, state, or local regulators on four occasions, as listed in Table 4.2.

Personnel from the TDEC Division of Water Resources conducted an NPDES compliance evaluation inspection on September 6, 2023. The inspection included outfalls, records, and the on-site laboratory. No issues were identified.

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 2023.

Personnel from the TDEC Division of Solid Waste Management conducted an unannounced RCRA hazardous waste compliance inspection of Y-12 on March 6–7, 2023. The inspections covered waste storage areas and records reviews. Two issues were identified: storage of three bags of spent aerosol cans for more than one year and one aerosol can puncturing device that was not closed securely. Immediate corrective actions were taken where possible. The issues and their causes are being reviewed to prevent recurrence.

Personnel from the TDEC Division of Air Pollution Control conducted an air quality inspection on March 24, 2023. The inspection covered 13 air emission sources, including some emergency generators, and inspections of the facilities. Title V air permit records were also reviewed. No issues were identified.

4.3.14. Radiological Release of Property

Releasing property from Y-12 is conducted in accordance with approved procedures that comply with DOE Order 458.1. Property consists of real property (i.e., land and structures) and personal property (i.e., property of any type except real property) (DOE 2011b).

At Y-12, there are three paths for releasing property to the public based on the potential for radiological contamination:

- Survey and release property potentially contaminated on the surface (Section 4.3.14.1).
- Evaluate materials with a potential to be contaminated in volume (Section 4.3.14.2).
- Evaluate using process knowledge (surface and volumetric) (Section 4.3.14.3).

Table 4.6 summarizes some examples of the property released in 2023 and their amounts. Y-12 recycled more than 5.8 million lb of materials off-site for reuse, including computers, electronic office equipment, used oil, scrap metal, tires, batteries, lamps, and pallets.

The paths discussed in Sections 4.3.14.1 and 4.3.14.2 use pre-approved authorized limits as outlined in DOE Order 458.1. The basis of these standards is to limit the dose to any member of the public to a maximum of 1.0 mrem (0.01 mSv) per year total effective dose from clearing materials from regulatory control. These authorized limits are applicable to the release of personal property only (including recycled material). No real property was released from Y-12 in 2023.

Table 4.6. Summary of materials released in 2023

Category	Amount released
Real property (land and structures)	None
Computer equipment recycle:	60,749 lb
– Computers	
– Monitors	
– Printers	
– Mainframes	
Recycling examples:	
– Used oils	18,887 gal
– Used tires	6,080 lb
– Scrap metal	3,189,754 lb
– Lead acid batteries	92,621 lb
Public and negotiated sales:	
– Brass	21,417 lb
– Miscellaneous furniture	7,200 lb
– Vehicles and miscellaneous equipment/materials	152,024 lb
External transfers	N/A

Note: *External transfers include vehicles, miscellaneous equipment, and materials transferred to various federal, state, and local agencies for reuse during FY 2023. Y-12 transferred property with an acquisition value of approximately $1,072,462; however, the weight of the transferred items in pounds was unable to be quantified.*

4.3.14.1. Property Potentially Contaminated on the Surface

Property that is potentially contaminated on the surface is completely surveyed, unless it can be released based on process knowledge or through a survey plan that provides survey instructions, along with technical justification (process knowledge) for the plan, based on NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual* (NRC 2000) and NUREG-1575, Supplement 1, *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual* (NRC 2009). Table 4.7 lists the surface contamination limits used at Y-12 to determine whether materials and equipment (M&E) are suitable for release to the public.

Y-12 uses an administrative limit for average and maximum activity of 240 dpm/100 cm^2 for radionuclides in Group 3 and 2,400 dpm/100 cm^2 for radionuclides in Group 4 (Table 4.7). Y-12 also uses an administrative limit for removable activity of 240 dpm/100 cm^2 for radionuclides in Group 3 (Table 4.7). Using 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 Packaging*.

4.3.14.2. Property Potentially Contaminated in Volume

Materials, such as activated materials, smelted-contaminated metals, liquids, and powders, are subject to volumetric contamination (i.e., radioactivity per unit volume or per unit mass) and are treated separately from surface-contaminated objects. Materials that may be subject to volumetric contamination are evaluated for release by one of the following three methods:

- **Unopened, sealed containers.** Material is in an original manufacturer's sealed, unopened container. A seal can be visible (e.g., lock tabs, heat shrink) or unseen (e.g., unbroken fluorescent bulbs, sealed capacitors), as long as the container remains unopened.
- **Process knowledge.** If contamination being able to enter a system is unlikely, then process knowledge is documented and used as the basis for release. Often, this is accompanied by confirmatory surveys.
- **Analytical.** The material is sampled, and the results are evaluated against the preapproved authorized limits in DOE Order 458.1. If preapproved authorized limits have not been obtained, then analytical results are evaluated against measurement method critical levels or background levels from materials that have not been impacted by Y-12 activities. If results meet defined criteria, then they are documented, and the material is released.

Table 4.7. DOE Order 458.1 preapproved authorized limits for surface contamination[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, 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 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 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. Wiping techniques to measure removable contamination levels are unnecessary 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 ^{90}Sr that is present in them. It does not apply to ^{90}Sr that has been separated from other fission products or mixtures where ^{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 nonremovable fractions and residual tritium in mass will not cause exposures that exceed DOE dose limits and constraints.

Acronyms:

N/A = not applicable

Y-12 was granted approval to use the DOE Order 458.1 preapproved authorized limits for volumetric contamination on July 20, 2021, which is documented in NPO letter COR-NP0-60 ESH-7.20.2021-919599, "Approval to Use Pre-Approved Authorized Limits for the Release and Clearance of Volumetric Radioactivity of Personal Property" (NNSA 2021). Table 4.8 lists these volumetric contamination limits for various groups of radionuclides. When multiple radionuclides exist in a single sample, a sum of fractions is used to verify that material meets the specified limits.

4.3.14.3. 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 (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 (Class I, NRC 2009). The process knowledge evaluation processes are outlined in Y-12 procedures.

The following are examples of M&E released without monitoring based on process knowledge; however, this does not preclude conducting verification monitoring before sale:

- All M&E from rad-free zones
- Pallets generated from noncontaminated areas
- Pallets that are returned to shipping during the same delivery trip
- Lamps from noncontaminated areas
- Drinking water filters
- M&E approved for release by radiological engineering technical review
- Portable restrooms used in noncontaminated 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, housekeeping materials, and associated waste
- Breakroom, cafeteria, and medical wastes
- Medical and bioassay samples generated in noncontaminated areas
- Subcontractor, vendor, and privately owned vehicles, tools, and equipment used in noncontaminated 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 the Central Computing Facility
- Subcontractor, vendor, and privately owned vehicles, tools, and equipment that have not been used for excavation activities
- New cardboard
- Consumer glass containers

Table 4.8. DOE Order 458.1 preapproved authorized limits for volumetric contamination[a]

Radionuclide groups[b]	SI units, volume (Bq/g)[f]	Conventional units, volume (pCi/g)[f]
Group 0 Special Case: ^{129}I[c]	0.01	0.3
Group 1 High-energy gamma, radium, thorium, transuranics, and mobile beta-gamma emitters: ^{22}Na, ^{46}Sc, ^{54}Mn, ^{56}Co, ^{60}Co, ^{65}Zn, ^{94}Nb, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{182}Ta, ^{207}Bi, ^{210}Po, ^{210}Pb, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{229}Th, ^{230}Th, ^{232}Th, ^{232}U, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{244}Pu, ^{241}Am, ^{243}Am, ^{245}Cm, ^{246}Cm, ^{247}Cm, ^{248}Cm, ^{249}Cf, ^{251}Cf, ^{254}Es, and associated decay chains[d], and others[b]	0.1	3
Group 2 Uranium and selected beta-gamma emitters: ^{14}C, ^{36}Cl, ^{59}Fe, ^{57}Co, ^{58}Co, ^{75}Se, ^{85}Sr, ^{90}Sr, ^{95}Zr, ^{99}Tc, ^{105}Ag, ^{109}Cd, ^{113}Sn, ^{124}Sb, ^{123m}Te, ^{139}Ce, ^{140}Ba, ^{155}Eu, ^{160}Tb, ^{181}Hf, ^{185}Os, ^{190}Ir, ^{192}Ir, ^{204}Tl, ^{206}Bi, ^{233}U, ^{234}U, ^{235}U, ^{238}U, natural uranium[e], ^{237}Np, ^{236}Pu, ^{243}Cm, ^{244}Cm, ^{248}Cf, ^{250}Cf, ^{252}Cf, ^{254}Cf, and associated decay chains[d], and others[b]	1	30
Group 3 General beta-gamma emitters: ^{7}Be, ^{74}As, ^{93m}Nb, ^{93}Mo, ^{93}Zr, ^{97}Tc, ^{103}Ru, ^{114m}In, ^{125}Sn, ^{127m}Te, ^{129m}Te, ^{131}I, ^{131}Ba, ^{144}Ce, ^{153}Gd, ^{181}W, ^{203}Hg, ^{202}Tl, ^{225}Ra, ^{230}Pa, ^{233}Pa, ^{236}U, ^{241}Pu, ^{242}Cm, and others[b]	10	300
Group 4 Low-energy beta-gamma emitters: ^{3}H, ^{35}S, ^{45}Ca, ^{51}Cr, ^{53}Mn, ^{59}Ni, ^{63}Ni, ^{86}Rb, ^{91}Y, ^{97m}Tc, ^{115m}Cd, ^{115m}In, ^{125}I, ^{135}Cs, ^{141}Ce, ^{147}Nd, ^{170}Tm, ^{191}Os, ^{237}Pu, ^{249}Bk, ^{253}Cf, and others[b]	100	3,000
Group 5 Low-energy beta emitters: ^{55}Fe, ^{73}As, ^{89}Sr, ^{125m}Te, ^{147}Pm, ^{151}Sm, ^{171}Tm, ^{185}W, and others[b]	1,000	30,000

[a] *The screening levels for clearance have been rounded to one significant figure and are assigned for volume radioactivity.*

[b] *To determine the specific group for radionuclides not shown, a comparison of the screening factors, by exposure scenario, listed in Tables B. 1, C.1, and D.1 of NCRP Report No. 1231 (NCRP 1996) for the radionuclides in question and the radionuclides in the general groups above will be performed and a determination of the proper group made, as described in ANSI/HPS N13.12-2013, Annex A.*

[c] *Because of potential ground-water concerns, the volume radioactivity values for ^{129}I when disposal to landfills or direct disposal to soil is anticipated is assigned to Group 0.*

[d] *For decay chains, the screening levels represent the total activity (i.e., the activity of the parent plus the activity of all progeny) present.*

[e] *The natural uranium screening levels for clearance shall be lowered from Group 2 to Group 1 if decay-chain progeny are present (i.e., uranium ore versus process or separated uranium, for example, in the form of yellowcake). The natural uranium activity equals the activity from uranium isotopes (48.9% from ^{238}U, plus 48.9% from ^{234}U, plus 2.2% from ^{235}U). This approach is consistent with summing radionuclide fractions discussed in ANSI/HPS N13.12-2013, Section 4.4.*

[f] *Each individual limit applies to the particular radionuclides, but must be summarized and the Sum of Fractions must be ≤ 1.*

Notes:

1. *COR-NP0-60 ESH-7.20.2021-919599, NNSA Production Office Approval to Use Pre-Approved Authorized Limits for the Release and Clearance of Volumetric Radioactivity of Personal Property*

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 control of asbestos, stratospheric ozone-depleting chemicals, and fugitive emissions.

The Title V permit contains specific requirements directly applicable to individual sources of air emissions at Y-12. Major requirements in that section include 40 CFR 61, *National Emission Standards for Hazardous Air Pollutants*, (NESHAP) and numerous requirements associated with emissions of criteria pollutants and other nonradiological hazardous air pollutants. 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 Y-12 Clean Air Program.

4.4.1. Construction and Operating Permits

The following Title V permitting actions were submitted and approved in 2023:

- An insignificant activity exemption was completed for the part cleaning station-sanding operation in Building 9204-2.
- An operational flexibility request was made to add a new Bridgeport mill machine to the electrorefining processing operations in Building 9998.
- An insignificant activity exemption was completed for the Dismantlement glovebox operation in Building 9204-2E.

Demonstrating compliance with air permits conditions is a significant effort at Y-12. Key compliance elements are maintaining and operating control devices, monitoring, recordkeeping, and reporting.

High-efficiency particulate air filters and scrubbers are control devices used throughout Y-12. In-place testing 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, onetime stack sampling, and operation of control devices. The radiological stack monitoring systems on numerous sources throughout Y-12 are part of continuous stack sampling efforts.

The Y-12 sitewide permit requires annual and semiannual reports, including the following:

- Annual ORR radiological NESHAP report, which includes specific information regarding Y-12 radiological emissions.
- Annual Title V compliance certification report, which indicates compliance status with all conditions of the permit.
- Title V semiannual report, which covers a 6-month period for some specific emission sources and consists of monitoring and recordkeeping requirements for the sources.
- Boiler maximum available control technology report for the Y-12 Steam Plant, which requires the boilers to be tuned annually.

Table 4.9 lists the actual emissions versus allowable emissions for the Y-12 Steam Plant.

Table 4.9. Actual versus allowable air emissions from the Y-12 Steam Plant, 2023

Emissions (tons/yr)[a]			
Pollutant	**Actual**	**Allowable**	**Percentage of allowable**
Particulate	2.74	41.0	6.7
Sulfur dioxide	0.22	39.0	0.6
Nitrogen oxides[b]	11.54	81.0	14.2
VOCs[b]	2.66	9.4	28.3
Carbon monoxide[b]	30.29	139.0	21.8

[a] *1 ton = 907.2 kg.*

[b] *When no applicable standard or enforceable permit condition exists for a pollutant, the allowable emissions are based on the maximum actual emissions calculation, as defined in TDEC Rule 1200-3-26-.02(2)(d)3 (maximum design capacity for 8,760 h/yr) (TDEC 2024a). Both actual and allowable emissions were calculated based on the latest EPA compilation of air pollutant emission factors (EPA 1995, 1998).*

Note: *The emissions are based on fuel usage data for January through December 2023. The VOC emissions include VOC hazard air pollutant emissions.*

Acronym:

TDEC = Tennessee Department of Environment and Conservation

VOC = volatile organic compound

4.4.1.1. Generally Applicable Permit Requirements

Y-12, like many industrial sites, has a number of generally applicable requirements, such as those pertaining to managing and controlling asbestos, ozone-depleting substances, and fugitive particulate emissions.

Asbestos Control

Y-12 also has a number of general requirements applicable to removing and disposing of asbestos-containing materials, including monitoring, notifying TDEC of demolitions and renovations, and prescribed work practices for abating and disposing of asbestos materials. There was no reportable release of asbestos in 2023. There were three notifications of asbestos demolitions and renovations. Asbestos, ozone-depleting substances, and fugitive particulate emissions are notable examples.

Stratospheric Ozone Protection and Hydrofluorocarbon Phasedown

As required by the 1990 CAA Amendment Title VI, *Stratospheric Ozone Protection,* and in accordance with 40 CFR 82, *Protection of Stratospheric Ozone,* actions have been implemented to comply with the prohibition against intentionally releasing ozone-depleting substances during maintenance activities performed on refrigeration equipment. EPA enacted major revisions to the stratospheric ozone rules in 2017, including regulating non-ozone-depleting substance 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. There were no appliances at Y-12 that leaked refrigerant in 2023 to trigger this reporting.

On October 1, 2021, EPA began implementing the hydrofluorocarbon phasedown requirements of the American Innovation and Manufacturing Act of 2020, which seeks to reduce hydrofluorocarbon consumption and production to 15 percent of a 2011–2013 baseline by 2036 (AIM 2020). Sitewide use of hydrofluorocarbons is being evaluated to understand future effects of Act phasedowns.

Fugitive Particulate Emissions

As modernization reduction efforts increase at Y-12, there is a mature project planning process to review, recommend, and implement appropriate work practices and controls to minimize fugitive dust emissions. The following precautions are used to prevent particulate matter from becoming airborne:

- Where possible, water or chemicals are used to control dust when demolishing existing buildings or structures, performing construction operations, grading roads, or clearing land.
- Asphalt, water, or suitable chemicals are applied on dirt roads, material stockpiles, and other surfaces that can create airborne dusts.
- Hoods, fans, and fabric filters are installed and used 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 4.11). The particle size and solubility class of the emissions are 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 following four categories of processes or operations are considered when calculating the total uranium emissions:

- Those that exhaust through monitored stacks
- Unmonitored processes for which calculations are performed according to 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)

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 cleaning at each source are incorporated into the respective emission point source terms. In 2023, 24 process exhaust stacks were continuously monitored, 23 of which were major sources, and the remaining stack was a minor source. The sampling systems on the stacks have been approved by EPA Region 4.

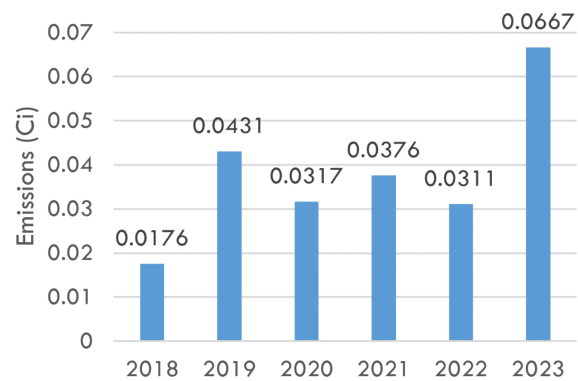


Figure 4.11. Total curies of uranium discharged from Y-12 to the atmosphere, 2018–2023

During 2023, unmonitored uranium emissions occurred from 46 points associated with on-site unmonitored processes and laboratories. Emission estimates for the processes and laboratory stacks were made using inventory data with emission factors provided in 40 CFR 61, Appendix D. The Y-12 source term includes an estimate of these emissions.

The Analytical Chemistry organization operates two main laboratories. One is located in Building 9995, and the other is located in a leased facility on Union Valley Road, about 0.3 mi east of Y-12 and outside the ORR boundary. In 2023, 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 *Compliance Plan, National Emission Standards for Hazardous Air Pollutants for Airborne Radionuclides on the Oak*

Ridge Reservation, Oak Ridge, Tennessee (DOE 2020a), are included in the annual source term. Annual average concentrations and design ventilation rates are used to calculate the annual emission estimate for those areas. Five emission points from room ventilation exhausts were identified in 2023 where emissions exceeded 10 percent of the derived air concentration. All emission points fed to monitored stacks, and any radionuclide emissions were accounted for as noted for monitored emission points; therefore, they are not included in the total overall source term for Y-12.

The Y-12 Title V (Major Source) operating permit contains a sitewide, streamlined alternate emission limit for enriched uranium and depleted uranium process emission units. A particulate limit of 907 kg/yr 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 radiological NESHAP compliance. An estimated 0.0667 Ci (35.1 kg) of uranium was released into the atmosphere in 2023 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 2023 was 0.5 mrem. This dose is well below the NESHAP standard of 10 mrem and is less than 0.2 percent of the roughly 300 mrem that the average individual receives from natural sources of radiation. Chapter 7 discusses how the airborne radionuclide dose was determined.

Lastly, the UPF is being designed and constructed to house some of the processes that are in existing production buildings. The UPF project was issued a construction air permit (967550P) in March 2014. With concurrence from TDEC Air Division, the UPF was included in the 2018 update of Y-12's Title V Operating Permit 571832 on February 18, 2019. The Title V air permit was administratively extended until a new permit is issued. The UPF project will be maintained on inactive status until operational readiness and startup.

4.4.1.3. Quality Assurance

Quality assurance (QA) activities for the radiological NESHAP program are documented in Y/TS 874, *Y-12 Plant Quality Assurance Project Plan for National Emission Standards for Hazardous Air Pollutants (NESHAP) Radionuclide Emission Measurements*, which satisfies the QA requirements in 40 CFR 61, Method 114, for ensuring that 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 (CNS 2020a).

The requirements are also referenced in TDEC Regulation 0400-30-38, "Emission Standards for Hazardous Air Pollutants" (TDEC 2022a). The plan ensures the quality of Y-12 radionuclide emission measurements data from the continuous samplers and minor radionuclide release points. It specifies the procedures for managing activities affecting data quality. 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 control devices, such as high-efficiency particulate air filters and scrubbers, helps control 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. Actual versus allowable emissions from the steam plant are listed in Table 4.9.

Particulate emissions from point sources result from many operations throughout Y-12. Compliance is demonstrated through several activities, including monitoring the operations of control devices, limiting process input materials, and using certified readers to conduct emission evaluations of visible stacks.

Use of solvent 140/142, methanol, and vertrel throughout Y-12 and volatile organic compounds (VOCs) from the steam plant are primary sources of 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 2023 are 4,505.93 lb (2.25 tons) and 5,082 lb (2.54 tons), respectively.

4.4.1.5. Mandatory Reporting of Greenhouse Gas Emissions Under 40 CFR 98

40 CFR 98, *Mandatory Reporting of Greenhouse Gases*, establishes 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 rule requires reporting 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 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 monitoring and reporting by sources emitting above the 25,000 CO_2e threshold level.

The Y-12 Steam Plant is subject to this rule. The steam plant has four boilers. The maximum heat input capacity of each boiler does not exceed 99 million Btu/h. Natural gas is the primary fuel source for the boilers; Number 2 fuel oil is a backup fuel source. 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/h. In Building 9215, 10 natural gas torches, each at 300 standard ft^3/h, are used to preheat tooling associated with a forging and forming press. In Building 9204-02, natural gas is used to heat two electrolytic cells. The maximum rated heat input to the burners on each cell is 550,000 Btu/h.

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 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 basic information required for calculating GHG emissions.

The emissions report is submitted electronically in the EPA-specified format. 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 4.10. The decrease in emissions from 2010 to 2017 is because coal is no longer burned since the natural gas-fired steam plant became operational. The slight increase in CO_2e emissions was because fuel oil was burned for a few days in December 2018. A slightly decrease in CO_2e emissions in 2023 was primarily due to no oil and less natural gas being burned in the steam plant boilers.

Table 4.10. Greenhouse gas emissions from 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
2016	50,671
2017	50,292
2018	51,010
2019	45,971
2020	46,126.8
2021	43,812.7
2022	43,224.2
2023	42,083.1

Acronyms:
CO_2e = CO_2 equivalent
GHG = greenhouse gas

4.4.1.6. Hazardous Air Pollutants (Nonradiological)

Beryllium emissions from machine shops are regulated under a state-issued permit and are subject to a limit of 10 g/24 h. Compliance is demonstrated through a onetime stack test and monitoring control device operations. Hydrogen fluoride is used at one emission source, and emissions are controlled through scrubber systems. The beryllium control devices and the scrubber systems were monitored during 2023 and found to be operating properly.

Methanol is released as fugitive emissions (e.g., pump and valve leaks) as part of the brine and methanol system. It is subject to state air permit requirements; however, due to the nature of its release (fugitive emissions only), no specific emission limits or mandated controls exist.

Mercury is a significant legacy contaminant at Y-12, and cleanup is being addressed by DOE EM. 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 as discussed in Section 4.4.2.1.

In 2007, EPA vacated a proposed Maximum Achievable Control Technology standard that was intended to minimize hazardous air pollutant emissions. At that time, a case-by-case Maximum Achievable Control Technology review was conducted as part of the construction-permitting process for the Y-12 replacement steam plant. The new natural gas-fired steam plant became operational on April 20, 2010, and coal is no longer combusted. Specific conditions aimed at minimizing hazardous air pollutant emissions from the new steam plant were incorporated into the operating permit issued on January 9, 2012, as discussed in Section 4.4.1. In addition, the boiler Maximum Achievable Control Technology 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 Maximum Achievable Control Technology requirements. The new requirements (work practice standards) include conducting annual tune-ups and a onetime energy assessment of the boilers to meet these requirements.

The steam plant has no numeric emission limit requirements. The new rule requires that a onetime energy assessment for the steam plant be completed on or after January 1, 2008. The new rule requires that tune-ups for the boilers must be completed 13 months from 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. Tune-ups for Boilers 1, 3, and 4 were completed on February 15, 2023. Boiler 2 was out of service in 2023.

Unplanned releases of hazardous air pollutants are regulated through 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, Section 112(r), "Accidental Release Prevention/Risk Management Plan Rule." Therefore, Y-12 is not subject to that rule.

Procedures are in place to review new processes and/or process changes against the rule thresholds.

EPA has created multiple national regulations to reduce air emissions from reciprocating internal combustion engines. Two federal air standards are applicable to these engines: 40 CFR 60, *Standards of Performance for New Stationary Sources*, Subpart IIII, and 40 CFR 63, *National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters*, Subpart DDDDD. The compression ignition engines and generators located at Y-12 are subject to these rules. EPA is concerned how reciprocating internal combustion engines are used and the emissions generated from these engines in the form of both hazardous air pollutants and criteria pollutants.

All previous stationary emergency engines and 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 hazardous air pollutants. Regardless of engine size, the rules apply to any existing, new, or reconstructed stationary reciprocating internal combustion engine located at a major source of hazardous air pollutant emissions.

To comply with the rules, Y-12 prepared a significant permit modification to its Title V (Major Source) Operating Air Permit to add numerous stationary emergency-use engines and generators located throughout the site. The permit application was submitted to TDEC on May 6, 2013. TDEC downgraded the significant modification to a minor modification according to 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 40 CFR 60, Subpart IIII, "Standards of Performance for Stationary Compression Ignition Internal Combustion Engines," as 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 and generators. Compliance for the engines and generators is determined through monthly operational records that are recorded through a nonresettable hour meter on each engine and generator. The number of hours spent for emergency operation, maintenance checks and readiness testing, and nonemergency operation must be documented. Each engine and generator must use only diesel fuel with low sulfur content (15 ppm) and an acetane index of 40. The vendor, Rogers Petroleum, supplied a onetime statement certifying that all diesel fuel will contain no more than 15 ppm of sulfur by weight and will either have a minimum acetane index of 40 or a maximum aromatic content of 35 volume percent.

Since the above rules were adopted into Tennessee Air Pollution Control regulations, the emergency engines and generators can be considered an insignificant activity if the potential to emit is below the significance thresholds (less than 5 tons/yr of each criteria pollutant and less than 1,000 lb/yr of any hazardous air pollutant evaluated at a 500 h/yr limit). There was also a change to the Tennessee Air Pollution Control regulations that allows for stationary engines to be eligible to be considered insignificant activities. Condition D14 of the Title V permit was amended to incorporate new language specifying stationary reciprocating internal combustion engines are eligible to be considered insignificant activities that must comply with any underlying applicable rules associated with a stationary internal combustion engine.

The emergency engines and generators are used to provide power for critical systems in the event of electrical power failures and outages at Y-12. The engines and generators operate exclusively as emergency engines and generators. Based upon historical usage of the emergency engines, generators, and fire water pumps, and EPA's 500-h default assumption (maximum hour usage), calculations verify and confirm that potential emissions from each stationary, emergency, internal combustion engine less than 645 hp qualifies, or should be reclassified, as an insignificant activity because the potential to emit is well below the significance thresholds of less than 5 tons/yr of each regulated air pollutant that is not a hazardous air pollutant, and less than 1,000 lb/yr of any hazardous air pollutant, in accordance with Tennessee Air Pollution Control Regulation 1200-03-09-.04(5)(a)4(i) (TDEC 2022b). Approximately 95 percent of Y-12's stationary, emergency engines, generators, and fire water pumps are considered and/or are reclassified as an insignificant activity in accordance with the regulation. These engines are listed in Y-12's Title V air permit.

4.4.2. Ambient Air

To understand the ambient air monitoring in and around Y-12, data must be considered from monitoring conducted specifically for Y-12, ORR perimeter monitoring, and monitoring conducted by TDEC Division of Remediation, Oak Ridge, personnel.

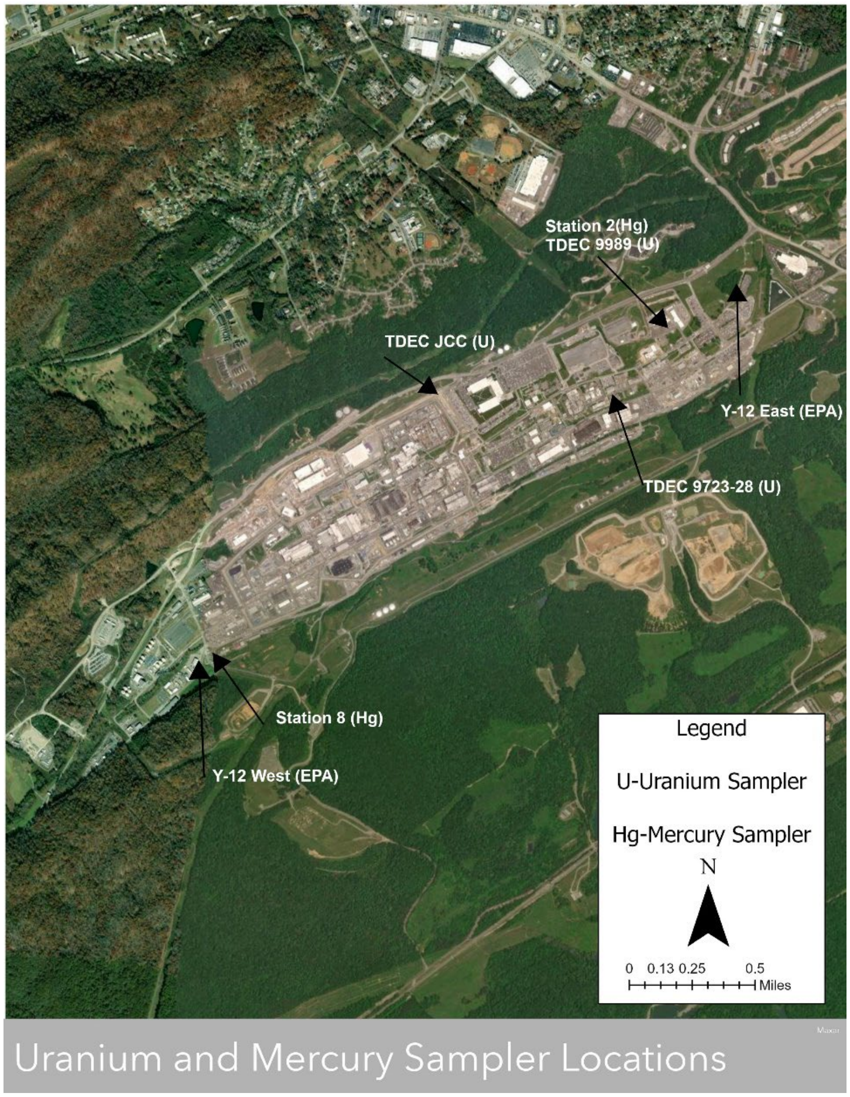
No federal regulations, state regulations, or DOE orders require ambient air monitoring within the Y-12 boundary; however, on-site ambient air monitoring for mercury and radionuclides is conducted as a best management practice. With the reduction of plant operations and improved emission and administrative controls, levels of measured pollutants have decreased significantly. In addition, major processes that emit enriched uranium and depleted uranium are equipped with stack samplers that have been approved by EPA to meet NESHAP requirements.

4.4.2.1. Mercury

The Y-12 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. There are two atmospheric mercury monitoring stations currently operating at Y-12—Ambient Air Station 2 (AAS2) and Ambient Air Station 8 (AAS8)—which are located near the east and west boundaries, respectively, as shown in Figure 4.12. AAS2 and AAS8 have monitored mercury in ambient air continuously since 1986, with the exception of short intervals of downtime because of electrical or equipment outages.

In addition to the Y-12 monitoring stations, two additional monitoring sites have been operated. A reference site (Rain Gauge 2) was developed 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.

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 about 1 L/min. Actual flows are measured bi-weekly with a calibrated Gilmont flowmeter in conjunction with changing 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.



Acronyms:
AAS = Ambient Air Station *JCC = Jack Case Center*
RadNet = EPA radiation monitoring program with Y-12 sampling by TDEC
TDEC = Tennessee Department of Environment and Conservation

Figure 4.12. Locations of ambient air monitoring stations at Y-12

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 4.11). Average mercury concentration at AAS2 for 2023 is 0.0031 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, possibly due to increased demolition and decommissioning work on the west end, the average concentration at AAS8 for 2023 was 0.0040 μg/m^3 (N = 25), similar to levels reported since 2008 and the early 2000s.

Table 4.11 summarizes the 2023 mercury results with data from 1986 through 1988 included for comparison. Figure 4.20 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 2023 [parts (a) and (b)] and seasonal trends at AAS8 from 1994 through 2023 [part (c)]. The dashed line superimposed on the plots in Figure 4.13(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 Perimeter Intrusion Detection and Assessment System installation and storm drain restoration projects underway at that time within the West End Mercury Area. In Figure 4.13(c), a monthly moving average has been superimposed over the AAS8 data to highlight seasonal trends in mercury at AAS8 from January 1994 through 2023.

Table 4.11. Summary of data for the Y-12 Ambient Air Monitoring Program for mercury, 2023

Ambient air monitoring stations	Mercury vapor concentration (μg/m^3)			
	2023 Minimum	2023 Maximum	2023 Average	1986–1988[a] Average
AAS2 (east end of the Y-12 Complex)	0.0011	0.0064	0.0031	0.010
AAS8 (west end of the Y-12 Complex)	0.0020	0.0074	0.0040	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.*

The average mercury concentrations at the two mercury monitoring sites in 2023 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 as determined by the National Institute for Occupational Safety and Health, the American Conference of Governmental Industrial Hygienists, and the EPA.

4.4.2.2. Quality Control

A number of QA and quality control (QC) steps are taken to ensure the quality of the data for 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.

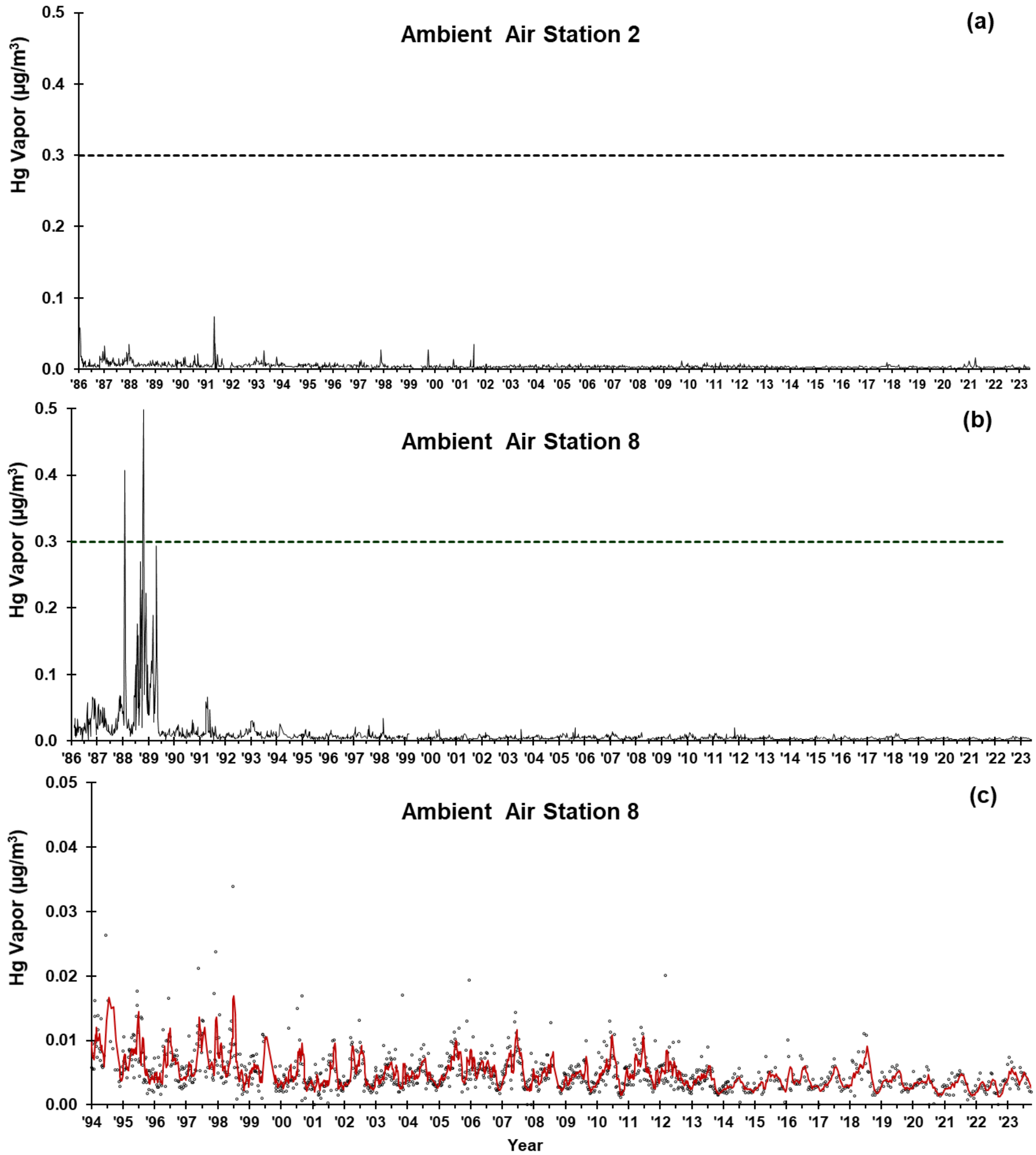
A Gilmont correlated flowmeter is used for measuring flows through the sampling train. Because these flowmeters have been discontinued, they are shipped back to the manufacturer annually for recalibration in accordance with standards set by the National Institute of Standards and Technology.

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 percent 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 typically conducted annually by the project manager to ensure that proper procedures are followed by the sampling technicians. Due to scheduling conflicts, a field performance evaluation was not conducted during 2023. AAS2 was taken offline from Aug. 30, 2023, through Oct. 5, 2023, due to facility construction in the area. No samples were taken during this time.



Note: *The dashed line superimposed on the plots in (a) and (b) is the EPA reference concentration of 0.3 µg/m³ for chronic inhalation exposure. A monthly moving average has been superimposed in (c) over the AAS8 data to highlight seasonal trends in mercury at AAS8 from January 1994 through 2023. Note the different concentration scale on (c).*

Figure 4.13. Temporal trends in mercury vapor concentration for the boundary monitoring stations at Y-12 Complex, July 1986 to December 2023 [(a) and (b)] and January 1994 to December 2023, for Ambient Air Station 8 [(c)].

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 (one per 10 samples) (Any laboratory duplicates differing by more than 10 percent at five or more times the detection limit are to be rerun [third duplicate] to resolve the discrepancy.)
- Archival of all primary laboratory records for at least 1 year

4.4.2.3. Complementary Ambient Air Monitoring

Ambient air monitoring is conducted at multiple locations near ORR to measure radiological and other selected parameters. 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 hazardous air pollutants, 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 ambient air station located in Oak Ridge's Scarboro community (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 city in the Country Club Estates neighborhood (Station 37).

In addition to this monitoring, TDEC and EPA perform ambient air monitoring to characterize the region in general and to characterize and monitor DOE operations locally. Multiple high-volume samplers (Figure 4.12) are being used by TDEC's Fugitive Radiological Air sampling project to monitor air at Y-12. One is located at the west end of the plant, one is east of Building 9212, one is located on the south side of Building 9723-28 change house, and the fourth was placed at the east end of Y-12 at the Y-12 Mercury Monitoring Station 2 in September 2020.

TDEC also performs ambient air monitoring via the EPA RadNet Program at two Y-12 locations, one 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 near Station 8.

Results from TDEC's air monitoring projects at Y-12 and other locations on the ORR are summarized in annual environmental monitoring reports issued by the TDEC Division of Remediation Oak Ridge Office, which are posted on its website **here**.

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

Water quality is monitored at Y-12 to satisfy the NPDES permit and the Industrial Wastewater Discharge Permit. It is also monitored in real time to indicate potential adverse conditions that could be causing an impact on water quality in Upper EFPC.

4.5.1. National Pollutant Discharge Elimination System Permit and Compliance Monitoring

For 2023, the Y-12 NPDES permit (TN0002968) required sampling, analysis, and reporting for about 62 outfalls. Major outfalls are shown in Figure 4.14. The NPDES permit became effective October 1, 2022. (The permit is currently under appeal in part. Y-12 is working with the regulators to resolve.) The number of outfalls changes as they are eliminated or consolidated or if permitted discharges are added. Currently, Y-12 has outfalls and monitoring points in EFPC, Bear Creek, and several tributaries on the south side of Chestnut Ridge, all of which eventually drain to the Clinch River.

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 sampling and analyzing 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 near Y-12 is affected by current and legacy operations. Discharges from Y-12 processes flow into EFPC before the water exits the site. EFPC eventually flows through the City of Oak Ridge to Poplar Creek and into 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 permit for 2023 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 2023 was nearly 100 percent, as shown in Table 4.12.

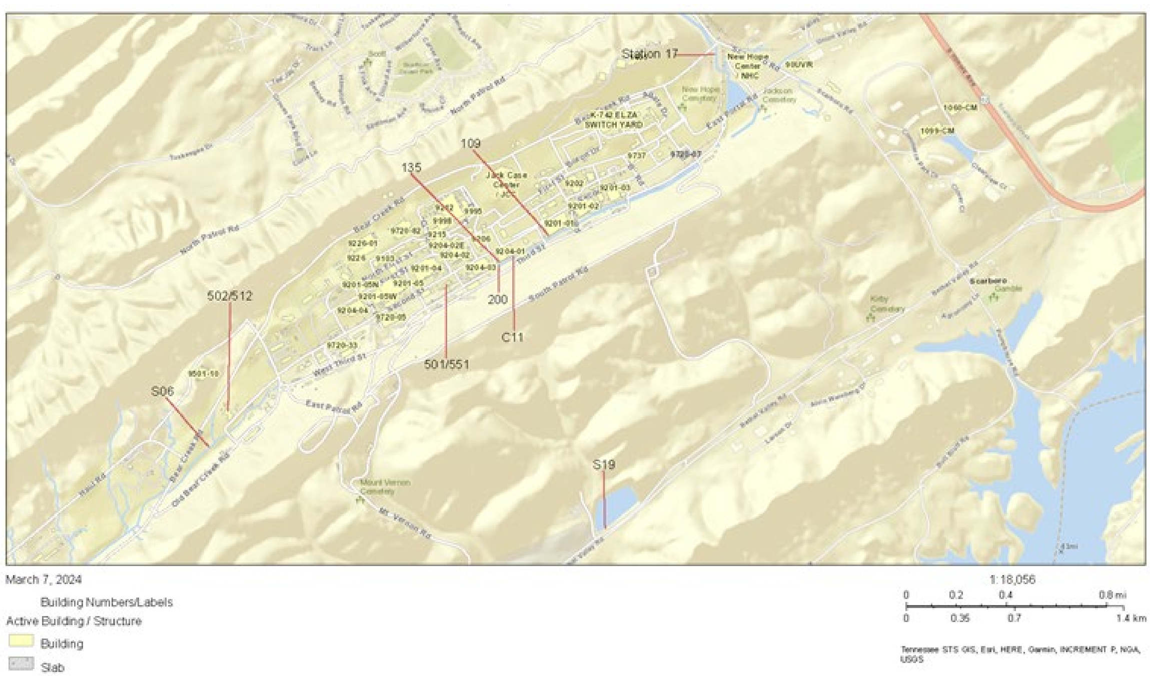


Figure 4.14. Major Y-12 National Pollutant Discharge Elimination System outfalls and monitoring locations

Table 4.12. National Pollutant Discharge Elimination System compliance monitoring requirements and record for Y-12, 2023

Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
Outfall 200 (North/South pipes)						
pH, standard units			*a*	9.0	100	12
Temperature, deg C				30.5	92	12
Hexane extractables			10	15	100	12
Cyanide			0.0052	0.022	92	12
Cadmium			0.0043	0.0118	100	12
Silver				0.0081	100	12
Selenium			0.0031	0.02	100	12
PCB, Total				0.00000064	100	13
Total residual chlorine			0.011	0.019	100	12
Ammonia (as N) Summer			1.01	2.02	100	6
Ammonia (as N) Winter			1.92	3.84	100	6
IC_{25} Ceriodaphnia			50% Minimum		100	5
IC_{25} Pimephales			50% Minimum		100	5
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	100	1
Total suspended solids		31		40	100	1
Total toxic organic				2.13	100	1
Hexane extractables			10	15	100	1
Cadmium		0.4		0.15	100	1
Chromium		1.7		1.0	100	1
Copper		2.0		1.0	100	1

Table 4.12. National Pollutant Discharge Elimination System compliance monitoring requirements and record for Y-12, 2023 (continued)

Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
Lead		0.4		0.2	100	1
Nickel		2.4		3.98	100	1
Nitrate/Nitrite				100	100	1
Silver		0.26		0.05	100	1
Zinc		0.9		1.48	100	1
Cyanide		0.72		1.20	100	1
PCB				0.001	100	1
Outfall 512 (Groundwater Treatment Facility)						
pH, standard units			*a*	9.0	100	12
PCB				0.001	100	1
Outfall 551						
pH, standard units			*a*	9.0	100	51
Mercury			0.002	0.004	100	51
Non-Process Outfalls (Dry Weather Sampling) (014, 021, 034, 042,047, 048, 067, 071, 088, 099, 109, 135)						
Temperature				30.5	100	28
pH, standard units			*a*	9.0	100	28
Ammonia (as N) Summer			1.01	2.02	100	2
Ammonia (as N) Winter			1.92	3.84	100	2
Total Residual Chlorine				0.019	100	24
Outfall 200 (North/South pipes) Wet Weather Flow						
pH, standard units			*a*	9.0	100	1
Temperature, deg C				30.5	92	1
Ammonia (as N) Summer				2.02	100	1
Ammonia (as N) Winter				3.84	100	0
Cyanide				0.022	100	1
Cadmium				0.0118	100	1
Copper				0.064	100	1
Lead				0.6265	100	1
Nickel				1.705	100	1
Silver				0.0081	100	1
Zinc				0.641	100	1
Selenium				0.02	100	1
Outfall C11 (Instream EFPC) Wet Weather						
Temperature				30.5	100	1
pH			*a*	9.0	100	1
Ammonia (as N) Summer				2.02	100	1
Ammonia (as N) Winter				3.84	100	0
Cyanide				0.022	100	1

Table 4.12. National Pollutant Discharge Elimination System compliance monitoring requirements and record for Y-12, 2023 (continued)

Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
Cadmium				0.0118	100	1
Copper				0.064	100	1
Lead				0.6265	100	1
Nickel				1.705	100	1
Silver				0.0081	100	1
Zinc				0.641	100	1
Selenium				0.020	100	1
Outfall C03 (Instream EFPC) Wet Weather						
Temperature				30.5	100	1
pH			*a*	9.0	100	1
Ammonia (as N) Summer				2.02	100	1
Ammonia (as N) Winter				3.84	100	0
Cyanide				0.022	100	1
Cadmium				0.0118	100	1
Copper				0.064	100	1
Lead				0.6265	100	1
Nickel				1.705	100	1
Silver				0.0081	100	1
Zinc				0.641	100	1
Selenium				0.020	100	1
Outfall EFP (Station 17) Wet Weather						
Temperature				30.5	100	1
pH			*a*	9.0	100	1
Ammonia (as N) Summer				2.02	100	1
Ammonia (as N) Winter				3.84	100	0
Cyanide				0.022	100	1
Cadmium				0.0118	100	1
Copper				0.064	100	1
Lead				0.6265	100	1
Nickel				1.705	100	1
Silver				0.0081	100	1
Zinc				0.641	100	1
Selenium				0.020	100	1
Outfall S06 Wet Weather						
Temperature				30.5	100	1
pH			*a*	9.0	100	1
Ammonia (as N) Summer				2.02	100	1
Ammonia (as N) Winter				3.84	100	0
Cyanide				0.022	100	1

Table 4.12. National Pollutant Discharge Elimination System compliance monitoring requirements and record for Y-12, 2023 (continued)

Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
Cadmium				0.0188	100	1
Copper				0.103	100	1
Lead				1.063	100	1
Nickel				2.604	100	1
Silver				0.0191	100	1
Zinc				0.979	100	1
Selenium				0.020	100	1
Outfall S24 Wet Weather						
Temperature				30.5	100	1
pH			*a*	9.0	100	1
Ammonia (as N) Summer				2.02	100	1
Ammonia (as N) Winter				3.84	100	0
Cyanide				0.022	100	1
Cadmium				0.0188	100	1
Copper				0.103	100	1
Lead				1.063	100	1
Nickel				2.604	100	1
Silver				0.0191	100	1
Zinc				0.979	100	1
Selenium				0.020	100	1
Outfall S06 Dry Weather						
Temperature				30.5	100	1
pH			*a*	9.0	100	1
Ammonia (as N) Summer				2.02	100	0
Ammonia (as N) Winter				3.84	100	1
Cyanide				0.022	100	1
Cadmium				0.0188	100	1
Copper				0.103	100	1
Lead				1.063	100	1
Nickel				2.604	100	1
Silver				0.0191	100	1
Zinc				0.979	100	1
Selenium				0.020	100	1
Outfall S24 Dry Weather						
Temperature				30.5	100	1
pH			*a*	9.0	100	1
Ammonia (as N) Summer				2.02	100	0
Ammonia (as N) Winter				3.84	100	1
Cyanide				0.022	100	1

Table 4.12. National Pollutant Discharge Elimination System compliance monitoring requirements and record for Y-12, 2023 (continued)

Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
Cadmium				0.0188	100	1
Copper				0.103	100	1
Lead				1.063	100	1
Nickel				2.604	100	1
Silver				0.0191	100	1
Zinc				0.979	100	1
Selenium				0.020	100	1
Outfall C11 (Instream EFPC) Dry Weather						
Temperature				30.5	100	4
pH			*a*	9.0	100	4
Ammonia (as N) Summer			1.01	2.02	100	2
Ammonia (as N) Winter			1.92	3.84	100	2
Cyanide			0.0052	0.022	100	4
Cadmium			0.0043	0.0118	100	4
Copper			0.0407	0.064	100	4
Lead			0.0244	0.6265	100	4
Nickel			0.189	1.705	100	4
Silver				0.0081	100	4
Zinc			0.646	0.641	100	4
Selenium			0.0031	0.020	100	4
Total Residual Chlorine			0.011	0.019	100	4
Outfall C03 (Instream EFPC) Dry Weather						
Temperature				30.5	100	4
pH			*a*	9.0	100	4
Ammonia (as N) Summer			1.01	2.02	100	2
Ammonia (as N) Winter			1.92	3.84	100	2
Cyanide			0.0052	0.022	100	4
Cadmium			0.0043	0.0118	100	4
Copper			0.0407	0.064	100	4
Lead			0.0244	0.6265	100	4
Nickel			0.189	1.705	100	4
Silver				0.0081	100	4
Zinc			0.646	0.641	100	4
Selenium			0.0031	0.020	100	4
Total Residual Chlorine			0.011	0.019	100	4
Outfall EFP (Station 17) Dry Weather						
Temperature				30.5	100	4
pH			*a*	9.0	100	4
Ammonia (as N) Summer			1.01	2.02	100	2

Table 4.12. National Pollutant Discharge Elimination System compliance monitoring requirements and record for Y-12, 2023 (continued)

Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
Ammonia (as N) Winter			1.92	3.84	100	2
Cyanide			0.0052	0.022	100	4
Cadmium			0.0043	0.0118	100	4
Copper			0.0407	0.064	100	4
Lead			0.0244	0.6265	100	4
Nickel			0.189	1.705	100	4
Silver				0.0081	100	4
Zinc			0.646	0.641	100	4
Selenium			0.0031	0.020	100	4
Total Residual Chlorine			0.011	0.019	100	4

[a] *Not applicable.*

[b] *No discharge.*

Acronyms:

IC_{25} = 25-percent inhibition concentration

PCB = polychlorinated biphenyl

4.5.2. Radiological Monitoring Plan and Results

Y-12 has a radiological monitoring plan to address compliance with DOE orders that was provided to TDEC as a matter of comity under NPDES Permit TN0002968. Y-12 submitted 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. In October 2022, the new NPDES permit became effective, and the requirement for a radiological monitoring plan was removed. 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 four types of locations: treatment facilities, other point source and area source discharges, instream locations, and storm water runoff from production area roofs. Operational history and past monitoring results provide a basis for parameters routinely monitored under the plan (Table 4.13). Y/TS-1704, *Radiological Monitoring Plan for the Oak Ridge Y-12 National Security Complex: Surface Water* was revised and issued in 2020 (CNS 2020b). This revision added Outfall 109 and roof runoff from production areas.

Radiological monitoring during storm water events is 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-d composite sample for radiological parameters taken at Station 17 on EFPC likely includes rain events.

Radiological monitoring plan locations sampled in 2023 are noted on Figure 4.15. Table 4.14 identifies the monitored locations, the frequency of monitoring, and the sum of the percentages of the derived concentration standards for radionuclides measured in 2023. Radiological data were well below the allowable derived concentration standards.

Table 4.13. Radiological parameters monitored at Y-12

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.
	^{3}H	Tritium is not expected to be high in fuel elements because tritium is produced primarily as an activation product in reactor coolants. Tritium is highly mobile and is detected in groundwater samples associated with the S-3 Site.
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.

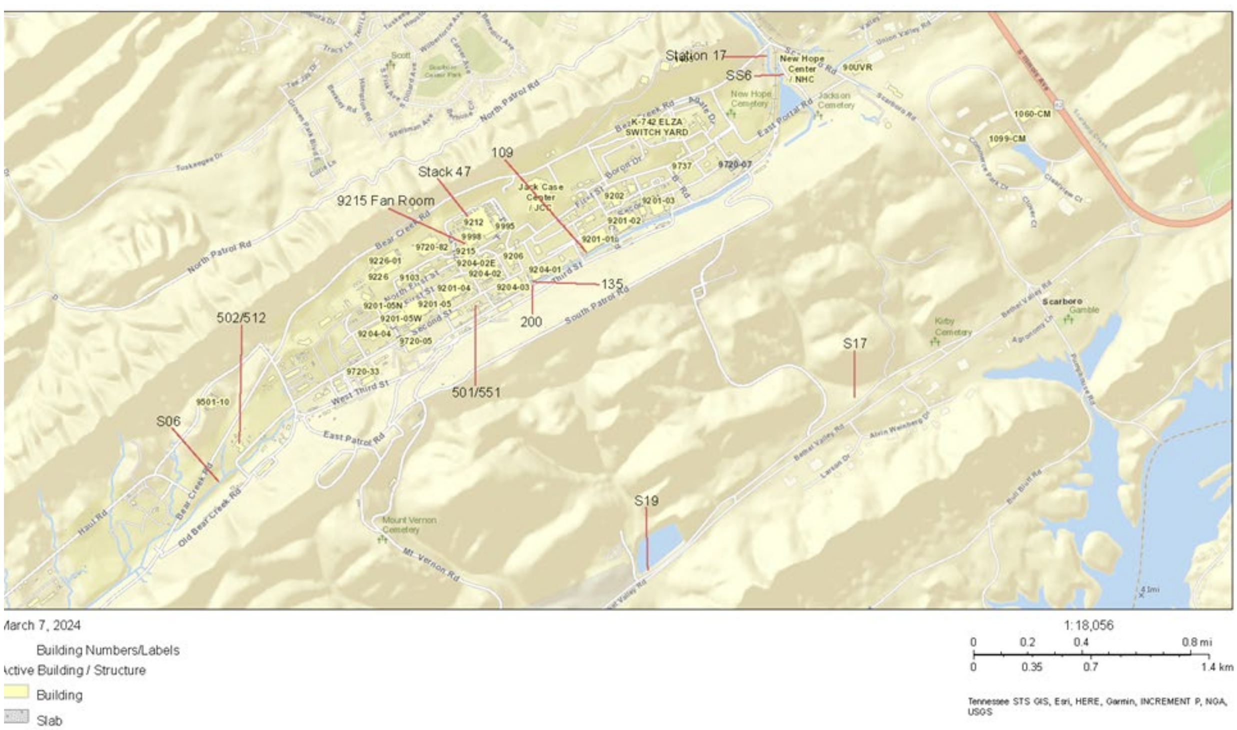


Figure 4.15. Radiological sampling locations at Y-12

Table 4.14. Summary of Y-12's radiological monitoring plan sample requirements and results, 2023

Location	Sample	Sample type	Sum of derived
Y-12 wastewater treatment facilities			
Central Pollution Control Facility	1/batch	Composite during batch operation	No flow
West End Treatment Facility	1/batch	24-h composite	0.07
Groundwater Treatment Facility	4/yr	24-h composite	2.7
Central Mercury Treatment Facility	4/yr	24-h composite	2.2
Other Y-12 point and area source discharges			
Outfall 109	4/yr	24 h composite	0.35
Outfall 135	4/yr	24-h composite	0.39
Kerr Hollow Quarry	1/yr	24-h composite	1.7
Y-12 instream locations			
Outfall S24	1/yr	7-d composite	4.6
East Fork Poplar Creek, complex exit (east)	1/month	7-d composite	1.8
North/south pipes	1/month	24-h composite	2.2
Y-12 Production roof runoff			
9215 Fan Room	4/yr	Grab during rain	18
Stack 47	4/yr	Grab during rain	34

In 2023, the total mass of uranium and associated curies released from Y-12 at the easternmost monitoring station—Station 17 on Upper EFPC—was 118 kg or 0.092 Ci, as shown in Table 4.15.

Table 4.15. Uranium release from Y-12 to the off-site environment as liquid effluent

Year	Quantity released	
	Ci[a]	kg
Station 17		
2014	0.061	90
2015	0.068	116
2016	0.045	88
2017	0.080	154
2018	0.084	205
2019	0.079	203
2020	0.082	173
2021	0.063	139
2022	0.071	167
2023	0.092	118

[a] *1 Ci = 3.7E+10 Bq.*

Figure 4.16 illustrates a 6-year trend of these releases. The total release is calculated by multiplying the average concentration (g/L) by the average flow (million gal/d). Converting units and multiplying by 365 d/yr yields the calculated discharge.

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, although no city-established radiological limits exist. 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 quarterly monitoring reports.

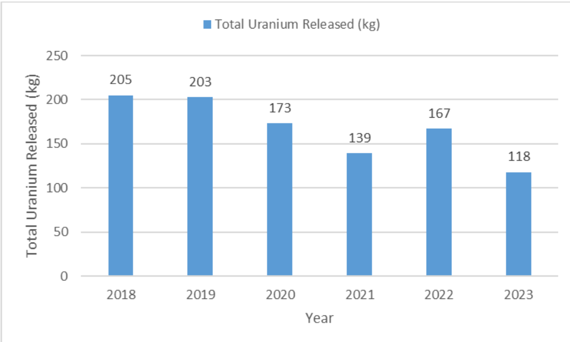


Figure 4.16. Y-12 uranium releases to East Fork Poplar Creek, 2018–2023

4.5.3. Storm Water Pollution Prevention

Y-12 has implemented a storm water pollution prevention program in alignment with the requirements of NPDES Permit TN0002968. program focuses primarily on storm water pollution prevention and continual improvement. It protects the quality of storm water runoff through identifying and properly managing outdoor storm water pollutant sources, implementing best management practices, sampling storm water and interpreting data to evaluate efficacy of pollutant controls, and conducting routine storm water inspections and surveillances.

For the Y-12 NPDES permit, storm water monitoring is performed at category outfalls and wet weather locations. These are described as follows:

- **Category 1 Storm Water Outfalls.** Annual monitoring of pH at Outfalls 002, 003, 004, 006, 007, 008, 009, 010, 011, 017, S17, S18, 019, 020, 033, 041, 044, 045, 046, 054, 057, 058, 062, 063, 064, 086, 087, 110, 114, 125, 126, 134.
- **Category 2 Storm Water Outfalls.** Annual monitoring of pH and total residual chlorine at Outfalls 034, 042, 071, 083, 088, 099, 113.
- **Sector AA Outfalls.** Annual monitoring of pH, nitrite plus nitrate (as N), total iron, total zinc, total aluminum, total mercury, and flow at Outfalls 014, 016, 047, 048, 067, 102, 135.
- **Other Wet Weather.** Annual monitoring as prescribed in the permit tables at Outfalls 200 and S30; Instream EFPC Locations C03, C11, EFP (Station 17); Instream Bear Creek Locations S06 and S24; and Instream Monitoring Station S19.

Y-12 completed the storm water sampling scheduled for sampling year 2023. All stormwater samples were collected as required in the current NPDES permit. The results were compared to the applicable permit table alert values and daily maximum benchmark values. The 2023 sampling year ran from October 2022 to the end of September 2023.

The following are the results for the stormwater sampling conducted in 2023:

- **Category 1 Storm Water Outfalls.** All water sample results were within the typical NPDES permit range for pH of 6.0 and 9.0 standard units.
- **Category 2 Storm Water Outfalls.** All water sample results were within the typical NPDES permit range for pH of 6.0 and 9.0 standard units and were less than 0.05 mg/L for total residual chlorine.
- **Sector AA Storm Water Outfalls.** None of the results exceeded the applicable surface water daily maximum benchmarks as described in the permit.
- **Other Wet Weather Samples.** None of the results exceeded the applicable surface water daily maximum benchmarks or alerts as described in the permit.

An area of concern continues to be on-site construction activities; however, site surveillances continue to identify issues, and they are addressed before they cause an impact to storm water runoff. In addition, overall, the housekeeping and general conditions that could impact storm water continue to improve. Based upon the results of the storm water sampling and site surveillances, the Y-12 stormwater pollution prevention program is effective at protecting the surface waters at Y-12 from storm water pollution. Y-12 will continue to seek opportunities for additional improvement to stormwater protections.

4.5.4. Ambient Surface Water Quality

A network of real-time monitors located at instream locations along Upper EFPC is used to monitor key indicators of water quality. The Surface Water Hydrological Information Support System is available for real-time water quality measurements, such as pH, temperature, dissolved oxygen, conductivity, and chlorine. The locations are shown in Figure 4.17. The system is used to indicate potential adverse conditions that could be causing an impact on water quality in Upper EFPC. It is operated as a best management practice.

Additional sampling of springs and tributaries is conducted in accordance with Y-12's Groundwater Protection Program to monitor trends throughout the three hydrogeologic regimes, as discussed in Section 4.6.

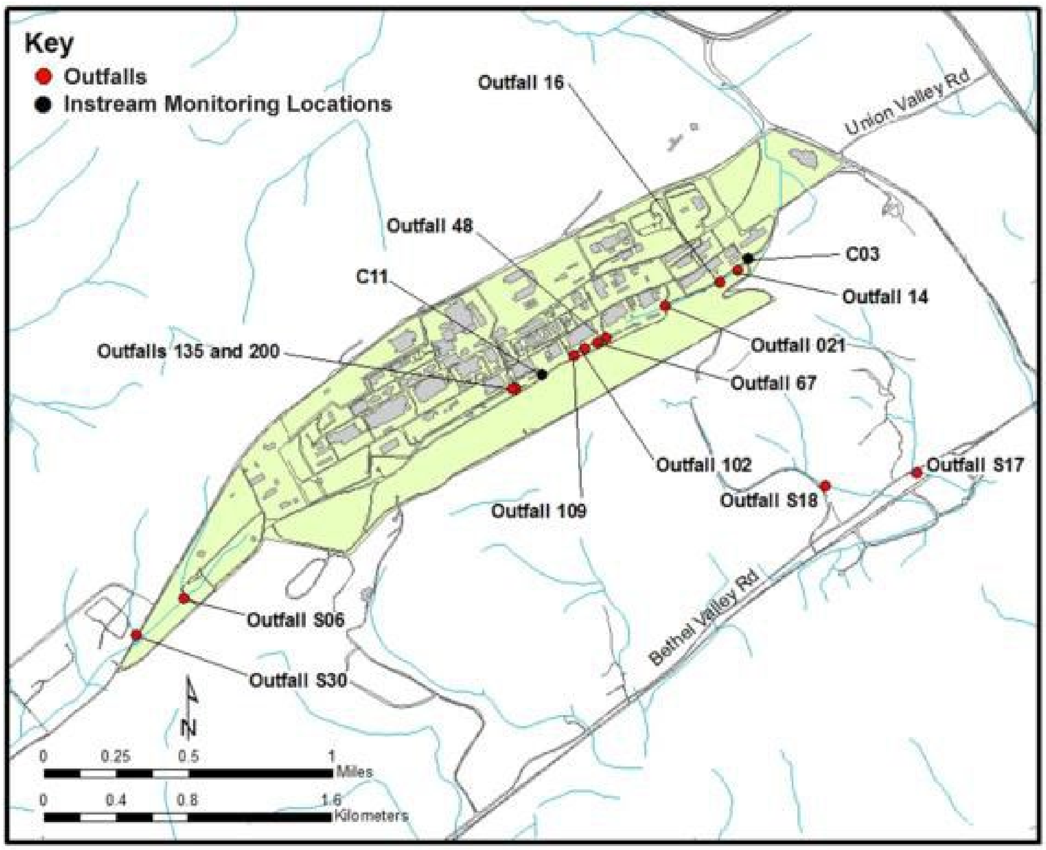


Figure 4.17. Y-12 storm water monitoring locations along East Fork Poplar Creek

4.5.5. Industrial Wastewater Discharge Permit

Industrial and Commercial User Wastewater Discharge Permit 1-91 defines requirements for discharging 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 and gross-beta are taken in a weekly 24-h composite sample. The sample is analyzed for uranium if the alpha or beta values exceed certain levels. Other parameters, including oil and grease, solids, and biological oxygen demand, are monitored on a monthly basis. Metals and 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 use the east end monitoring station (also known as SS6) to conduct compliance monitoring as required by the pretreatment regulations. City personnel also conduct compliance inspections twice a year.

Monitoring results from 2023 are listed in Table 4.16. Three permit limits were exceeded, all of which were of the 2,100-gal/min instantaneous flow limit. To reduce storm water inflow and infiltration, a project is evaluating approximately 15,000 linear feet of the Y-12 sewage collection system via smoke tests and video inspection. The project also performs needed repairs identified during the evaluation, including manhole relining, pipe bursting, and installing cured-in-place piping. Repair work was completed in the B-449, C-409A, and B408A networks. Flow data evaluation indicates this project has reduced inflow and infiltration.

Table 4.16. Discharge point SS6 monitoring results, 2023

Effluent parameter	Number of samples	Average value	Daily maximum (gal/min)[a]	Monthly average (effluent limit)[a]	Number of limit exceedances
Max flow rate (gal/min)	Continuous	N/A	2,100	N/A	3
Flow (average kgpd) January through March	90	475	N/A	500[b]	0
Flow (average kgpd) April through June	91	375	N/A	500[b]	0
Flow (average kgpd) July through September	92	330	N/A	500[b]	0
Flow (average kgpd) October through December	92	347	N/A	500[b]	0
pH (standard units)	16	7.8	N/A	9 and 6[c]	0
Biochemical oxygen demand	13	53.2	N/A	300	0
Kjeldhal nitrogen	14	30.7	N/A	45	0
Phenols—total recoverable	13	<0.031	N/A	0.15	0
Oil and grease	13	<7.8	N/A	25	0
Suspended solids	13	75.5	N/A	200	0
Cyanide	13	<0.0027	N/A	0.006	0
Arsenic	6	<0.0012	N/A	0.01	0
Cadmium	6	<0.0005	N/A	0.0033	0
Chromium, hexavalent	4	0.005	N/A	0.053	0
Copper	6	0.0283	N/A	0.14	0
Iron	6	0.7527	N/A	10	0
Lead	6	<0.0025	N/A	0.049	0
Mercury	13	0.0019[d]	N/A	0.035[d]	0
Nickel	6	<0.005	N/A	0.021	0
Silver	6	0.0013	N/A	0.05	0
Zinc	6	0.1712	N/A	0.35	0
Molybdenum	6	0.0173	N/A	0.05[e]	N/A
Selenium	6	<0.0025	N/A	0.01[e]	N/A
Toluene	5	0.005	N/A	0.005[e]	N/A
Ammonia	6	24.2	N/A	0.10[e]	N/A
Methanol	5	0.98	N/A	1.0[e]	N/A
Benzene	5	0.005	N/A	0.005[e]	N/A

Table 4.16. Discharge point SS6 monitoring results, 2023 (continued)

Effluent parameter	Number of samples	Average value	Daily maximum (gal/min)[a]	Monthly average (effluent limit)[a]	Number of limit exceedances
1,1,1-Trichloroethane	5	0.005	N/A	0.005[e]	N/A
Ethylbenzene	5	0.005	N/A	0.005[e]	N/A
Carbon tetrachloride	5	0.005	N/A	0.005[e]	N/A
Chloroform	5	0.0052	N/A	0.005[e]	N/A
Tetrachloroethene	5	0.0038	N/A	0.005[e]	N/A
Trichloroethene	5	0.005	N/A	0.005[e]	N/A
trans-1,2-Dichloroethene	5	0.005	N/A	0.005[e]	N/A
Methylene chloride	5	0.0044	N/A	0.005[e]	N/A

[a] *Industrial and commercial user wastewater permit limits.*

[b] *Average daily flow allowed in gal/d.*

[c] *Maximum and minimum value.*

[d] *Units are lb/d.*

[e] *This parameter does not have a permit limit. This value is the required detection limit. All units are mg/L unless noted otherwise.*

Acronyms: *kgpd = thousand gallons per day N/A = not applicable*

4.5.6. Quality Assurance and Quality Control

The Environmental Monitoring Management Information System is used to manage surface water monitoring data at Y-12. It 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:

- Using standard operating procedures for sample collection and analysis
- Using chain-of-custody and sample identification, customized chain-of-custody documents, and sample labels provided by the Environmental Monitoring Management Information System
- Standardizing, calibrating, and verifying instruments
- Training sample technicians
- Preserving, handling, and decontaminating samples
- Using 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. The Environmental Monitoring Management Information System routinely accesses the Laboratory Information Management System electronically to capture pertinent data. Generally, the system will store data in the form of concentrations.

A number of electronic data management tools automatically flag data points and allow monitoring and trending of data over time. Field information on all routine samples taken for surface water monitoring is entered in the Environmental Monitoring Management Information System, which also retrieves data nightly from the analytical laboratory. The system then performs numerous data checks, including comparing individual results against any applicable screening criteria, regulatory thresholds, compliance limits, best management practices, or other water quality indicators, and then 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 to determine whether the effluent is contributing chronic toxicity to the receiving water. The permit changed the permit limit and requires quarterly testing of Outfall 200. Chronic toxicity testing is performed using 100 percent effluent and the dilution series shown in Table 4.17.

Table 4.18 summarizes the results of the 2023 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. The permit limit is 50-percent whole effluent for Outfall 200.

Table 4.17. Serial dilutions for whole effluent toxicity testing, as a percent of effluent Serial dilutions for whole effluent toxicity testing, as a percent of effluent

Outfall 200	Control	0.25 x Permit limit	0.50 x Permit limit	Permit limit	(100+Permit limit)/2	100% Effluent
	0	12.5	25	50	75	100

Notes:

1. *Under permit effective Oct. 1, 2022.*
2. *The effluent water is diluted with control laboratory water.*

Table 4.18. Biomonitoring program summary information for Outfall 200, 2023

Water collection dates	Test type	Test organism	End point	Metric[a]	IC_{25}[b] (%)
3/15/23–3/22/23	Chronic	Water fleas (*Ceriodaphnia dubia*)	Survival	IC_{25}	>100%
			Reproduction	IC_{25}	>100%
		Fathead minnow (*Pimephales promelas*)	Survival	IC_{25}	>100%
			Growth	IC_{25}	>100%
5/3/23–5/10/23	Chronic	Water fleas (*Ceriodaphnia dubia*)	Survival	IC_{25}	>100%
			Reproduction	IC_{25}	>100%
		Fathead minnow (*Pimephales promelas*)	Survival	IC_{25}	>100%
			Growth	IC_{25}	>100%
8/9/23–8/16/23	Chronic	Water fleas (*Ceriodaphnia dubia*)	Survival	IC_{25}	>100%
			Reproduction	IC_{25}	>100%
		Fathead minnow (*Pimephales promelas*)	Survival	IC_{25}	>100%
			Growth	IC_{25}	>100%
11/1/23–11/8/23	Chronic	Water fleas (*Ceriodaphnia dubia*)	Survival	IC_{25}	>100%
			Reproduction	IC_{25}	>100%
		Fathead minnow (*Pimephales promelas*)	Survival	IC_{25}	>100%
			Growth	IC_{25}	>100%

[a] *IC_{25} is summarized for the discharge monitoring location (Outfall 200).*

[b] *IC_{25} as a percentage of full-strength effluent from Outfall 200 diluted with laboratory control water. IC_{25} is the concentration that causes a 25-percent reduction in water fleas (Ceriodaphnia dubia) survival or reproduction or fathead minnow (Pimephales promelas) survival or growth.*

4.5.8. Biological Monitoring and Abatement Program

The NPDES permit issued for Y-12 mandates a biological monitoring and abatement program to demonstrate that the effluent limitations established for the facility protect the classified uses of the receiving stream—EFPC. The 2023 program sampling efforts follow the NPDES-required *Y-12 National Security Complex Biological Monitoring and Abatement Program Plan* (ORNL 2013).

Y-12's program, which has been monitoring the ecological health of EFPC since 1985, consists of three major tasks that reflect complementary approaches to evaluating the effects of Y-12 discharges on the aquatic integrity of EFPC—bioaccumulation studies, benthic macroinvertebrate community surveys, and fish community monitoring. Data collected on contaminant bioaccumulation and the composition and abundance of communities of aquatic organisms directly evaluate the effectiveness of abatement and remedial measures in improving ecological conditions in the stream.

Monitoring is conducted at seven primary EFPC sites (Figure 4.18), although sites may be excluded or added depending on the specific objectives of the various tasks. The primary sampling sites include the following:

- Upper EFPC at EFPC kilometers (EFKs) 24.4 and 23.4, located upstream and downstream of Lake Reality, respectively
- EFKs 18.7 and 18.2, located off ORR and below an area of intensive commercial and light industrial development, respectively
- EFKs 13.8 and 13.0, located upstream and downstream of the Oak Ridge Wastewater Treatment Facility, respectively
- EFK 6.3, located about 1.4 km downstream of the ORR boundary

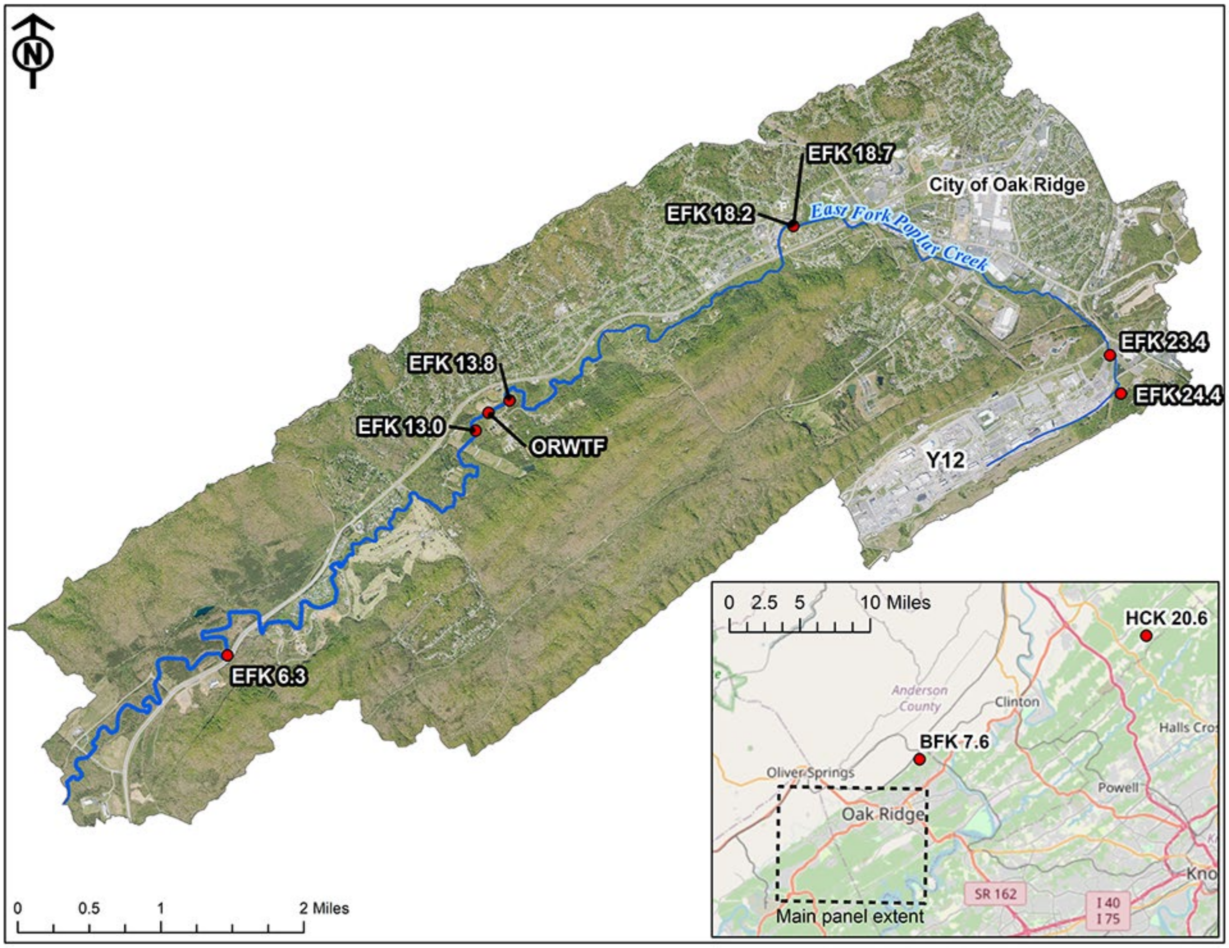
Brushy Fork at Brushy Fork kilometer 7.6 had been used as a reference stream for the fish and macroinvertebrate community tasks; however, the site may be replaced because of limitations in site access and degraded ecological conditions at the site. Hinds Creek at Hinds Creek kilometer 20.6 is also used as a reference for the macroinvertebrate and fish community monitoring task.

Generally, the number of invertebrate and fish species in EFPC has increased over the last three decades (primarily in the upstream sites), demonstrating that the overall ecological health of the stream continues to improve. However, the richness of pollution-intolerant invertebrate taxa at some sites in EFPC has declined since the end of flow augmentation in 2014. Further, 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 concentrations 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/or rock bass (*Ambloplites rupestris*) are collected from five sites throughout the length of EFPC and are analyzed twice a year for tissue concentrations of mercury (Figure 4.19) and annually for PCBs (Figure 4.20). Mercury concentrations remained higher in fish from EFPC in 2023 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.



Note: *BFK 7.6 and HCK 20.6 are reference sites.*

Acronyms:

BFK = Brushy Fork kilometer

EFK = East Fork Poplar Creek kilometer

Y12 = Y-12 National Security Complex

HCK = Hinds Creek kilometer

ORWTF = Oak Ridge Wastewater Treatment Facility

Figure 4.18. Biological monitoring sites in East Fork Poplar Creek relative to Y-12

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. Waterborne mercury concentrations in the upper reach of EFPC have decreased substantially over the years in response to various remedial actions.

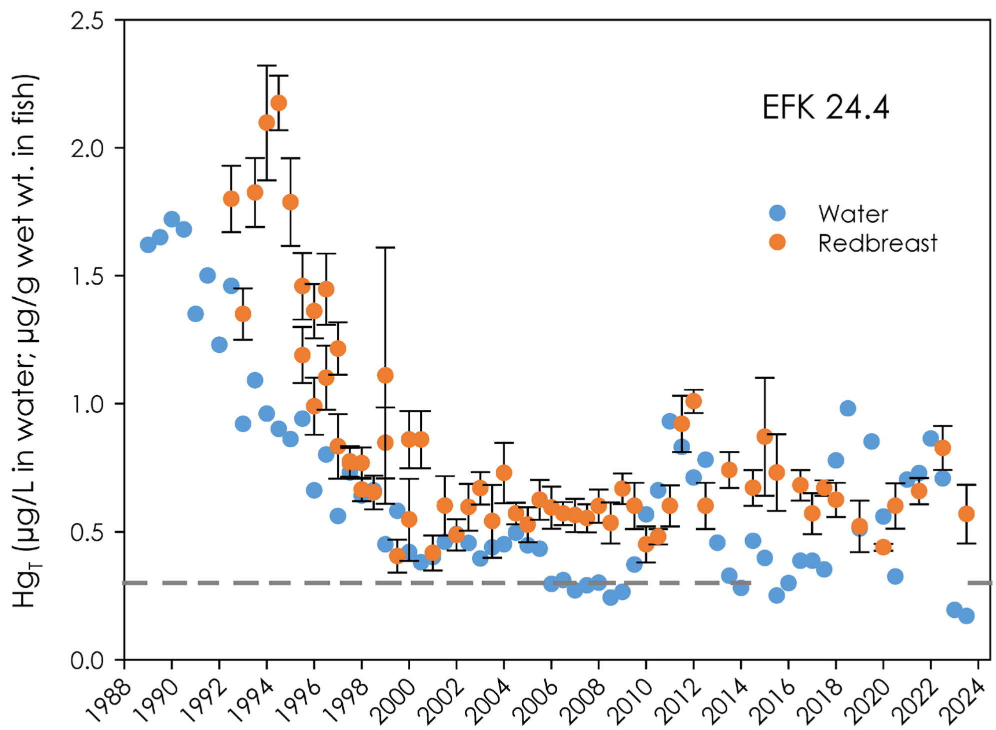
Significant fluctuations in aqueous mercury concentrations (thought to be the result of storm drain relining and cleanout) have been seen at EFK 23.4 since 2009. In July 2018, aqueous mercury concentrations spiked as a result of a onetime flux of mercury that occurred during construction and demolition activities at the west end of Y-12. The elevated mercury concentrations were associated with toxicity and a fish kill (ORNL 2019, 2022).

Aqueous mercury and fish concentrations at Station 17 decreased significantly in 2023, and mean mercury concentrations in fish collected at EFK 24.4 increased slightly (0.56 µg/g) but remained above the EPA-recommended ambient water quality criterion for mercury (0.3 µg/g mercury as methylmercury in fish fillet).

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 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 0.26 µg/g in FY 2023, slightly higher than concentrations seen in FY 2022 (0.17 µg/g) (Figure 4.20). Regulatory guidance and human health risk levels vary widely for PCBs, depending on the regulatory program and the assumptions used in the risk analysis. The Tennessee water quality criterion for both individual Aroclors and total PCBs is 0.00064 µg/L under the recreation designated-use classification and is the target for PCB-focused total maximum daily loads, including for local reservoirs, such as Melton Hill, Watts Bar, and Fort Loudoun (TDEC 2010a, 2010b, 2010c).

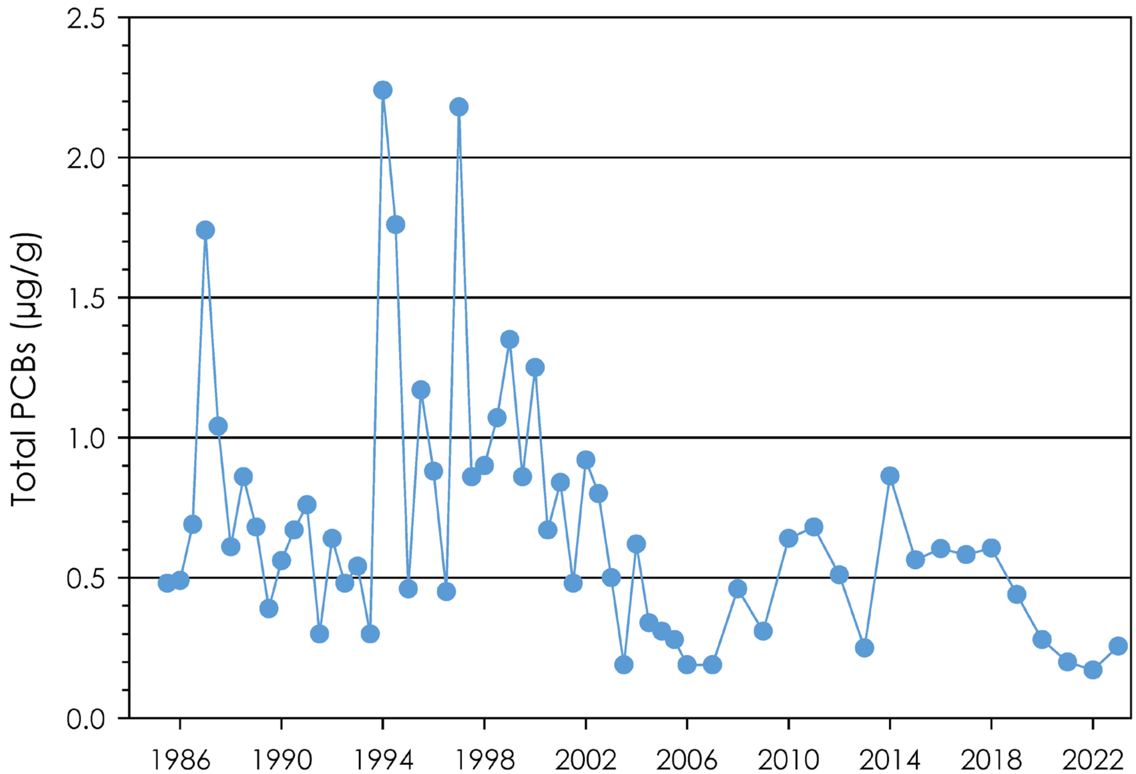
In the state of Tennessee, assessments of impairment for water body segments, as well as public fishing advisories, are based on fish tissue concentrations. Historically, the US Food and Drug Administration threshold limit of 2-µg/g PCBs in fish fillets was used for advisories. For many years, an approximate range of 0.8 to 1 µg/g was used, depending on the data available and factors such as the fish species and size. Most recently, the water quality criterion has been used to calculate the fish tissue concentration triggering impairment and a total maximum daily load (TDEC 2024b). This concentration is 0.02-µg/g PCBs in fish fillets (TDEC 2010a, 2010b, 2010c). The mean fish PCB concentration in Upper EFPC, is well above this concentration.



Notes:

1. *Dashed gray line represents the ambient water quality criterion for methylmercury in fish fillets (0.3 µg/g).*
2. *Water: At East Fork Poplar Creek kilometer 23.4.*
3. *Fish: At East Fork Poplar Creek kilometer 24.4.*

Figure 4.19. Semiannual average mercury concentration in muscle fillets of redbreast sunfish and water from East Fork Poplar Creek, 1988–2023



Note: *At East Fork Poplar Creek kilometer 23.4.*

Acronym:

PCB = polychlorinated biphenyl

Figure 4.20. Annual mean concentrations of polychlorinated biphenyls in rock bass muscle fillets, 1986–2023

4.5.8.2. Benthic Invertebrate Surveys

Monitoring the benthic macroinvertebrate community continued in the spring of 2023 at three sites in EFPC and at one reference stream (Hinds Creek). There have been long-term changes in the macroinvertebrate community at EFPC sites since monitoring began in 1986 (Figure 4.21).

Total taxa richness (number of taxa and sample) increased at EFK 24.4 from 1986 until the mid-2000s and then remained steady for approximately 14 years (Figure 4.21). After flow management ended in 2014, total taxa richness decreased at EFK 24.4 and has remained at these lower values since that time, with the exception of an increase in 2021 to a value similar to that measured before 2014, before decreasing again in 2022.

Total taxa richness at EFK 23.4 steadily increased since monitoring began, and values also decreased after flow management ceased (Figure 4.21). In 2023, total taxa richness remained similar to 2022 values at EFK 23.4, which are comparable to values observed from 2015 to 2019.

Total taxa richness at EFK 13.8 and the reference sites has been fairly consistent over the entire monitoring period, although the value at EFK 13.8 declined in 2023 and was the lowest observed since 2009 (Figure 4.21).

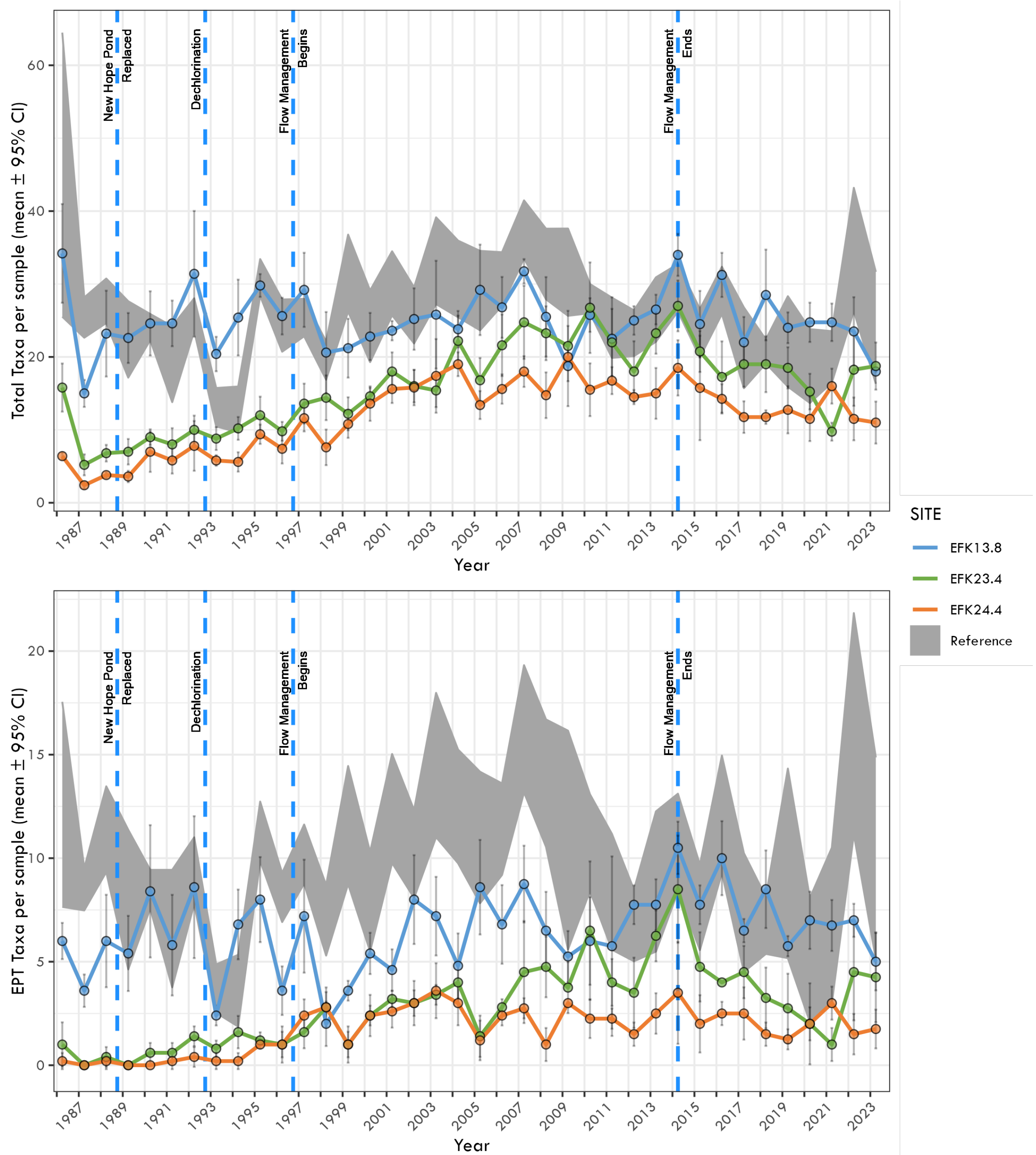
Total taxa richness at EFK 24.4 has consistently been lower than at the reference sites throughout the monitoring period, while total taxa richness at EFK 13.8 has generally fallen within or above the 95-percent confidence interval of reference site values, especially in the past decade (Figure 4.21). Total taxa richness at EFK 23.4 was lower than the 95-percent confidence interval of the reference sites from 1986 to 2009, but since then total taxa richness has mostly been within the 95-percent confidence interval of the reference sites (Figure 4.21).

Temporal patterns in the number of pollution-intolerant taxa (Ephemeroptera, Plecoptera, and Trichoptera [EPT] taxa richness) were similar to those observed for total taxa richness (Figure 4.21). EPT taxa richness at EFK 24.4 was very low (less than 1 EPT taxa and sample) from 1986 until 1994 and then increased slightly (greater than 1 but less than 5 taxa per sample) until 2014. Since 2014, EPT taxa richness has generally been slightly lower, with values in 2023 remaining similar to 2022 (Figure 4.21).

EPT taxa richness at EFK 23.4 steadily increased since 1986 but decreased after flow management ended (Figure 4.21). In 2023, EPT taxa richness at EFK 23.4 remained similar to values observed in 2022 and comparable to those observed from 2017 to 2019 following the lowest values observed in recent years in 2021 (Figure 4.21). EPT taxa richness at EFKs 24.4 and 23.4 has typically been lower than the 95-percent confidence interval of EPT taxa richness at the reference streams, indicative of degraded conditions.

The number of pollution-intolerant taxa at EFK 13.8 has remained fairly steady during the monitoring period, although with large interannual variation. EPT taxa richness values at EFK 13.8 have been within the reference site confidence limits since 2012, with the exception of 2022, which was below the confidence limits (Figure 4.21).

The implications of ending flow management in 2014 on invertebrate communities in EFPC are still uncertain. After flow augmentation ceased, EPT taxa richness at EFK 23.4 has consistently declined until 2022 (Figure 4.21). EPT taxa richness at EFK 24.4 has also shown a slight decrease since flow augmentation ended, with some recovery evident in 2020 and 2021, though this recovery was erased in 2022 (Figure 4.21). The effects of ending flow augmentation on Lower EFPC (EFK 13.8) do not seem as evident, which makes sense as flow augmentation contributed a smaller percentage of total discharge at downstream sites. The long-term effects of ending flow management on the invertebrate community in EFPC will become more evident as conditions stabilize and additional data become available.



Notes:

1. *Top: Total taxonomic richness (mean number of taxa per sample with 95 percent confidence interval).*
2. *Bottom: Taxonomic richness of the pollution-intolerant taxa (Ephemeroptera, Plecoptera, and Trichoptera [EPT]) (i.e., mean number of EPT taxa per sample with 95 percent confidence interval).*
3. *The timing of various activities within the watershed is shown with vertical blue lines.*
4. *Reference streams are Brushy Fork and Hinds Creek; however, Brushy Fork was not sampled in 2022 or 2023 due tolack of access to the survey site.*

Acronyms:

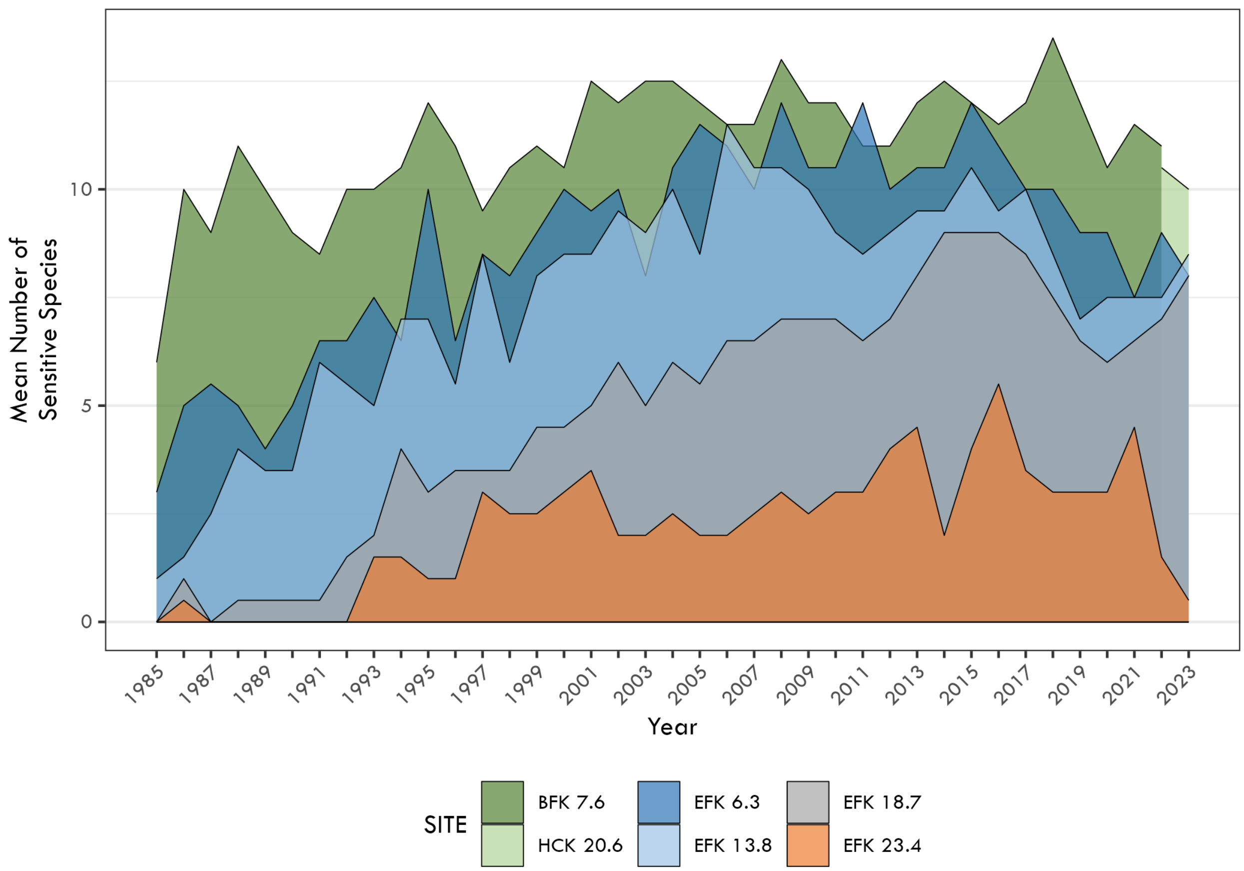
EFK = East Fork Poplar Creek kilometer

EPT = Ephemeroptera, Plecoptera, and Trichoptera

Figure 4.21. Benthic macroinvertebrate communities in three sites along East Fork Poplar Creek and the 95 percent confidence interval for two nearby reference streams

4.5.8.3. Fish Community Monitoring

Fish communities were monitored in the spring and fall of 2023 at sites along EFPC and at Hinds Creek, a comparable local reference stream. 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 seasonal conditions, such as flooding and drought, can cause minor fluctuations in values but rarely cause long-term impacts on larger systems such as EFPC. However, some species of fish are considered sensitive, 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 streams is shown in Figure 4.22, dramatically highlighting major improvements in the fish community in the middle to lower sections (EFKs 6.3 and 13.8) of the stream. However, the EFPC fish community continues to lag behind reference stream communities (Brushy Fork kilometer 7.6 and Hinds Creek kilometer 20.6) in the most important metrics of fish diversity and community structure, especially at the monitoring sites closest to Y-12 (EFKs 23.4 and 24.4).



Notes:

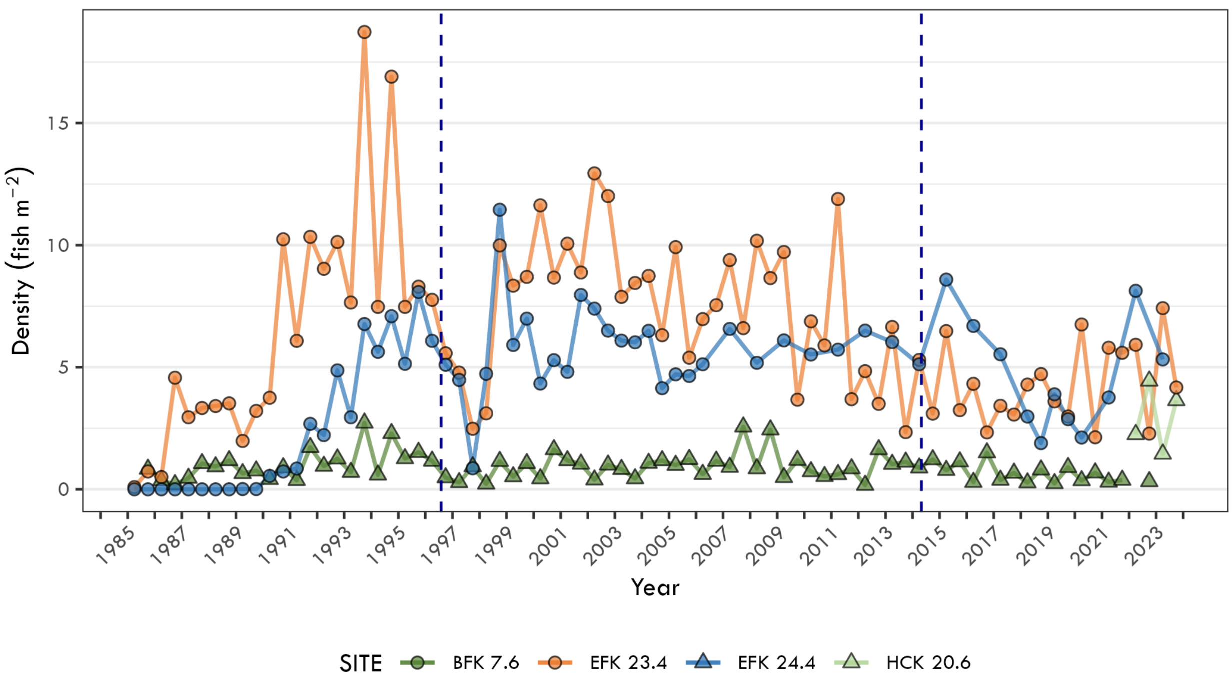
1. *Mean sensitive species richness refers to the number of species.*
2. *Reference sites are Brushy Fork kilometer 7.6 and Hinds Creek kilometer 20.6.*

Acronyms:

BFK = Brushy Fork kilometer *EFK = East Fork Poplar Creek kilometer* *HCK = Hinds Creek kilometer*

Figure 4.22. Comparison of mean sensitive fish species richness collected from East Fork Poplar Creek and reference sites, 1985–2023

Fish communities in Upper EFPC continued to fluctuate in density during 2023. Reduced stream flows associated with the termination of flow augmentation from Melton Hill in April 2014 and occasional unexpected fish kills are likely factors driving the decrease in fish densities in these upper sites (Figure 4.23). Despite this, fish diversity remained relatively consistent at these sites. 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.



Notes:

1. *Access to the Brushy Fork site (BFK 7.6) was restricted in spring 2022 and 2023, and no samples were collected. A comparable reference site was sampled beginning in spring 2022.*
2. *The interval of time between the dashed lines represents the period of flow management in East Fork Poplar Creek.*
3. *Fish density refers to the number of fish per m^2.*
4. *Reference sites are Brushy Fork (BFK 7.6) and Hinds Creek (HCK 20.6).*

Acronyms:

BFK = Brushy Fork kilometer *EFK = East Fork Poplar Creek kilometer* *HCK = Hinds Creek kilometer*

Figure 4.23. Fish density for two sites in Upper East Fork Poplar Creek and reference sites, 1985–2023

4.6. Groundwater at the Y-12 National Security Complex

Groundwater is monitored to comply with federal, state, and local requirements and to determine the environmental impact from legacy and current operations. There are approximately 190 known or potential sources of contamination identified in the Federal Facility Agreement for Y-12 (DOE 2023c). Groundwater monitoring provides information on the nature and extent of contamination, which is used to identify actions needed to protect the worker, public, and environment. Figure 4.24 depicts major source areas where groundwater is monitored.

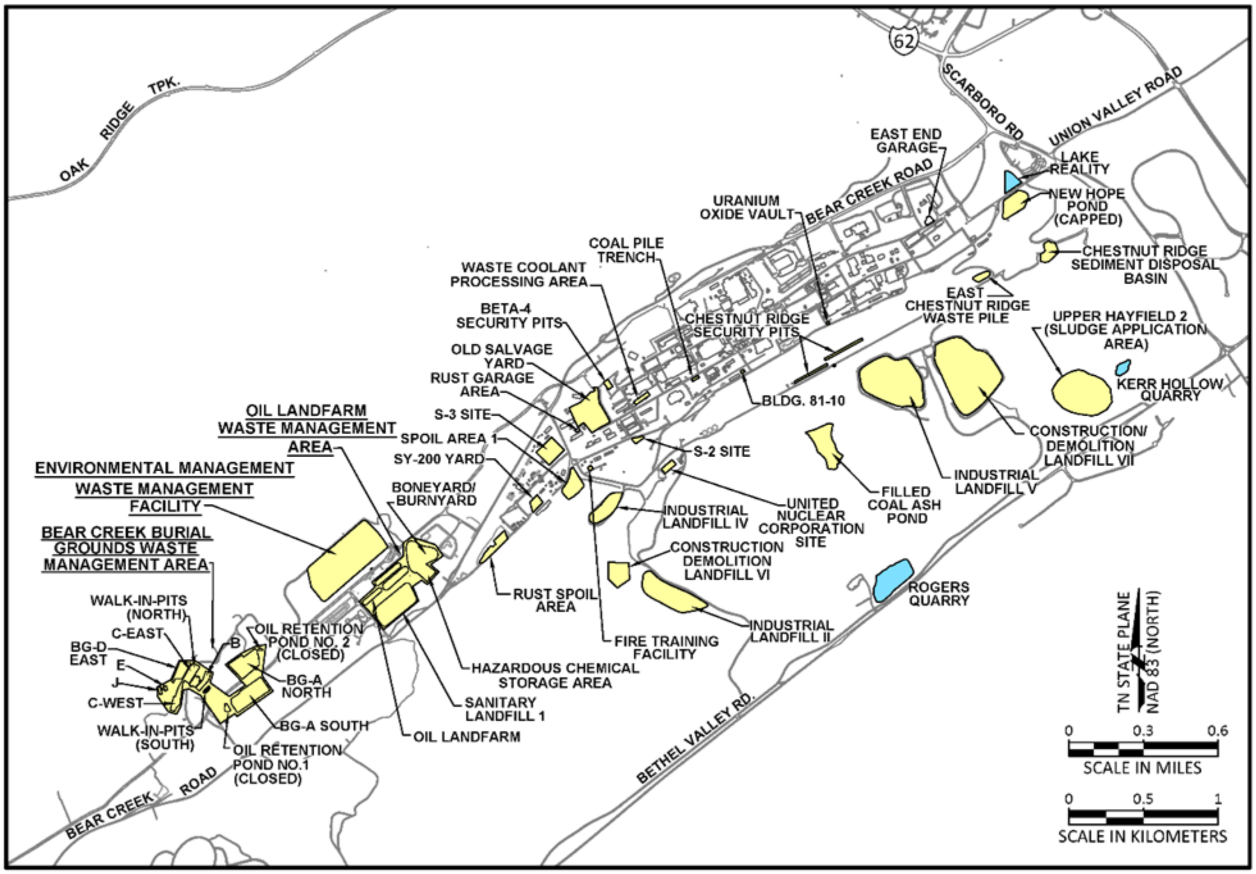


Figure 4.24. Known or potential contaminant source areas where groundwater is monitored at Y-12

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.

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 4.26). Shallow flow in the Bear Creek and Upper EFPC regimes diverges 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 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/yr) but can be quite rapid within solution conduits in the Maynardville Limestone (10 to 5,000 ft/d).

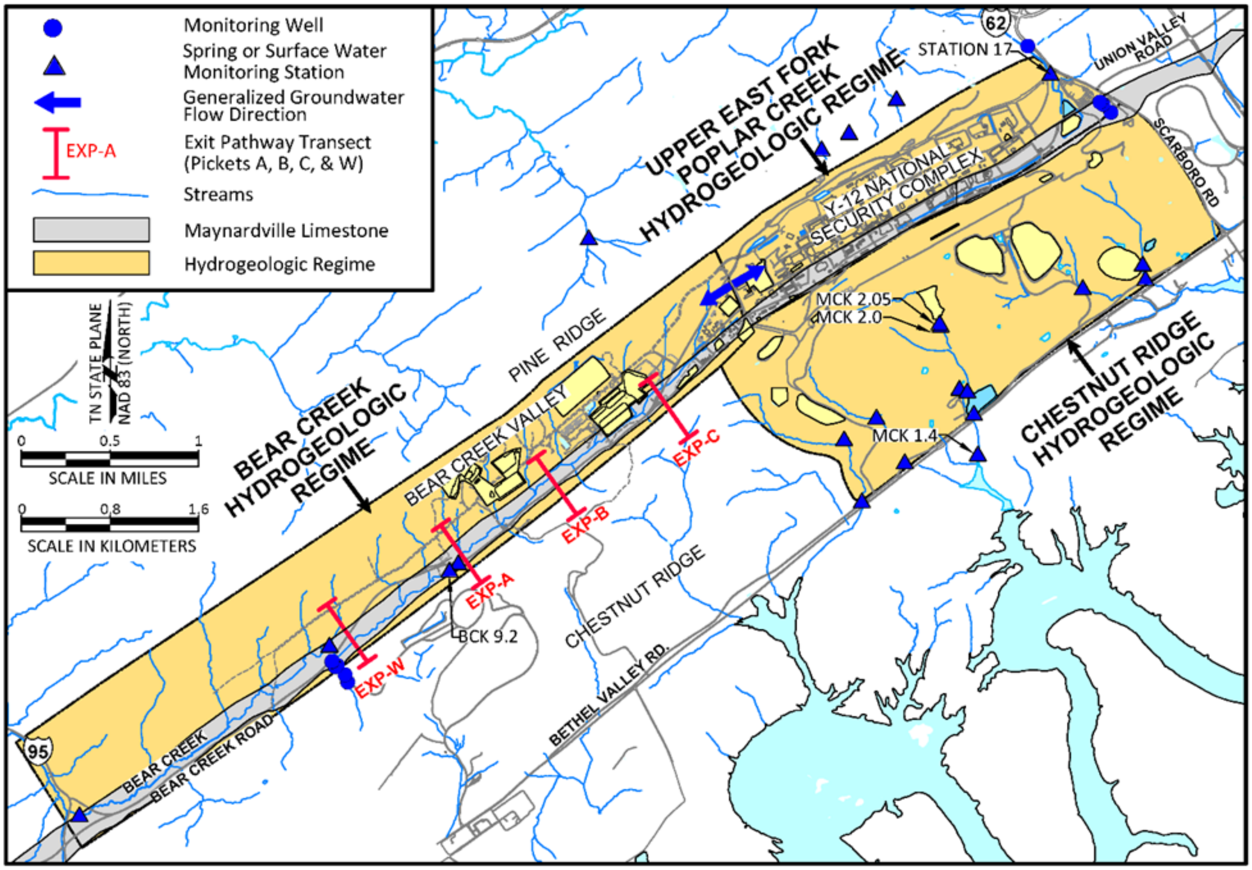


Figure 4.25. Hydrogeologic regimes, flow directions, perimeter/exit pathway locations, and position of Maynardville Limestone at Y-12

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 Y-12's industrial area. 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-3 site for thousands of feet. Extensive 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. VOCs (e.g., petroleum products, coolants, and solvents) in groundwater within the fractured bedrock of the aquitard units can remain close to source areas for long durations. This is because they tend to adsorb to the bedrock matrix, diffuse into pore spaces within the matrix, and very slowly diffuse back out of the matrix when concentration gradients change 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 aquifer. Discharge points for intermediate and deep flow are not well-known. However, following the crest of the Chestnut Ridge, water table elevations decrease from west to east, demonstrating an overall easterly trend in groundwater flow.

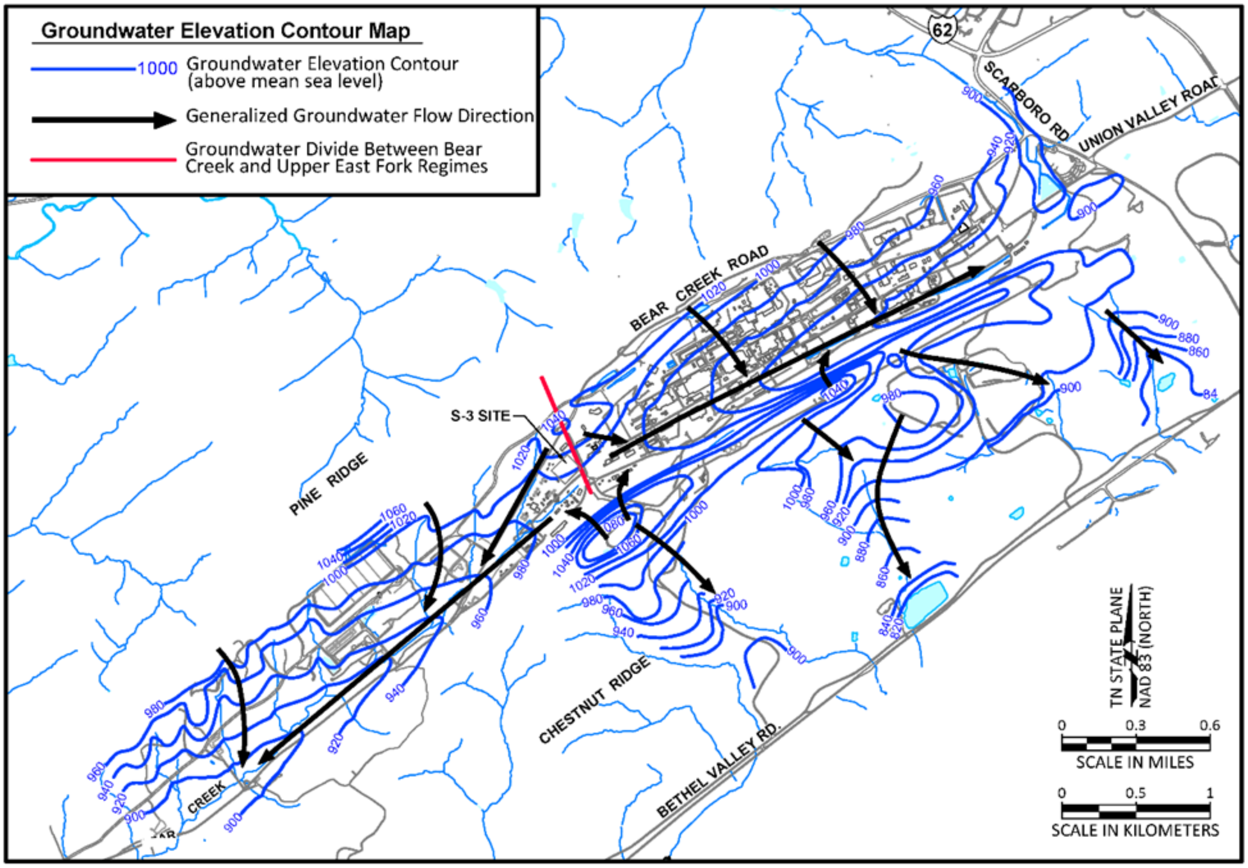


Figure 4.26. Groundwater elevation contours and flow directions at Y-12

4.6.2. Groundwater Monitoring

Groundwater monitoring in 2023 was performed as part of Y-12's Groundwater Protection Program, DOE EM programs such as the Water Resources Restoration Program, and other projects. Compliance requirements were met by monitoring 210 wells and 61 surface water locations and springs (Table 4.19). (Locations sampled for research projects are not included in the wells and locations monitored for compliance requirements.)

Specific wells of interest, based on 2023 data, are discussed later in this section. Figure 4.25 shows the locations of perimeter/exit pathway stations that are routinely monitored.

Table 4.19. Summary of groundwater monitoring at the Y-12 National Security Complex, 2023

	Restoration[a]	Waste management[b]	Surveillance[c]	Other[d]	Total
Purpose for which monitoring was performed					
Number of active wells	62	33	115	77	287
Number of other monitoring stations (e.g., springs, seeps, and surface water)	36	10	15	3	64
Number of samples taken[e]	282	282	145	82	791
Number of analyses performed	11,423	9,746	17,182	1,944	40,295
Percentage of analyses that are non-detects	63.0	87.8	69.4	NA	72.2
Ranges of results for positive detections, VOCs (µg/L)[f]					
Chloroethenes	0.15-1800	2.77-5.9	0.8-44000	NA	
Chloroethanes	0.13-250	59.7-66.2	1-1300	NA	
Chloromethanes	0.2-1400	0.51-1.25	1-670	NA	
Petroleum hydrocarbons	0.18-7300	ND	1-490	NA	
Uranium (mg/L)	0.00003-0.35	0.000078-0.014	0.000516-0.333	NA	
Nitrates (mg/L)	0.048-4200	ND-1.44	0.0452-11300	NA	
Ranges of results for positive detections, radiological parameters (pCi/L)[g]					
Gross-alpha activity	0.68-370	1.25-7.08	0-140	NA	
Gross-beta activity	0.63-3800	2.88-25.6	0-420	NA	

[a] *Monitoring to comply with CERCLA requirements.*

[b] *Solid waste landfill detection monitoring and CERCLA landfill detection monitoring.*

[c] *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*

Acronyms:

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act

NA = not analyzed

Water quality results of groundwater monitoring activities are presented in the 2023 groundwater monitoring report (CNS 2024). The groundwater sampling technicians shown in Figure 4.27 are taking water quality samples from a well in the East Fork regime.

Monitoring efforts performed specifically for CERCLA baseline and remediation evaluation are published in the FYs 2023 and 2024 Water Resources Restoration Program sampling and analysis plans (UCOR 2022, 2023b respectively) and the annual CERCLA remediation effectiveness reports (DOE 2023b, 2024).

Thirty-five monitoring wells were installed near the S-3 site by the Ecosystems and Networks Integrated with Genes and Molecular Assemblies research group in 2023. Three monitoring wells were installed by the Y-12 Groundwater Protection Program. Twenty-one monitoring wells were plugged and abandoned by the DOE Water Resources Restoration Program in 2023. Eight of these monitoring wells were located around Building 9201-02, which will be demolished. The remaining were located around the future Environmental Management Disposal Facility site.

Figure 4.27. Groundwater monitoring well sampling in the Upper East Fork regime at Y-12

4.6.3. 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 ^{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.

4.6.3.1. 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. Contaminants from the S-3 site (nitrate and ^{99}Tc) and VOCs from multiple source areas are observed in 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 2023 include the S-2 site, Fire Training Facility, S-3 site, Waste Coolant Processing Facility, former petroleum USTs, New Hope Pond, Old Salvage Yard, and process/production buildings throughout Y-12.

The S-3 site is near the hydrologic divide that separates the Upper EFPC regime from the Bear Creek regime and has contributed groundwater contamination to both regimes. Contaminant plumes in both regimes (shown in orange shading on Figures 4.28, 4.30, 4.31, and 4.32) are elongated as a result of preferential transport of contaminants parallel to strike (parallel to the valley axis) in both the Knox aquifer and the fractured bedrock of the aquitard.

The plumes depicted reflect the average concentrations and radioactivity in groundwater between 2013 and 2017. The circular icons presented on the plume maps (Figures 4.28, 4.30, 4.31, and 4.32) represent 2023 monitoring results for the Upper EFPC regime (discussed in this section), the Bear Creek regime (discussed in Section 4.6.3.2), and the Chestnut Ridge regime (discussed in Section 4.6.3.3).

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 the past, these were ponds that received large quantities of nitric acid wastes. In 2023, there was a maximum nitrate concentration of 9,360 mg/L in well GW-275. This well is located approximately 396 m (1,300 ft) east of the S-3 site and is screened in the shallow-intermediate bedrock interval about 19 m (63 ft) below ground surface (Figure 4.28).

Increasing concentration trends are indicated by the nitrate data for wells 55-2A, 55-2B, 55-2C, and GW-275 in the East Fork regime (Figure 4.29). Considering the mobility of nitrate, the increasing trends suggest increased flux of nitrate via some of the fracture flowpaths in the Nolichucky Shale east of the S-3 site. This is consistent with both the heterogeneous transport characteristics of the groundwater flow system as well as described in the conceptual model for contaminant transport from the S-3 site, whereby the center of mass of the nitrate (and other intermixed contaminants) plume in the Nolichucky Shale east of the site continues to slowly move eastward via permeable flowpaths (e.g., bedding plane fractures) that parallel geologic strike (DOE 1998).

The nitrate trends for wells 55-2A, 55-2B, and 55-2C appear to be fairly stable since 2010, and the nitrate trend at well GW-275 appears to be stable or decreasing since 2017, which demonstrates the continued eastward strike-parallel migration of the nitrate plume. Nitrate trends in the groundwater at well clusters reflect conditions at different depth intervals at the same location. Whereas wells 55-2A, 55-2B, and 55-2C show similar nitrate trends, divergent nitrate trends occur at wells GW-274 and GW-275 (decreasing and increasing). The decreasing trend at well GW-274 likely reflects higher groundwater flow (flushing) in the shallow groundwater system (Figure 4.29).

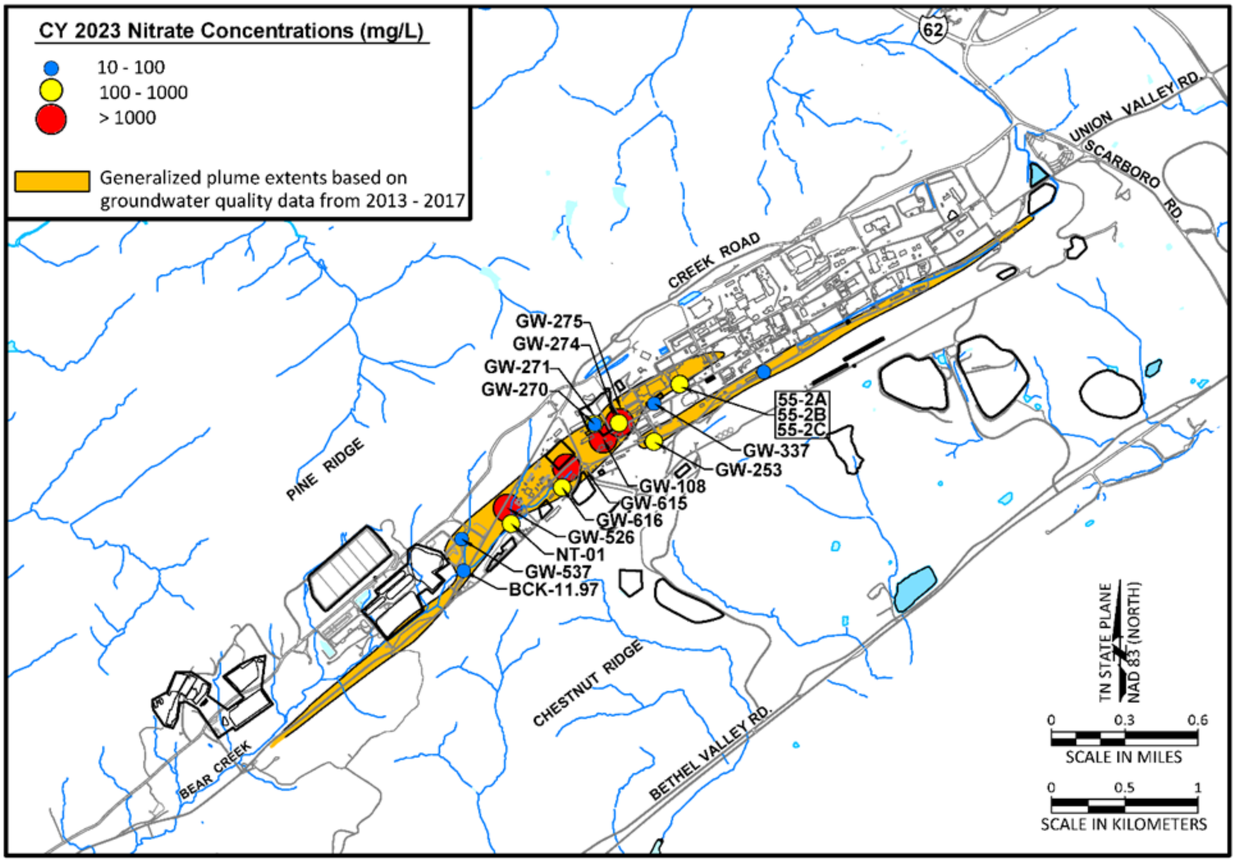


Figure 4.28. Nitrate in groundwater at Y-12, 2023

Trace Metals

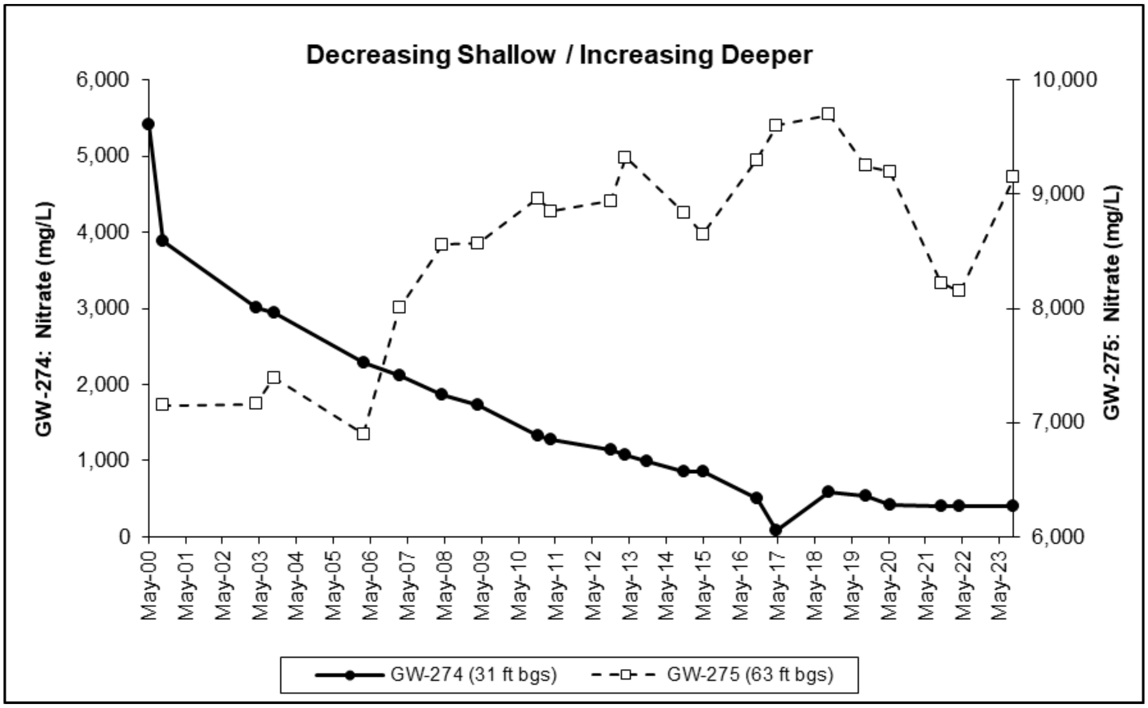
In 2023, barium, beryllium, cadmium, chromium, copper, nickel, thallium, and uranium exceeded primary drinking water standards in groundwater in the Upper EFPC regime. Uranium was found predominately downgradient of the S-2 and S-3 sites, and upgradient of the New Hope Pond site. Trace metal concentrations above standards occur adjacent to source areas because of their low solubility and high adsorption to the clay-rich soils and bedrock.

VOCs

VOCs, the most widespread contaminants in the Upper EFPC regime, consist of chlorinated and petroleum hydrocarbons. In 2023, the highest summed concentration of dissolved chlorinated hydrocarbons (52,296 µg/L) was again observed at well 55-3B in the western portion of Y-12, adjacent to currently inactive manufacturing facilities. The highest dissolved concentration of petroleum hydrocarbons was again seen at well GW-658 (14,310 µg/L) at the closed East End Garage.

Most monitoring results are consistent with data from previous years because a dissolved plume of legacy VOCs in the bedrock zone extends eastward from the S-3 site over the entire length of the regime (Figure 4.30). 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 in the western and central portions of the Upper East Fork regime. 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 the regime.



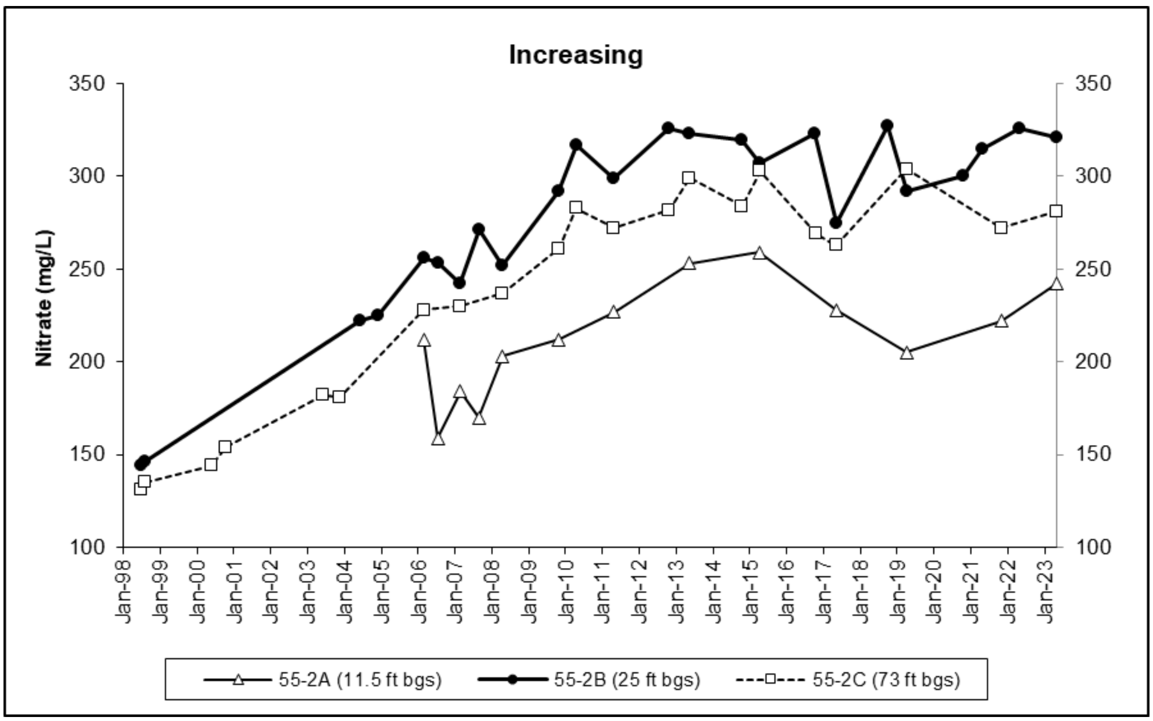


Figure 4.29. Nitrate concentration trends in surveillance monitoring wells GW-274/GW-275 and 55-2A/55-2B/55-2C in the East Fork regime

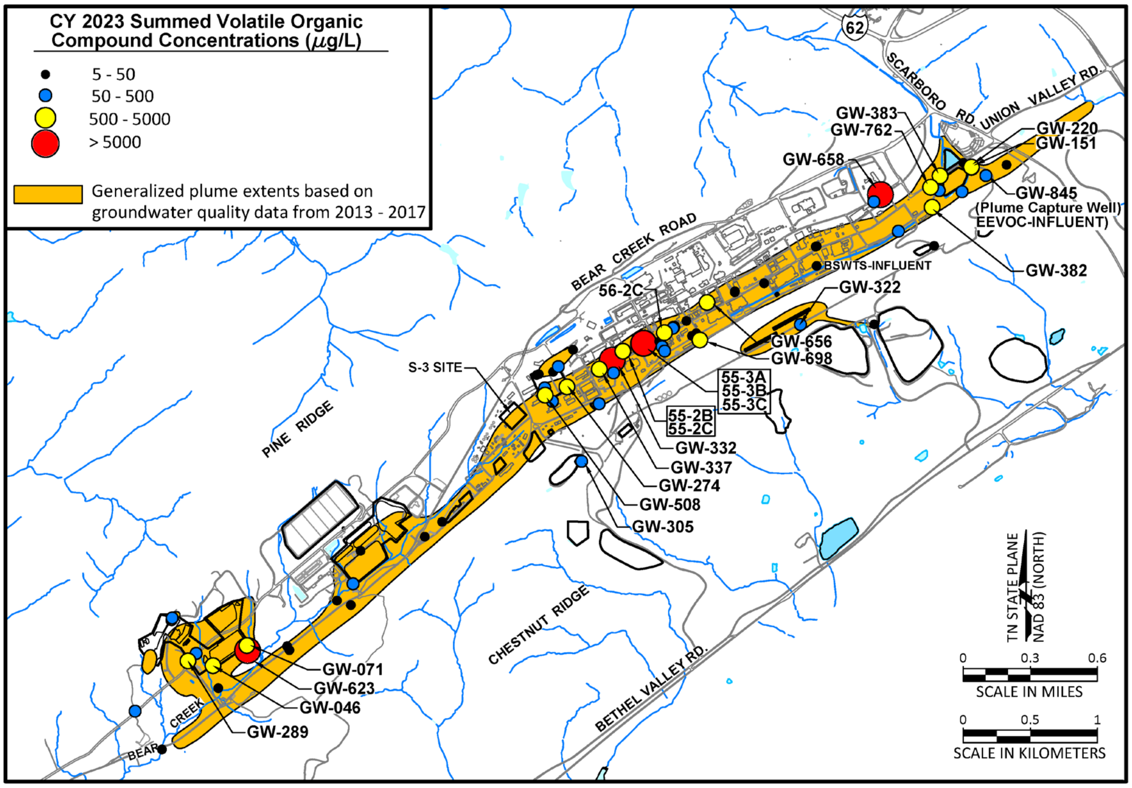


Figure 4.30. Summed volatile organic compounds in groundwater at Y-12, 2023

Variability in concentration trends of chlorinated and petroleum VOCs is seen within the Upper EFPC regime. Increasing trends have been observed in wells associated with the Rust Garage, Old Salvage Yard, and S-3 site, as well as some legacy sources at production/process facilities in central areas. While data from most monitoring wells have remained relatively constant since the late 1980s/early 1990s, some wells show trends in recovery from legacy contamination, especially where petroleum hydrocarbons are the predominant contaminant. For example, while GW-658 has the highest dissolved concentration of petroleum hydrocarbons in the regime, the concentration is an order of magnitude lower than measured in the same well in 1992 and 1993 (>100,000 mg/L).

Radionuclides

The primary alpha-emitting radionuclides found in the Upper EFPC regime during 2023 are isotopes of uranium. Exceedances of the drinking water standard for gross-alpha (15 pCi/L) have been observed near the S-3 site, Old Salvage Yard, and other western source areas; in the central areas near production facilities and the Uranium Oxide Vault; and in the east end near the former oil skimmer basin at the former inlet to New Hope Pond, which was capped in 1988. In 2023, the maximum occurrence of gross-alpha activity in groundwater in the Upper EFPC regime was 370 pCi/L, again at well GW-154 near the former oil skimmer basin as shown in Figure 4.31.

The primary beta-emitting radionuclides observed in the Upper EFPC regime are ^{99}Tc and isotopes of uranium. Historically, elevated gross-beta activity in groundwater shows a pattern similar to that observed for gross-alpha activity as shown in Figure 4.32.

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 2023 from well GW-108 (3,800 pCi/L), down from a maximum gross-beta (21,300 pCi/L) in 2008 in the same well.

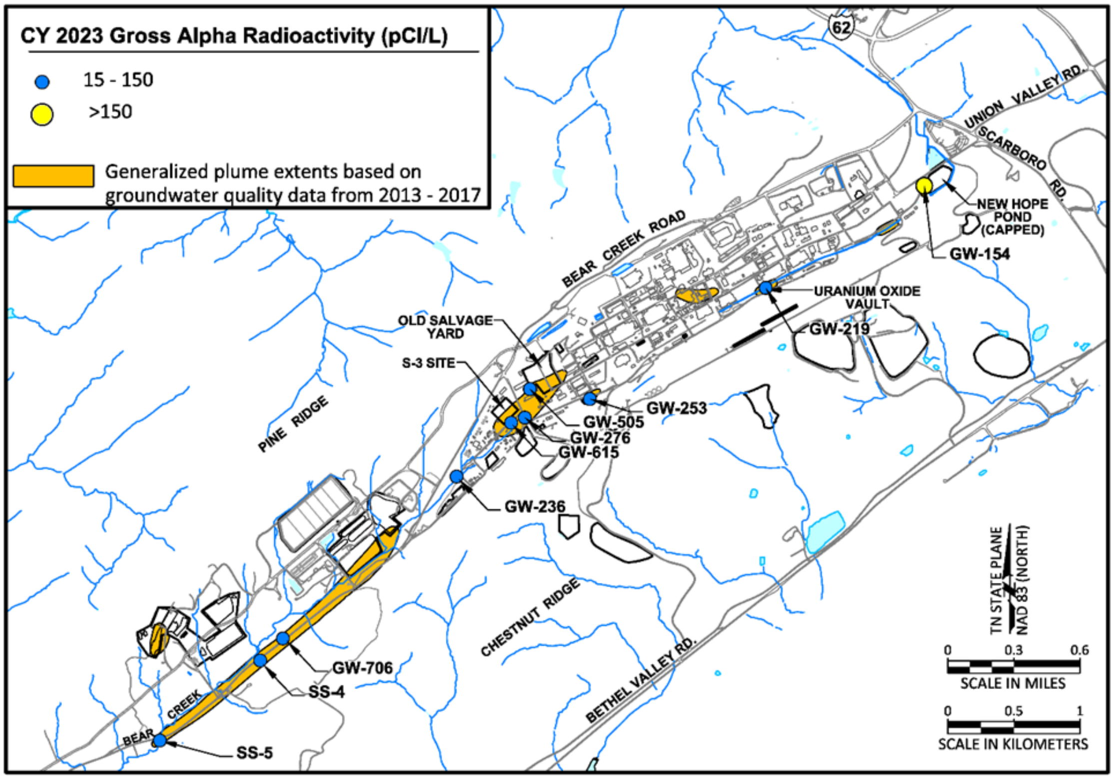


Figure 4.31. Gross-alpha activity in groundwater at Y-12, 2023

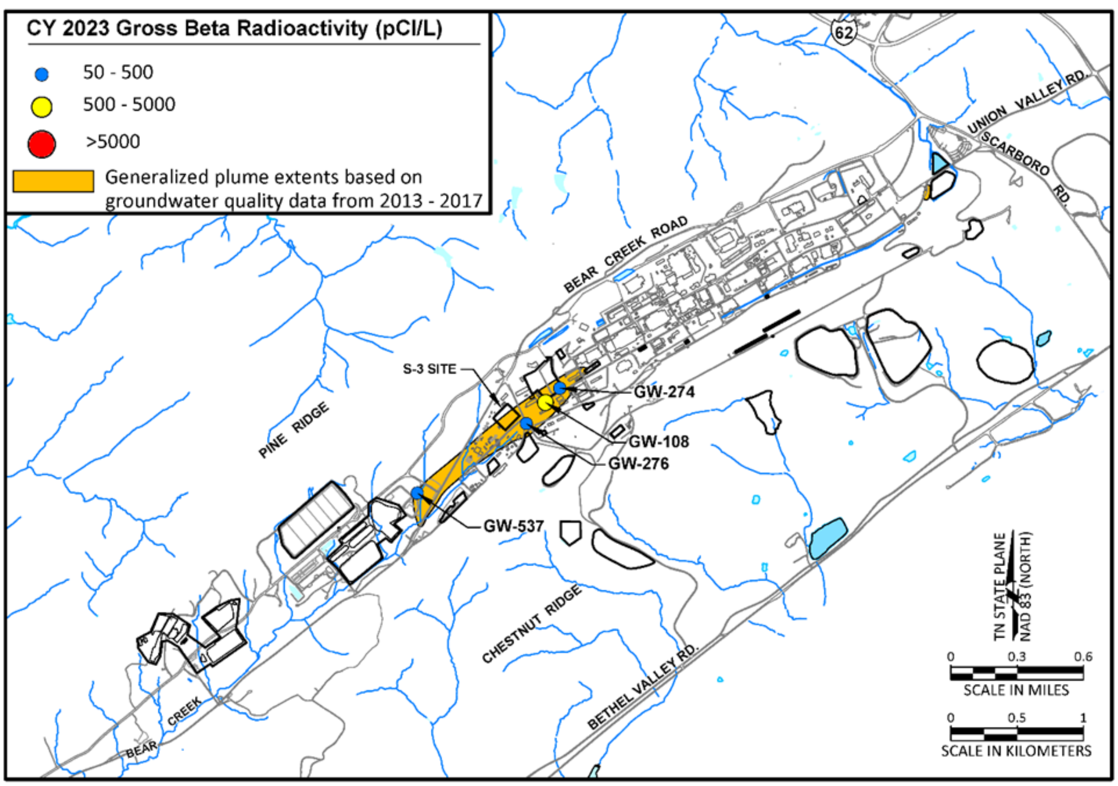


Figure 4.32. Gross-beta activity in groundwater at Y-12, 2023

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 in the Maynardville Limestone (the primary exit pathway) appear to be well connected and facilitate contaminant migration into Union Valley off-site to the east of Y-12.

Because of off-site migration of contaminants, a plume capture system (the East End VOC Treatment System) was constructed in and around well GW-845 (shown on Figure 4.30) and began continuous operation in October 2000. Groundwater is 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. The effectiveness of this system is reported annually in remediation effectiveness reports published by DOE EM (DOE 2023b, 2024).

Monitoring wells near the plume capture system continue to show an encouraging response. The trends near the East End VOC plume show that contaminants in shallow-intermediate wells located perpendicular to strike across lithologic units from the plume capture system installed in GW-845 may be mobilized by the system. However, no downgradient detection of these compounds is apparent; therefore, migration is limited. An example is observed in the Westbay system installed in well GW-722. This multiport well, located downgradient from the East End VOC Treatment System, allows sampling of several vertically discrete zones within the Maynardville Limestone. Monitoring results from GW-722 indicate reductions in VOCs due to the plume capture system, derived from summed VOC levels above 1,000 μg/L before the treatment system was installed to below 50 μg/L in the last 4 years.

Five zones in well GW-722 were sampled in 2023, with four zones showing summed VOCs greater than 5 μg/L. Four zones exceeded the drinking water standard for carbon tetrachloride, with the highest concentration (15 μg/L) measured at zone 722-17 (385 ft below ground surface). Zone 722-20 (333 ft below ground surface) also exceeded the drinking water standard for PCE at 5.1 μg/L.

In addition to the deep system in the eastern portion of the Upper EFPC regime, VOCs have also been observed in 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 former New Hope Pond. During 2023, the summed concentrations of VOCs at the New Hope Pond distribution channel underdrain remained low (15.6-17.7 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 this exit pathway. GW-816 in this pathway gap was monitored in 2023, and no groundwater contaminants were observed above primary drinking water standards.

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. Another 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 ORR into those communities.

Union Valley Monitoring

Groundwater monitoring data obtained in 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 remedial investigation (DOE 1998) discussed the nature and extent of VOC contamination in Union Valley.

In 2023, monitoring locations in Union Valley continued to show overall decreasing or low concentration stable trends. Vinyl chloride at

2.6 µg/L (above the maximum contaminant level of 2 µg/L) was detected at monitoring well GW-230, located in the University of Tennessee Arboretum (approximately 3,500 ft east of the ORR boundary). A groundwater flow divide west of GW-230, coincident with Scarboro Creek, Illinois Avenue, and a gap in Chestnut Ridge, probably restricts transport of VOCs from the ORR further east (MMES 1995). This would indicate that the VOCs observed in the well are from a source other than Y-12.

Under the terms of an interim Record of Decision, restrictions on potential future groundwater use have been established and maintained. Additionally, the previously discussed plume capture system (well GW-845) was installed to mitigate groundwater migration contaminated with VOCs into Union Valley (DOE 1997b).

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 *Public Health Assessment: Evaluation of Potential Exposures to Contaminated Off-Site Groundwater from the Oak Ridge Reservation*, 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 there is no public health hazard from exposure to contaminated groundwater originating on the ORR. At that time, 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 institutional and administrative controls established in the Record of Decision do not provide for reduction in toxicity, mobility, or volume of contaminants of concern, but it concluded the controls protect public health to the extent that they limit or prevent community exposure to contaminated groundwater in Union Valley.

4.6.3.2. 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.

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 Oil Landfarm waste management areas are sources of uranium, other trace metals, and VOCs. Chlorinated hydrocarbons and PCBs have been observed in groundwater 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. 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).

The plumes in the Bear Creek regime (Figures 4.28, 4.30, 4.31, and 4.32) represent the average concentrations and radioactivity between 2013 and 2017. The circular icons presented on the figures represent 2023 monitoring results.

Nitrate

Data from 2023 indicate 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 (11,300 mg/L) was observed at well GW-615 adjacent to the S-3 site at a depth of 245 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 2023, concentrations of nitrate appear to be lower in the Bear Creek Regime. In past years, it has been reported that concentrations exceeding the drinking water standard were detected in groundwater as far as 2,438 m (8,000 ft) west of the S-3 site, from spring location SS-4. However, these concentrations are now slightly lower than the drinking water standard of 10 mg/L (8 mg/L). In 2023, monitoring well GW-537 located 762 m (2,500 ft) from the S-3 site showed elevated concentrations above the drinking water standard (74.8 mg/L).

Natural attenuation processes have reduced nitrate levels in the shallow groundwater downgradient of the site. Despite the slightly elevated nitrate result for aquitard well GW-537 in 2023, the overall decreasing trend in nitrate indicates more efficient natural attenuation of nitrate in the shallow flow system, including seasonal discharge of nitrate-contaminated groundwater to the surface drainage network in Bear Creek Valley, compared to the substantially slower attenuation of nitrate in less permeable groundwater flow/contaminant transport pathways deeper in the bedrock.

Under the conceptual model for contaminant transport in the valley, elevated nitrate concentrations in the shallow groundwater from well GW-537 (1,285 in 1992 and 8.44 mg/L in 2020) were sustained by nitrate-contaminated groundwater upwelling from deeper flowpaths in the Nolichucky Shale (DOE 1997b).

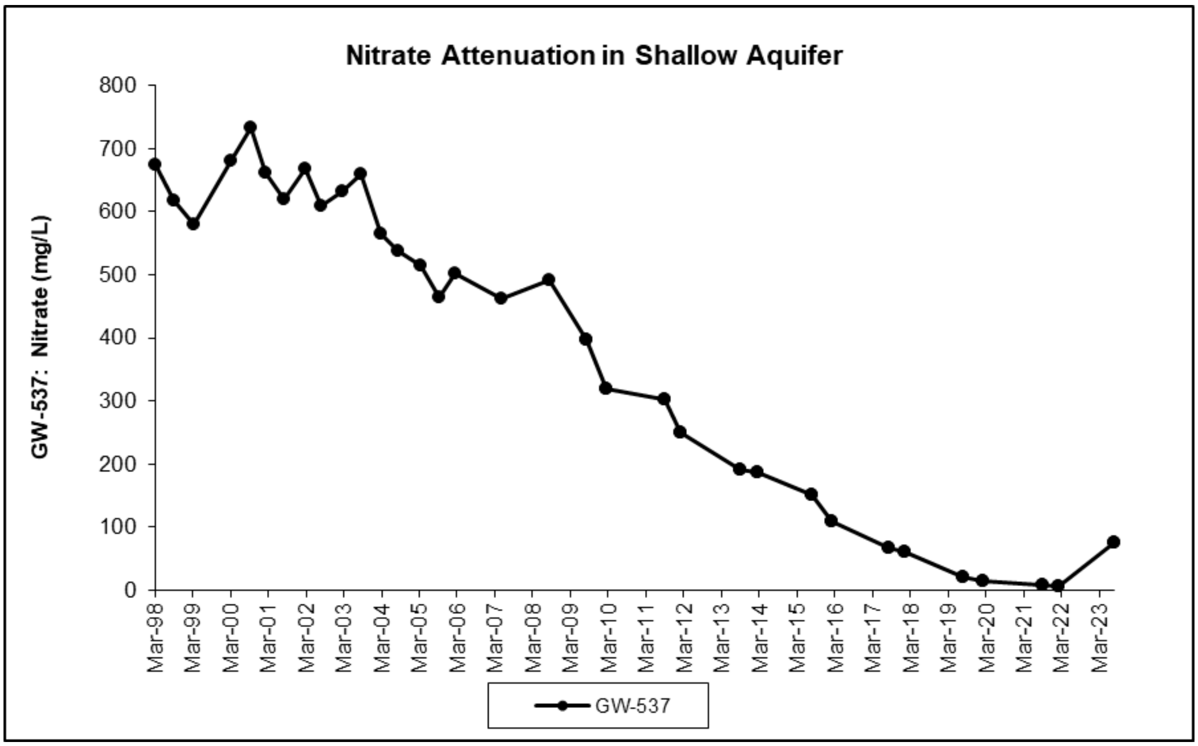


Figure 4.33. Nitrate trend in surveillance monitoring well GW-537, Bear Creek Regime, 1998–2023

Trace Metals

During 2023, arsenic, barium, cadmium, 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. Disposal of acidic liquid wastes at the site reduced the pH of the groundwater, which allows the metals to remain in solution longer and migrate further from the source area. In other areas of 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.

The most prevalent trace metal contaminant is uranium. There has been a decrease in uranium in

Bear Creek since 1990, as shown in Table 4.20; however, uranium concentrations in the upper reaches of Bear Creek have been stable, indicating that this contaminant still presents an impact to surface water and groundwater.

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)			
		1990–1999	2000–2009	2010–2019	2020–2023
BCK[b]-11.84 to 11.97	Nitrate	91.9	75.2	43.4	26.25
(~0.5 miles downstream)	Uranium	1.61	0.124	0.183	0.166
BCK-09.20 to 09.47	Nitrate	12.4	11.3	4.8	2.7
(~2 miles downstream)	Uranium	0.096	0.115	0.061	0.052
BCK-04.55	Nitrate	3.8	2.5	0.96	2.56
(~5 miles downstream)	Uranium	0.033	0.028	0.018	0.016

[a] *Excludes results that do not meet data quality objectives.*

[b] *BCK = Bear Creek kilometer, measured upstream from the confluence with East Fork Poplar Creek.*

VOCs

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 groundwater and can occur in bedrock at depths up to 92 m (300 ft) below ground surface. VOCs that occur in groundwater of the fractured bedrock aquitard units are found within about 305 m (1,000 ft) laterally of source areas.

The highest concentration observed in 2023 occurred in the Nolichucky Shale aquitard at the Bear Creek Burial Ground waste management area, with a maximum summed VOC concentration of 6,520 µg/L in well GW-623; trichloroethene (4,300 µg/L), tetrachloroethene (1,700 µg/L), and cis 1,2-dichloroethene (320 µg/L) comprised most of the summed total. The summed VOC concentrations of GW-623 show wide temporal concentration fluctuations that do not display any consistently increasing or decreasing long-term trend.

As illustrated by respective time-series plots for wells GW-229, GW-289, and GW-706 (Figure 4.34), the summed VOC concentrations either show wide temporal concentration fluctuations that do not display any consistently increasing or decreasing long-term trend, or exhibit a generally stable trend that suggests little corresponding change in the overall flux of dissolved VOCs via the groundwater flow/transport pathways intercepted by the well. The indeterminate long-term trends probably reflect the combined influence of the large volume of VOCs in the subsurface at source areas, low permeability of the groundwater flow/transport pathways monitored by the wells, and/or minimal natural attenuation of the VOCs during residence/transport in the subsurface.

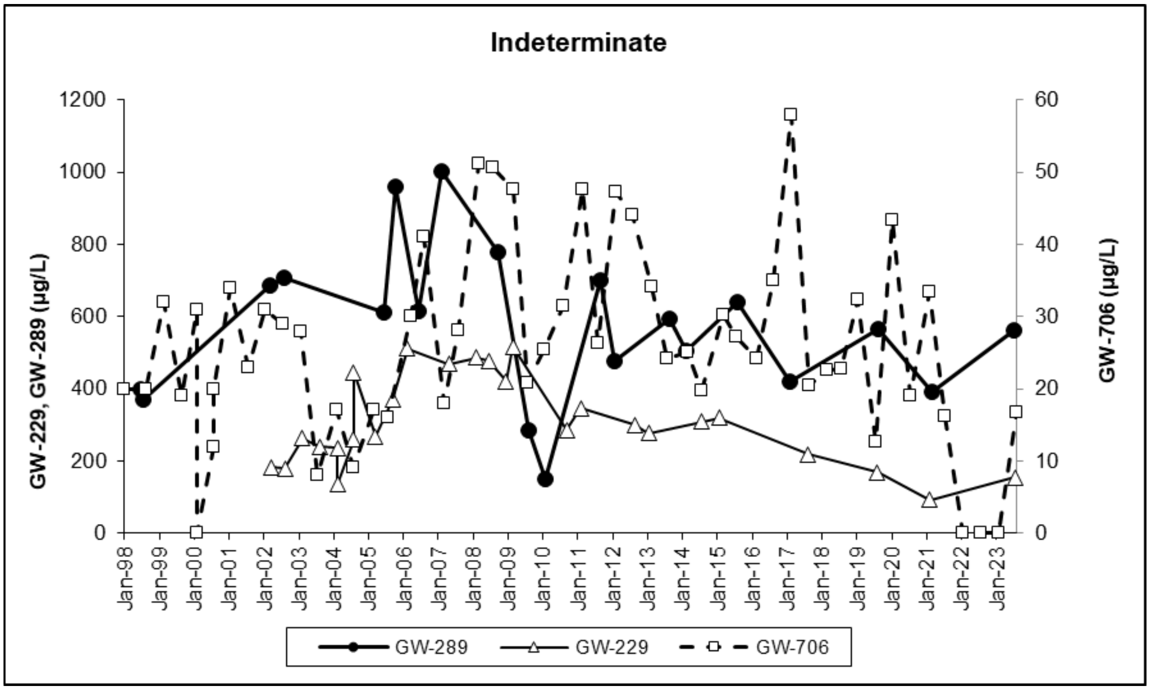


Figure 4.34. Indeterminate VOC trends in surveillance monitoring wells GW-229, GW-289, and GW-706

Radionuclides

As in the EFPC regime, the primary radionuclides identified in the Bear Creek regime are isotopes of uranium and ^{99}Tc. The extent of radionuclides in groundwater in the Bear Creek regime during 2023 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 areas. 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 4.32).

In 2023, the highest gross-alpha activity observed in a monitoring well in the Bear Creek regime (100 pCi/L) was in GW-276, which is adjacent to the S-3 site (Figure 4.31).

In 2023, the highest gross-beta activity in groundwater in the Bear Creek regime was also at GW-276 at 100 pCi/L (Figure 4.32)

Exit Pathway and Perimeter Monitoring

Bear Creek, which flows over 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 the surface water in Bear Creek, the springs along the valley floor, and the groundwater in the Maynardville Limestone are hydraulically connected. Surveys have identified gaining (groundwater discharging into surface waters) and losing (surface water discharging into a groundwater system) reaches of Bear Creek. The western exit pathway monitoring well transect (EXP-W) serves as the perimeter well location for the Bear Creek regime (Figure 4.25).

Exit pathway monitoring continues at four exit pathway transects (A, B, C, and W; Figure 4.25) also referred to as pickets, and selected springs and surface water stations. Data obtained during 2023 indicate groundwater is contaminated above drinking water standards in the Maynardville Limestone as far as Picket W. The drinking water standard for gross-alpha was exceeded (24 pCi/L) in deep well GW-710. Historically, this well has presented elevated levels of gross-alpha activity. At 164.6 m (540 ft) below ground surface, the well is affected by deep brine water that likely contains naturally occurring radium and radon, which could account for the elevated gross-alpha activity. Concentration trends throughout the exit pathway continue to be generally stable to decreasing, as shown in Figure. 4.35.

In 2023, GW-713 in exit pathway transect W showed a trace concentration (0.33 µg/L) of TCE (below drinking water standards), thus indicating migration of contaminants potentially thousands of feet from likely sources areas to the east (e.g., Boneyard/Burnyard, the S-3 site, or Spoil Area 1). TCE is sporadically detected in GW-713 but has never been detected above drinking water standards.

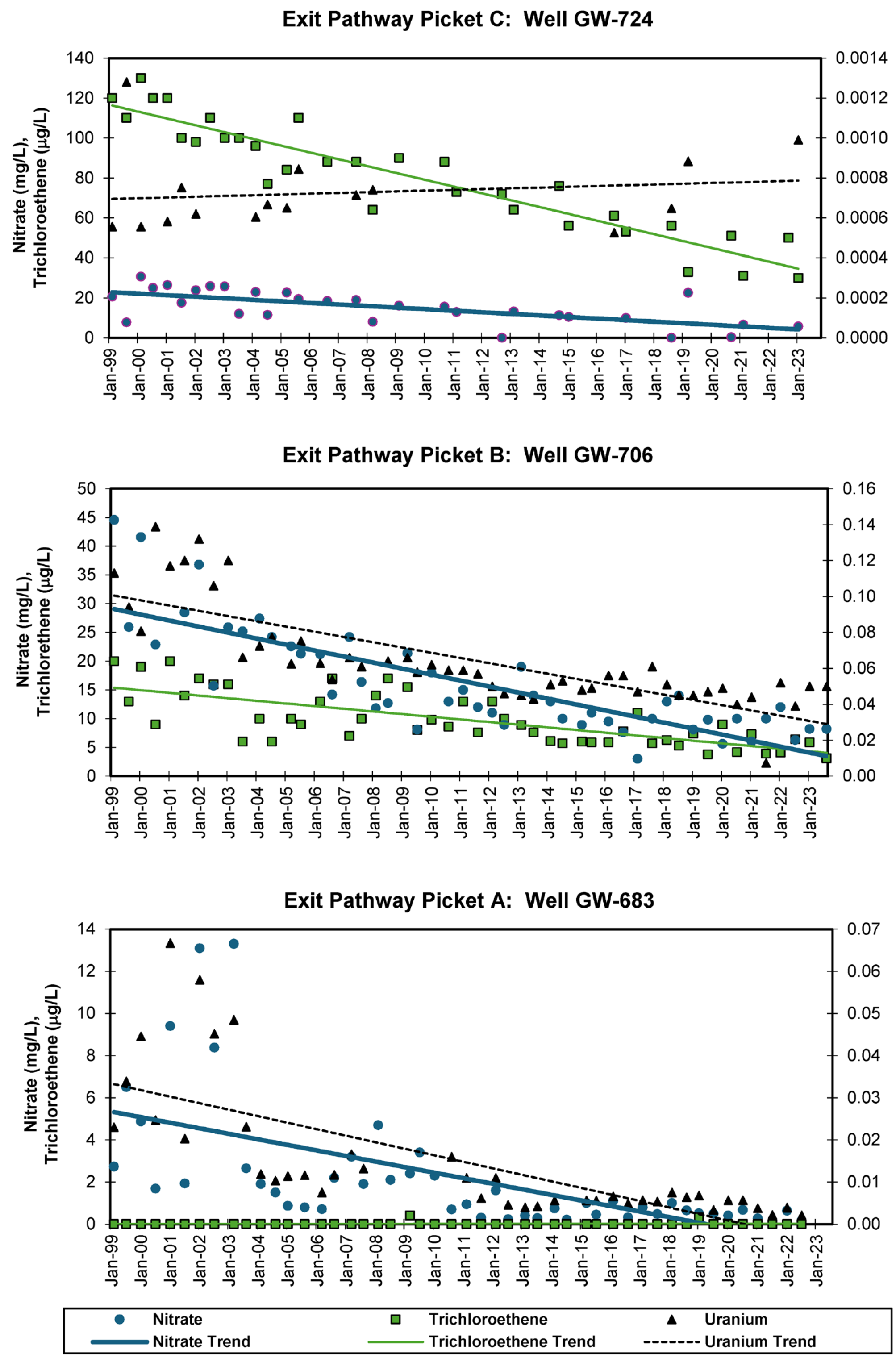
Surface water samples collected in 2023 indicate water in Bear Creek contains many of the same compounds found in the groundwater. Uranium concentrations exceeding the drinking water standard have been observed in surface water west of the Burial Grounds as far as Picket W. This location is 4,724 m (15,500 ft) west of the S-3 site. The concentrations in the creek generally decrease with distance downstream of the waste disposal sites (Table 4.20).

Exit pathway monitoring stations sampled in 2023 show that gross-alpha activity in the Maynardville Limestone exceeds the drinking water standard as far as 3,353 m (11,000 ft) west of the S-3 site at Spring SS-5 (19 pCi/L). The alpha activity at this spring recently shows a decreasing trend.

4.6.3.3. 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 4.24). 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.

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.



Note: *Only nitrate and uranium results above the detection limit are plotted; non-detected trichloroethene results are plotted at zero.*

Figure 4.35. Concentrations of selected contaminants in exit pathway monitoring wells in the Bear Creek hydrogeologic regime, 2023

Plume Delineation

The extent of the VOC plume at the Chestnut Ridge Security Pits is reasonably well defined in the water table and shallow bedrock zones. With two possible exceptions, historical monitoring indicates the VOC plume from the Chestnut Ridge Security Pits has shown minimal migration in any direction (<305 m [<1,000 ft]).

Data obtained during 2022 indicate the western lateral extent of the VOC plume at the site has not changed significantly. VOC contaminants at a well about 458 m (1,500 ft) southeast and downgradient of the Chestnut Ridge Security Pits continue to show 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 Chestnut Ridge Security Pits) at a natural spring about 2,745 m (9,000 ft) to the east and along geologic strike may suggest that Chestnut Ridge Security Pits contaminants have migrated further than the monitoring well network indicates. However, as in 2021 and 2022, no VOCs were detected at this spring in 2023.

The Chestnut Ridge Security Pits plume in the Chestnut Ridge regime (shown by orange shading on Figure 4.30) represents the average VOC concentrations between 2013 and 2017. The circular icons presented on the figure represent 2023 monitoring results.

Nitrate

Nitrate concentrations continue to be below the drinking water standard at all monitoring stations in the Chestnut Ridge regime in 2023.

Trace Metals

Concentrations of arsenic above drinking water standards have been observed in two surface water monitoring locations downstream from the Filled Coal Ash Pond, which is monitored under a CERCLA Record of Decision (DOE 1996b). Under the decision, migration of contaminated effluent from the Filled Coal Ash Pond is reduced by a constructed wetland area. In recent years, it became apparent the wetland efficiency was decreasing because, in part, of erosion channels forming around the wetland. During 2019, a maintenance activity was conducted at the site to improve the aquatic habitat for plant growth and to increase retention time for water within the wetland. The elevated arsenic levels were detected both upgradient (McCoy Branch kilometer [MCK] 2.05) and downgradient (MCK 2.0) of this wetland area. In 2023, the passive wetland treatment area continued to be effective in reducing arsenic.

VOCs

Overall, concentrations of VOCs in groundwater at the Chestnut Ridge Security Pits have decreased since 1988. Summed VOC concentrations were observed at monitoring well GW-322 (78 µg/L) during 2023.

At Industrial Landfill IV, VOCs have been observed in the groundwater since 1992. Well GW-305, located immediately to the southeast of the facility (Figure 4.30), exhibited increasing trends of summed VOCs from 1992 to 2014 but have stabilized, with the 2023 concentration at 71.45 µg/L. GW-305 was sampled in January and July 2023 with results for 1,1 DCE of 5.25 µg/L and 4.86 µg/L, respectively. (The drinking water standard for this compound is 5 ug/L.)

Radionuclides

In 2023, no gross-alpha (15 pCi/L) or gross-beta (50 pCi/L) above the drinking water standards were observed in the Chestnut Ridge hydrogeologic regime.

Exit Pathway and Perimeter Monitoring

Contaminant and groundwater flowpaths 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 (approximately 9,000 ft from the Chestnut Ridge Security Pits) 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. Springs along Scarboro Creek are monitored for water quality, and trace concentrations of VOCs are intermittently detected. The detected VOCs are suspected to originate from the Chestnut Ridge Security Pits; however, this has not been confirmed. In 2023, two springs along Scarboro Creek 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 three surface water monitoring locations were sampled during 2023. No contaminants at any of these monitoring stations were detected at levels above primary drinking water standards.

4.6.4. Emerging Contaminants

Per- and polyfluoroalkyl substances (PFAS) are emerging contaminants that constitute a large family of fluorinated chemicals. The persistence and mobility of some PFAS, combined with decades of widespread use in industrial processes, certain types of firefighting foams, and consumer products, have resulted in their being present in environmental media at trace levels across the globe. It was not until the early 2010s that analytical methods to detect a limited number of PFAS became widely available and had detection limits in water low enough to be commensurate with levels of potential human health effects. Toxicological studies have raised concerns regarding the bioaccumulative nature and potential health concerns of some PFAS.

The following actions and activities were conducted at Y-12 during 2023 to address these emerging contaminants of concern:

- Y-12 continues to maintain compliance with the DOE requirements pertaining to PFAS storage, use, and disposal (DOE 2021a, DOE 2021b). No PFAS-containing aqueous film-forming foam (AFFF) was used for training purposes, and no new AFFF systems were installed in 2023. One waste storage building (Building 9720-09) has an active AFFF fire suppression system that is only approved for fire emergencies. This system undergoes periodic maintenance and post-maintenance testing, which generates AFFF wastes that contain PFAS. No new releases or spills of PFAS-containing AFFF occurred in 2023.
- Y-12 has a fire department and fire training facility. The Y-12 Fire Department has one firetruck with a foam induction system that uses a fluorine-free foam.
- Current and historic uses of 196 PFAS or PFAS-related substances are being tracked using the Y-12 Hazardous Material Information System. No PFAS substances were used in excess of the Emergency Planning and Community Right-to-Know Act Toxics Release Inventory reporting threshold during 2023.
- No production-related activities, equipment, or processes are known to have generated or released PFAS to the environment; however, several products and/or chemicals containing PFAS have been used in small quantities, primarily in the Analytical Chemistry laboratories and in the Development facilities.
- Y-12 personnel began to coordinate with the EPA and prepare for the Unregulated Contaminant Monitoring Rule 5 (EPA 2024) sampling efforts to begin in 2024. The Safe Drinking Water Act requires that, once every 5 years, the EPA issue a list of unregulated contaminants to be monitored by public water systems. The new rule requires that samples be collected for 30 chemical contaminants between 2023 and 2025 using standard analytical methods. Twenty-nine of these contaminants are PFAS. This action provides scientifically valid data on the national occurrence of these contaminants in drinking water to improve the agency's understanding of the frequency of detection and concentrations of PFAS in the nation's drinking water systems. The monitoring data on PFAS will help determine future regulations and other actions to protect public health.

- In accordance with the DOE *PFAS Strategic Roadmap: DOE's Commitments to Action 2022-2025* (DOE 2022), Y-12 participated in the 2023 site-specific status update survey. The results will be published in 2024.

4.7. Quality Assurance Program

Y-12's QA Program establishes a quality policy and requirements for the Y-12 site. Internal procedures detail the methods used to carry out work processes safely and securely and in accordance with established procedures. They also describe mechanisms in place to identify and correct findings and prevent 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 recordkeeping. QA programs are designed to minimize these sources of variability and control all phases of the monitoring process.

Field sampling QA encompasses many practices that minimize error and evaluate sampling performance. The following are some key quality practices:

- Using work control processes and standard operating procedures for sample collection and analysis
- Using chain-of-custody and sample identification procedures
- Standardizing, calibrating, and verifying instruments
- Training sample technicians and laboratory analysts
- Preserving, handling, and decontaminating samples
- Using QC samples, such as field and trip blanks, duplicates, and equipment rinses

The Y-12 Environmental Sampling Services organization is responsible for field sampling activities, sample preservation and handling, chain-of-custody, and field QC sample transport in accordance with Y-12 Environmental Compliance procedures. Environmental Sampling Services developed a standards and calibration program that conforms to ISO/IEC 17025, *General Requirements for the Competence of Testing and Calibration Laboratories* (ISO 2017), and provides a process for uniform standardization, calibration, and verification of measurement and test equipment. The 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 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; frequent use of check sources and background counts, replicate and spiked sample analyses, and matrix and reagent blanks; and maintenance of control charts to indicate analytical deficiencies. These activities are supported by using standard materials or reference materials (e.g., materials of known composition that are used to calibrate instruments, methods standardization, spike additions for recovery tests, and other practices). Certified standards traceable to the National Institute of Standards and Technology, DOE sources, or EPA are used, when available.

Y-12's Analytical Chemistry organization has an internal manual that describes program elements; customer-specific requirements; certification program requirements; federal, state, and local regulations; and waste acceptance criteria. As a government-owned, contractor-operated laboratory that performs work for DOE, the Analytical Chemistry laboratory operates in accordance with DOE Order 414.1D, *Quality Assurance* (DOE 2011c).

Other internal practices used to ensure laboratory results represent of actual conditions and include training and managing staff; maintaining adequacy of the laboratory environment; ensuring safety; controlling the storage, integrity, and identity of samples; maintaining recordkeeping; maintaining and calibrating instruments; and using technically validated and properly documented methods.

Y-12's Analytical Chemistry organization participated in Mixed Analyte Performance Evaluation Program studies conducted in 2023 for water and soil matrices for metals, organics, and radionuclides. The overall acceptability rating from both studies was 96.23 percent.

Verification and validation of environmental data are performed as components of the data collection process, which includes planning, sampling, analyzing, and performing 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 to check whether data have been accurately transcribed and recorded, appropriate procedures have been followed, electronic and hard copy data show one-to-one correspondence, and 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 a remedial investigation 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 identifying 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.

A due diligence analysis is performed for facilities used for the treatment, storage, or disposal of radiological and hazardous waste to ensure that each facility is well operated and maintained; has minimal environmental issues and impacts; employs personnel who are properly trained, competent, and work safely; is in compliance with regulatory requirements; and is adequately insured against personal and environmental liabilities.

This evaluation includes a review of information on the facility's compliance history, design, operations, recordkeeping and reporting requirements, emergency response procedures, closure/post-closure plans, and insurance coverage, as well as any environmental issues, remediation, litigation or regulatory agency concerns related to the facility. Y-12 limits the number of facilities used and avoids or discontinues using facilities that present significant environmental and/or safety liability. This evaluation may rely on results of third-party accreditation assessments reported under the DOE Consolidated Audit Program.

Table 4.21 lists treatment, storage, and disposal facilities used in 2023 for the disposition of radiological and hazardous waste.

Table 4.21. Treatment, storage, and disposal facilities used to disposition radiological and hazardous waste, 2023

Facility Name	Location	Identification Number
Clean Harbors Cincinnati (Spring Grove) Facility	Cincinnati, Ohio	OHD000816629
Clean Harbors of Baltimore	Baltimore, Maryland	MDD980555189
Clean Harbors Baton Rouge	Baton Rouge	LAD010395127
Clean Harbors Cleveland Technical Services	Cleveland, Ohio	OHD000724153
Clean Harbors Deer Park Incineration Facility	La Porte, Texas	TXD055141378
Clean Harbors El Dorado Incineration Facility	Ed Dorado, Arkansas	ARD069748192
Clean Harbors Environmental Services	Kimball, Nebraska	NED981723513
Clean Harbors Grassy Mountain Landfill Facility	Clive, Utah	UTD991301748
Clean Harbors La Porte Technical Services	La Porte, Texas	TXD982290140
Clean Harbors Lone Mountain Facility	Waynoka, Oklahoma	OKD065438376
Clean Harbors Reidsville	Reidsville, North Carolina	NCD000648451
Diversified Scientific Services, Inc.	Kingston, Tennessee	TND982109142
Energy Solutions Bear Creek Processing Facility	Kingston, Tennessee	TND982157570
EnergySolutions Clive Disposal Facility	Grantsville, Utah	UTD982598898
Nevada National Security Site	Mercury, Nevada	NV3890090001
Perma-Fix of Florida, Inc.	Gainesville, Florida	FLD980711071
Safety-Kleen Systems	Smithfield, Kentucky	KYD053348108
Veolia ES Technical Solutions	Port Washington, Wisc.	WID988566543
Veolia ES Technical Solutions	Tallahassee, Florida	FL0000207449
Waste Control Specialists	Andrews, Texas	TXD988088464

4.8. Environmental Management and Waste Management Activities

The three sites on ORR have a rich history of research, innovation, and scientific discovery. Unfortunately, despite their vitally important missions, they are hindered by environmental legacies remaining from past operations. The contaminated portions of ORR are on the EPA National Priorities List, 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 DOE EM is working to clean those areas under the Federal Facility Agreement with the EPA and TDEC. The *2023 Cleanup Progress: Annual Report on Oak Ridge Reservation Cleanup* (UCOR 2023a) provides detailed information on DOE EM cleanup activities.

4.8.1. Environmental Management Activities

At Y-12, DOE EM is working to address excess and contaminated facilities, remove mercury soil and groundwater contamination, and enable modernization that allows NNSA to continue its crucial national security and nuclear nonproliferation responsibilities.

Biology Complex Site Transferred

EM's steady work removing old, contaminated structures is paving the way for new uses of land, including a site where NNSA recently hosted a groundbreaking ceremony for the new LPF.

The new 245,000-ft^2 facility will feature updated technology, increase processing capacity, and make the work environment safer for employees. Construction is forecasted to begin in mid-2025, with completion projected in the early 2030s.

Work Continues on the Mercury Treatment Facility

In 2023, progress continued on construction of the Outfall 200 Mercury Treatment Facility. The facility is the linchpin for DOE EM's cleanup strategy at Y-12. This vital piece of infrastructure will open the door for demolition of Y-12's large, deteriorated, mercury-contaminated facilities and subsequent soil remediation by providing a mechanism to limit potential mercury releases into the Upper EFPC.

At the headworks site, the first lift concrete walls are complete on both major structures—the storm flow pump station and the grit flow chamber. The second lift walls are being installed with rebar and formwork.

Backfill of the excavation is also in process. A total of 1,800 yards of concrete have been placed, with 200 tons of rebar installed. At the treatment site, work continues with construction of a 500,000-gal equalization tank. All underground piping has been installed and tested. Chemical storage tanks are stored on location, and the clarifier plates are installed. Painting of concrete surfaces and structural steel is progressing.

When operational, the facility will be able to treat 3,000 gal of water per minute and help DOE meet regulatory limits in compliance with EPA and state of Tennessee requirements.

Deactivation Continued on Processing Facilities

Deactivation activities continued at three large former uranium processing facilities throughout FY 2023. Those facilities—Building 9201-02, Building 9201-04, and Building 9204-01—were home to the historic calutron (mass spectrometer) racetracks used for separating isotopes of uranium.

- **Building 9201-02.** The three-story facility is approximately 320,000 gsf. In FY 2023, crews removed a variety of contaminants. Approximately 4,500 gal of water were drained from the facility's demineralized water system, and 280,000 lb of lead-shielding blocks were removed from the second floor of the facility. All deactivation activities were completed in the aboveground floors in 2023. In the basement, workers recovered 113 lb of elemental mercury. The building is set for demolition starting in 2024.
- **Building 9201-04.** During 2023, workers began preparing the four-story facility for deactivation. With 600,000 ft^2, the building one of Y-12's larger high-risk facilities, with elemental mercury contaminating much of the structure. After the electromagnetic separation process was abandoned, column exchange processing structures were added to the outside of the facility to perform a new method of processing, which required substantial quantities of mercury.
- As part of preparing for building deactivation, workers have been sampling asbestos-containing material, performing utility isolations to bring the building to cold and dark status, and characterizing more than 400 legacy drums.
- **Building 9204-01.** Next to Building 9201-02 is a two-story building with approximately 210,500 gsf. Most of the deactivation in the upper floors was completed in 2023, and the small amount remaining will be completed early in FY 2024. In the basement, crews worked to remove, treat, and discharge more than 1 million gal of water using a special water treatment skid system, which filters water through micron bag filters and carbon

vessels inside the unit to achieve the water quality standards needed for discharge. Once the water is removed, the basement can be accessed for deactivation in 2024.

Slab Removal at Demolished Lab Site

Workers have finished removing the slab at the former Criticality Experiment Laboratory at Y-12. DOE EM and UCOR demolished the structure in 2022. The Criticality Experiment Laboratory was constructed in 1949 and was used to conduct experiments and collect reactor physics data from 1950 to 1987. The facility was permanently shut down in 1992, with the exception of limited use for training exercises. The area is planned to be used as a storage/laydown area to support other Y-12 projects.

4.8.2. Waste Management Activities

Waste management is performed at multiple locations on the ORR for both solid and liquid wastes, including landfills and water treatment facilities.

4.8.2.1. CERCLA Waste Disposal

Most of the waste generated during FY 2023 cleanup activities in Oak Ridge went to disposal facilities on the ORR. The Environmental Management Waste Management Facility received 5,221 waste shipments, totaling 41,410 yd^3, from cleanup projects at ETTP, ORNL, and Y-12. This engineered landfill consists of six disposal cells that only accept low-level radioactive and hazardous waste meeting specific criteria. These wastes include soil, dried sludge and sediment, building debris, and personal protective equipment.

4.8.2.2. Solid Waste Disposal

DOE operates and maintains solid waste disposal facilities known as the ORR Landfills. In FY 2023, these three active landfills received 5,767 waste shipments, totaling 79,977 yd^3 of waste.

4.8.2.3. Wastewater Treatment

Safe and compliant treatment of more than 48.5 million gallons of wastewater and groundwater generated from both production and environmental cleanup activities was provided at various facilities during 2023:

- The West End Treatment Facility and the Central Pollution Control Facility processed approximately 267,715 gallons of wastewater, primarily in support of NNSA operational activities.
- The Big Springs Water Treatment System treated more than 31 million gallons of mercury-contaminated groundwater.
- The East End VOC Treatment System treated 12.9 million gallons of VOC-contaminated groundwater.
- The Liquid Storage Facility and Groundwater Treatment Facility treated more than 2.5 million gallons of leachate from burial grounds and well purge waters from remediation areas.
- The Central Mercury Treatment System treated approximately 1.4 million gallons of mercury-contaminated sump waters from Building 9201-04.

4.9. References

10 CFR 1021. *National Environmental Policy Act Implementing Procedures. US Code of Federal Regulations.* US Department of Energy. Washington, DC.

40 CFR 60, *Standards of Performance for New Stationary Sources. US Code of Federal Regulations.* US Environmental Protection Agency, Washington, DC.

40 CFR 61. *National Emission Standards for Hazard Air Pollutants. US Code of Federal Regulations.* US Environmental Protection Agency, Washington, DC.

40 CFR 63. *National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters. US Code of Federal Regulations.* US Environmental Protection Agency, Washington DC.

40 CFR 82, *Protection of Stratospheric Ozone. US Code of Federal Regulations*. Environmental Protection Agency, Washington, DC.

40 CFR 98. *Mandatory Reporting of Greenhouse Gases. US Code of Federal Regulations*. Environmental Protection Agency, Washington, DC.

49 CFR 173. *Shippers—General Requirements for Shipments and Packaging. US Code of Federal Regulations.* US Department of Transportation, Washington, DC.

AIM 2020. *American Innovation and Manufacturing Act of 2020.* 42 U.S.C. 7675. US Government.

ATSDR 2006. *Public Health Assessment: Evaluation of Potential Exposures to Contaminated Off-Site Groundwater from the Oak Ridge Reservation*. Agency for Toxic Substances and Diseases Registry, Atlanta, Georgia.

BWXT 2003. *Y-12 National Security Complex National Historic Preservation Act Historic Preservation Plan.* Y/TS-1983, BWXT Y-12, L.L.C., Y-12 National Security Complex, Oak Ridge, Tennessee.

CAA 1970. *Clean Air Act.* 42 U.S.C. §7401 et seq. US Government.

CERCLA 1980. *Comprehensive Environmental Response, Compensation, and Liability*. 42 US Code 103. US Government.

CNS 2020a. *Y-12 Plant Quality Assurance Project Plan for National Emission Standards for Hazardous Air Pollutants (NESHAP) Radionuclide Emission Measurements*. Y/TS-874, Revision 5. Consolidated Nuclear Security, LLC, Y-12 National Security Complex, Oak Ridge, Tennessee. October.

CNS 2020b. *Radiological Monitoring Plan for the Oak Ridge Y-12 National Security Complex: Surface Water*. Y/TS-1704/R4, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, Oak Ridge, Tennessee. October.

CNS 2022. *Spill Prevention, Control, and Countermeasure Plan for the U.S. Department of Energy Y-12 National Security Complex, Oak Ridge, Tennessee*. Y/SUB/02-001091/8, Consolidated Nuclear Security, LLC, Y-12 National Security Complex, Oak Ridge, Tennessee, October.

CNS 2024. *Calendar Year 2023 Groundwater Monitoring Report*, Y/SUB/24-173959/1. US Department of Energy Y 12 National Security Complex, Oak Ridge, Tennessee.

CWA 1972. *Clean Water Act*. 33 US Code §1251 et seq. US Government.

DOE 1996b. *Record of Decision for Chestnut Ridge Operable Unit 2 (Filled Coal Ash Pond and Vicinity), Oak Ridge, Tennessee*. DOE/OR/02-1410&D3, US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee.

DOE 1997a. *Report on the Remedial Investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.* DOE/ORR/01-1455/V1/V6&D2, US Department of Energy, Washington, DC.

DOE 1997b. *Record of Decision for an Interim Action for Union Valley, Upper East Fork Poplar Creek Characterization Area, Oak Ridge, Tennessee*. DOE/OR/02-1545&D2. US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee.

DOE 1998. *Report on the Remedial Investigation of the Upper East Fork Poplar Creek Characterization Area at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee*. DOE/OR/01-1641/V1-V4&D2, US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2011a. *Final Site-Wide Environmental Impact Statement for the Y-12 National Security Complex.* DOE/EIS-0387, US Department of Energy, National Nuclear Security Administration, Y-12 Site Office, Oak Ridge, Tennessee, February.

DOE 2011b. *Radiation Protection of the Public and the Environment.* DOE Order 458.1. Approved February 11, 2011, Chg. 4 approved September 15, 2020. US Department of Energy, Washington, DC.

DOE 2011c. *Quality Assurance.* DOE Order 414.1D, approved April 25, 2011, Chg. 2 approved September 15, 2020, US Department of Energy, Washington, DC.

DOE 2012. *Compliance Agreement Between the United States Department of Energy and the United States Environmental Protection Agency Region 4.* ORR-PCB-FFCA, Revision 5. US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee. May. https://ucor.com/regulatory-agreements-for-the-oak-ridge-reservation/

DOE 2020a. *Compliance Plan, National Emission Standards for Hazardous Air Pollutants for Airborne Radionuclides on the Oak Ridge Reservation, Oak Ridge, Tennessee.* DOE/ORO/2196, Revision 2, US Department of Energy, Washington, DC.

DOE 2021a. *Memorandum for Heads of Departmental Elements: Addressing Per- and Polyfluoroalkyl Substances at the Department of Energy.* NNSA-2021-004992, US Department of Energy, Washington, DC, David M. Turk, Deputy Secretary of Energy, September 16, 2021.

DOE 2021b. *Memorandum for Distribution: Direction to Implement Department of Energy Policy on Per- and Polyfluoroalkyl Substances*. US Department of Energy, Washington, DC, James J. McConnell, Associate Administrator for Safety, Infrastructure, and Operations, October 26, 2021.

DOE 2022. *DOE PFAS Strategic Roadmap: DOE's Commitments to Action 2022-2025*. US Department of Energy, Washington, DC, August. https://www.energy.gov/pfas/articles/pfas-strategic-roadmap-doe-commitments-action-2022-2025

DOE 2023a. *Departmental Sustainability*. DOE Order 436.1a. Approved 04-25-23. US Department of Energy, Washington, DC.

DOE 2023b. *2023 Remediation Effectiveness Report for the US Department of Energy, Oak Ridge Reservation, Oak Ridge, Tennessee*, DOE/OE/01-2916&D1. US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2023c. *Federal Facility Agreement for the Oak Ridge Reservation.* FFA-PM/23-001, DOE/OR-1014. US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee. https://ucor.com/wp-content/uploads/2021/07/ffa.pdf.

DOE 2024. *2024 Remediation Effectiveness Report for the US Department of Energy, Oak Ridge Reservation, Oak Ridge, Tennessee*, DOE/OE/01-2960&D1. US Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee.

EA 2020. *The Energy Act of 2020.* US Government.

EISA 2007. *Energy Independence and Security Act of 2007*. Public Law 110-140. US Government.

EPA 1995, 1998. *Compilation of Air Pollutant Emission Factors from Stationary Sources.* AP-42, Fifth Edition. *Volume 1: Stationary Point and Area Sources*. US Environmental Protection Agency, Research Triangle Park, North Carolina, January 1995, September 1998.

EPA 2024. *Fifth Unregulated Monitoring Rule*. US Environmental Protection Agency, Washington, DC. https://www.epa.gov/dwucmr/fifth-unregulated-contaminant-monitoring-rule.

EPCRA 1986. *Emergency Planning and Community Right-to-Know*. 42 US Code Chapter 116. US Government.

FFCA 1992. *Federal Facility Compliance Act.* 42 US Code 6961(a). US Government. https://ucor.com/wp-content/uploads/2021/07/ffa.pdf

ISO 2015. E*nvironmental management systems—Requirements with guidance for use*. ISO 14001:2015, International Organization for Standardization, Geneva, Switzerland, September.

ISO 2017. *General Requirements for the Competence of Testing and Calibration Laboratories.* ISO/IEC 17025:2017, International Organization for Standardization, Geneva, Switzerland.

MMES 1990. *Report and Preliminary Assessment of the Occurrence of Dense, Nonaqueous Phase Liquids in the Bear Creek Burial Grounds Hazardous Waste Disposal Unit at the Oak Ridge Y-12 Plant.* Y/TS-960. Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

MMES 1995. *Calendar Year 1994 Groundwater Quality Report for the Upper East Fork Poplar Creek Hydrogeologic Regime, Y-12 Plant, Oak Ridge, Tennessee.* Y/SUB/95-EAQ10C/2/P2, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

NCRP 1996. *Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground – Vol. I and Vol II*. NCRP Report No. 123. National Council on Radiation Protection and Measurements, Bethesda, MD, 1996.

NEPA 1969. *National Environmental Policy*. Title 42, US Code Chapter 55. US Government.

NHPA 1966. *National Historic Preservation Act.* Public Law 89-665; Title 54 US Code §300101 et seq. US Government.

NNSA 2016. *Supplement Analysis for the Site-Wide Environmental Impact Statement for the Y-12 National Security Complex*. DOE/EIS-0387-SA-01, National Nuclear Security Administration, NNSA Production Office, Oak Ridge, Tennessee, April.

NNSA 2018. *Supplement Analysis for the Site-Wide Environmental Impact Statement for the Y-12 National Security Complex*. DOE/EIS-0387-SA-03, National Nuclear Security Administration, NNSA Production Office, Oak Ridge, Tennessee, August.

NNSA 2020. *Final Supplement Analysis for the Final Site-Wide Environmental Impact Statement for the Y-12 National Security Complex, Earthquake Accident Analysis.* DOE/EIS-0387-SA-04, National Nuclear Security Administration, NNSA Production Office, Oak Ridge, Tennessee, June.

NNSA 2021. "NNSA Production Office Approval to Use Pre-Approved Authorized Limits for the Release and Clearance of Volumetric Radioactivity of Personal Property." COR-NP0-60 ESH-7.20.2021-919599, National Nuclear Security Administration, NNSA Production Office, Oak Ridge, Tennessee, July 20, 2021.

NRC 2000. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*. NUREG-1575, Revision 1/EPA 402-R-97-016, Revision 1/DOE/EH-0624, Revision 1. US Nuclear Regulatory Commission, Washington, DC. August.

NRC 2009. *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual (MARSAME)*. NUREG-1575, Supplement 1/EPA 402-R-09-001/DOE/HS-0004. US Nuclear Regulatory Commission, Washington, DC. January.

ORNL 2013. *Y-12 National Security Complex Biological Monitoring and Abatement Program Plan*. ORNL/TM-2013/171, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

ORNL 2019. *Oak Ridge National Laboratory Toxicity Identification/Reduction Evaluation for the Y-12 National Security Complex Outfall 200*. ORNL/TM-2019/1268, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September.

ORNL 2022. *Mercury Remediation Technology Development for Lower East Fork Poplar Creek—FY 2022 Update*. ORNL/SPR-2020/1577, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

RCRA 1976. *Resource Conservation and Recovery Act.* 40 CFR 239–282. US Government.

TDEC 2018. "Underground Storage Tank Program." Chapter 0400-18-01. Tennessee Department of Environment and Conservation, Nashville, TN. 2018.

TDEC 2010a. *Proposed Total Maximum Daily Loads (TMDLs) for Polychlorinated Biphenyls (PCBs) and Chlordane in Melton Hill Reservoir: Lower Clinch River Watershed (HUC 06010207), Anderson, Knox, Loudon, and Roane Counties, Tennessee*. Tennessee Department of Environment and Conservation, Nashville, TN. 2010.

TDEC 2010b. *Proposed Total Maximum Daily Loads (TMDLs) for Polychlorinated Biphenyls (PCBs) and Chlordane in Watts Bar Reservoir: Watts Bar Lake Watershed (HUC 06010201), Lower Clinch River Watershed (HUC 06010207), and Emory River Watershed (HUC 06010208), Loudon, Meigs, Morgan, Rhea, and Roane Counties, Tennessee*. Tennessee Department of Environment and Conservation, Nashville, TN. 2010.

TDEC 2010c. *Proposed Total Maximum Daily Loads (TMDLs) for Polychlorinated Biphenyls (PCBs) and Chlordane in Fort Loudon Reservoir: Fort Loudon Lake Watershed (HUC 06010201), Blount, Knox, and Loudon Counties, Tennessee.* Tennessee Department of Environment and Conservation, Nashville, TN. 2010.

TDEC 2019. "Public Water Systems." Chapter 0400-45-01. Tennessee Department of Environment and Conservation, Division of Water Pollution Control, Nashville, TN. Approved February 2019.

TDEC 2022a. "Emission Standards for Hazardous Air Pollutants." TDEC Regulation 0400-30-38, Tennessee Department of Environment and Conservation, Division of Air Pollution Control, Nashville, TN, Approved December 2022.

TDEC 2022b. "Construction and Operating Permits." TDEC Regulation 1200-03-09, Tennessee Department of Environment and Conservation, Division of Air Pollution Control, Nashville, TN, Approved December 2022.

TDEC 2023. *Site Treatment Plan for Mixed Wastes on the U.S. Department of Energy Oak Ridge Reservation*. TDEC-VER. 28.0, US Department of Energy, Oak Ridge Reservation, Oak Ridge, Tennessee. October. https://ucor.com/regulatory-agreements-for-the-oak-ridge-reservation/

TDEC 2024a. "Administrative Fees Schedule." TDEC Regulation 1200-03-26. Tennessee Department of Environment and Conservation, Division of Air Pollution Control, Nashville, TN. Revised March 2024.

TDEC 2024b. "General Water Quality Criteria." Chapter 0400-40-03. Tennessee Department of Environment and Conservation, Division of Water Pollution Control, Nashville, TN. Revised March 2024.

TSCA 1976. *Toxic Substances Control Act*. Title 15 US Code §2601 et seq. US Government.

UCOR 2022. *Sampling and Analysis Plan for the Water Resources Restoration Program for Fiscal Year 2023 Oak Ridge Reservation, Oak Ridge, Tennessee*, UCOR-4587-R8. United Cleanup Oak Ridge, LLC, Oak Ridge, Tennessee.

UCOR 2023a. *2023 Cleanup Progress: Annual Report on Oak Ridge Reservation Cleanup.* OREM-23-7632, United Cleanup Oak Ridge, Oak Ridge, Tennessee.

UCOR 2023b. *Sampling and Analysis Plan for the Water Resources Restoration Program for Fiscal Year 2024 Oak Ridge Reservation, Oak Ridge, Tennessee*, UCOR-4587-R9. United Cleanup Oak Ridge, LLC, Oak Ridge, Tennessee.

DOE's Oak Ridge National Laboratory is the nation's largest multiprogram science and technology laboratory. ORNL's mission has grown and expanded through the years, and now it is at the forefront of supercomputing, advanced manufacturing, materials research, neutron science, clean energy, and national security.

Photo by Carlos Jones

5

Oak Ridge National Laboratory

As DOE's largest multidisciplinary laboratory, ORNL delivers scientific discoveries and technical breakthroughs to realize solutions for complex challenges, including the transition to clean energy, mitigation of climate change, improvements to human health, and innovation that strengthens economic competitiveness.

ORNL plays a pivotal role in building a clean, efficient, flexible, and secure energy future. Scientists work with many of America's best innovators and businesses to research, develop, and deploy cutting-edge technologies and to break down market barriers in sustainable transportation, smart power systems, and energy efficiency for homes, buildings, and manufacturing.

ORNL advances the science behind national security by securing critical assets to keep national infrastructure running and people safe. ORNL's work protects nuclear materials to enable their secure, peaceful use for energy production, medical applications, and scientific discovery around the world.

More than 6,000 scientists, engineers, technicians, and support staff representing more than 60 nations form a dynamic culture of innovation at ORNL. ORNL's focus on community, collaboration, and the environment shapes its culture and is integral to its success.

ORNL is managed by UT-Battelle LLC, a partnership between the University of Tennessee and Battelle Memorial Institute. Other DOE contractors that conducted activities at ORNL in 2023 included UCOR and Isotek Systems LLC (Isotek).

5.1. Description of Site, Missions, and Operations

ORNL 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 was supporting 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.

Leveraging the talents of its world-class researchers and exceptional support staff, ORNL is helping solve critical scientific and technical challenges and in so doing is creating economic opportunity for the nation. ORNL's unique facilities, laboratories, and equipment draw thousands of visiting researchers each year and enable the development of scientific and technological solutions in these areas:

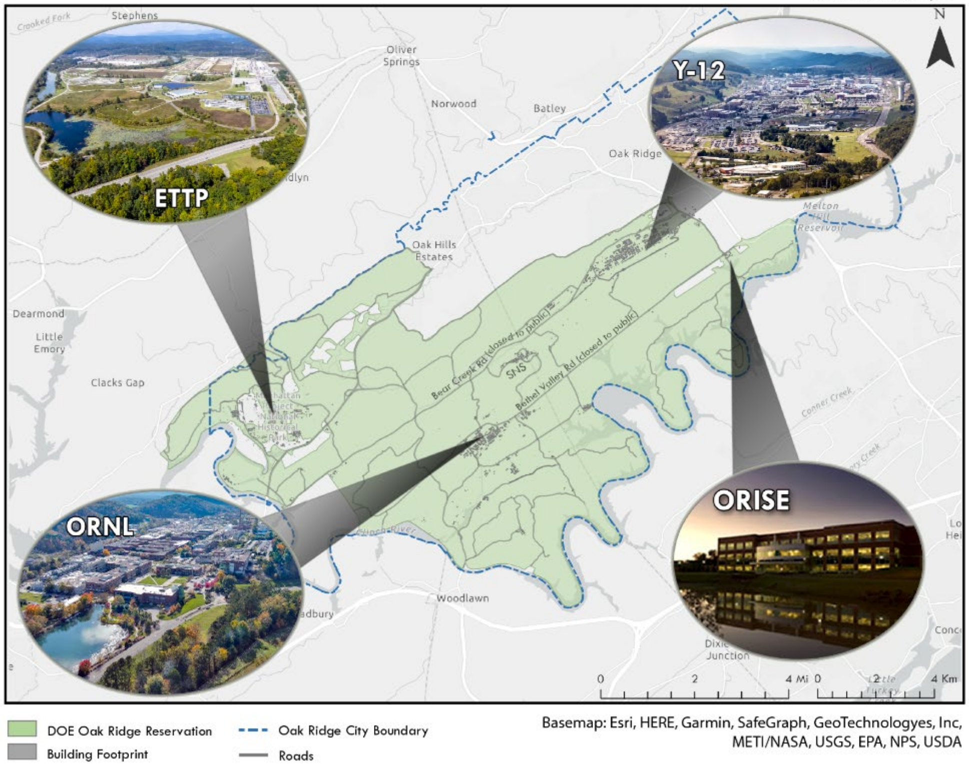
- Biology and environment
- Materials
- Clean energy
- National security
- Fusion and fission
- Neutron science
- Isotopes
- Supercomputing

World-class facilities that support ORNL's research and development (R&D) activities are available to users from universities, industry, and other institutions:

- Building Technologies Research and Integration Center
- Carbon Fiber Technology Facility
- Center for Nanophase Materials Sciences
- High Flux Isotope Reactor
- Manufacturing Demonstration Facility
- National Transportation Research Center
- Oak Ridge Leadership Computing Facility
- Spallation Neutron Source

In March 2007, 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 analysis of alternatives 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 2011a) were endorsed. The Phase I recommendations included (1) transfer of Zero-Power Reactor plate canisters to the National Nuclear Security Administration and disposal of Consolidated Edison Uranium Solidification Project material canisters and (2) completion of a Phase II alternatives analysis for processing the remaining 50 percent of the inventory. The transfer of the reactor plate canisters was completed in 2012. Disposal of the Consolidated Edison Uranium Solidification Project material canisters began in 2015 and was completed in 2017.

ORNL 2022-G00265/mhr
2022-ASER-M030/tf9



Acronyms:

ETTP = East Tennessee Technology Park
ORISE = Oak Ridge Institute for Science and Education
ORNL = Oak Ridge National Laboratory
Y-12 = Y-12 National Security Complex

Figure 5.1. Location of ORNL within ORR and its relationship to other local DOE facilities

Responsibility for Building 2026 was transferred from UT-Battelle to Isotek in May 2017. Isotek began processing ^{233}U material inside glove boxes in Building 2026 in the fall of 2019. This campaign was completed in August 2021. The remaining inventory requires processing in shielded hot cells because of the high radiation levels of the material. Isotek began processing ^{233}U material in Building 2026 hot cells in October 2022. Hot cell processing is expected to continue for the next few years. The processing of the ^{233}U material produces a solidified, low-level radioactive waste (LLW) form that is acceptable for disposal. Additionally, Isotek is extracting ^{229}Th from the material and transferring it to a customer for use as source material to produce vital medical isotopes ideal for targeted alpha therapy, a promising new cancer treatment.

UCOR is the DOE ORR cleanup contractor for the DOE Oak Ridge Office of Environmental Management (OREM). The scope of UCOR activities at ORNL includes operation of the Transuranic Waste Processing Center (TWPC) and the long-term surveillance, maintenance, and management of inactive waste disposal sites, structures, and buildings. The *FY 2023 Cleanup Progress: Annual Report on Oak Ridge Reservation Cleanup* (UCOR 2023) **here** provides detailed information on UCOR activities at ORNL. These activities included the demolition of the Low Intensity Test Reactor, preparation of the Oak Ridge Research Reactor (Figure 5.2) and three support facilities at the Graphite Reactor for demolition, removal of a highly irradiated component from a hot cell in Building 3026, and continued processing of the ^{233}U inventory stored at ORNL.

Photograph by UCOR. Approved for public release.

Figure 5.2. Removal of the 30-ft-long Low Intensity Test Reactor

In October 2022, UCOR assumed responsibility for operations at TWPC, which is located on about 26 acres of land adjacent to the Melton Valley Storage Tanks along State Route 95. UCOR's mission at TWPC is to receive, process, treat, and repackage transuranic (TRU) wastes for shipment to designated facilities for final disposal. TWPC consists of a waste-processing facility, a personnel building, and numerous support buildings and storage areas. TWPC began processing supernatant liquid from the Melton Valley Storage Tanks in 2002, contact-handled debris waste in December 2005, and remotely handled 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 TWPC, and results are included in water-monitoring discussions in Section 5.5. 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 are 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) (see website **here**), the Grid Research Integration and Deployment Center (see website **here**), and the Manufacturing Demonstration Facility (see website **here**). The HVC is located on a 23-acre site owned by Pellissippi Investors LLC and is leased to UT-Battelle and the University of Tennessee. Approximately 152 industry partners work on the HVC to shape the mobility, energy infrastructure, and manufacturing future of the United States.

NTRC is DOE's only user facility dedicated to transportation and serves as the gateway to UT-Battelle's comprehensive capabilities for transportation 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 cybersecurity, and intelligent transportation systems.

The Grid Research Integration and Deployment Center combines multiple electrification research activities (e.g., utilities, buildings, vehicles) into one facility. The combination of the following innovative R&D disciplines enables breakthroughs to support a resilient and secure power grid from the first instant of electricity generation to end use:

- Power and energy systems
- Vehicle and buildings science
- Power electronics
- Energy storage
- Sensors and controls
- Data science and modeling
- Cybersecurity

The Manufacturing Demonstration Facility focuses on advanced manufacturing research, including the development of carbon fiber composites and additive manufacturing involving polymers, metal wires, and metal powders. The facility provides lab space for the Institute for Advanced Composites Manufacturing Innovation and hosts an outreach program for local high school students.

The Carbon Fiber Technology Facility (CFTF), 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. The 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.

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 436.1A, Departmental Sustainability (DOE 2023a), UT-Battelle, UCOR, and Isotek have implemented environmental management systems (EMSs) modeled after the International Organization for Standardization (ISO) 14001 standard to measure, manage, and control environmental impacts (ISO 2015). 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 comply fully with all applicable requirements and to improve ORNL's environmental performance continually. Until August 2018, UT-Battelle was registered to the ISO 14001:2015 standard and had maintained ISO 14001 registration since 2004. In fiscal year (FY) 2018, a management decision was made to transition from registration to a declaration of conformance to ISO 14001:2015, and external registration audits were replaced with annual internal independent ISO 14001 audits.

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 policies and translates environmental laws, applicable DOE orders, and other requirements into laboratory-wide documents (procedures and guidelines). Through environmental protection officers, environmental compliance representatives, waste services representatives, and environment, safety, health, and quality (ESH&Q) coordinators, 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 ESH&Q requirements and controls into all work activities and to ensure protection of workers, the environment, and the public. The UT-Battelle EMS and 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 ESH&Q 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 ESH&Q, including pollution prevention, waste minimization, and resource conservation. Therefore, the guiding principles and core functions in the ISMS include protection of the environment. 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, which can be found on the ORNL website **here**, clearly states expectations and includes commitments to continual improvement, pollution prevention, environmental justice, and compliance with regulations and other requirements.

5.2.1.3. Environmental Management System Planning

The ISO 14001 planning clause requires organizations to identify the environmental aspects and impacts of their operations, products, and services; identify applicable regulations and requirements; establish objectives; implement plans to achieve the objectives; and identify and control risks and opportunities.

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 the line organization level and the 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 on the ORNL website **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; 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 for monitoring the progress of appropriate functions and activities. Laboratory-level environmental objectives are documented in the site sustainability plan (SSP) (ORNL 2024 [**here**]). Line organization objectives are developed annually, entered into a commitment tracking system, and tracked to completion. In all cases, the objectives are consistent with the UT-Battelle environmental policy for ORNL (found on the ORNL website **here**), support the laboratory mission, and, where practical, are measurable.

UT-Battelle programs

UT-Battelle has established an organizational structure to ensure that environmental stewardship practices are integrated into all facets of its 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 2023 compliance status, activities, and accomplishments is presented in Section 5.3.

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 1969) compliance
- Air quality compliance
- Water quality compliance
- US Department of Agriculture (USDA) compliance
- Environmental sampling and data evaluation
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA 1980) interface

Subject matter experts (SMEs) at UT-Battelle provide expertise in waste management, transportation, and disposition support services to research, operations, and support divisions:

- Pollution prevention staff manage recycling programs and work with staff to reduce waste generation and to promote sustainable acquisition.
- Radiological engineering staff provide radiological characterization support to generators and waste service representatives, develop tools to help ensure compliance with facility safety and transportation, and provide packaging support requirements.
- Waste acceptance and disposition staff 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.
- Waste service representatives 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 performs waste-packing operations and conducts inspections of waste items, areas, and containers.
- The transportation management team ensures that both on-site and off-site packaging and transportation activities are performed in a safe, efficient, and compliant manner.
- The hazardous material spill response team is the first line of response to hazardous material spills at ORNL and controls and contains spills until the situation is stabilized.

5.2.1.4. Site Sustainability

To attain the sustainability goals outlined in the DOE SSP instructions **here** (DOE 2023b), sites operated by DOE are expected to contribute toward all targets and to identify strengths that can be adapted as agencywide best practices.

Sustainable ORNL

To achieve sustainability goals at ORNL, the UT-Battelle Sustainable ORNL program identifies opportunities for continuous improvements in operational and business processes and implements practices to maximize the return on investment in modernizing facilities and equipment. This program—led by two coleads, one from R&D and one from mission support—promotes systemwide best practices, management commitment, and employee engagement that will help lead ORNL into a future of efficient, sustainable operations. The Sustainable ORNL website is actively managed and is available for employee and public view **here**.

The Sustainable ORNL roadmap structure endorses 15 vital roadmaps. Figure 5.3 summarizes the current sustainability focus areas (i.e., roadmaps). Designated SMEs report the sustainability progress for their respective focus areas annually. Continuous employee engagement and regular status reports confirm the goals of the program are being met.

The roadmap structure is not static; as the science mission advances and the needs of the organization evolve, structural elements in the Sustainable ORNL roadmaps are modified to align with developing priorities. In FY 2022, Sustainable ORNL made roadmap changes that were implemented in FY 2023 to better align ORNL to support updated goals and requirements as issued by federal and DOE directives.

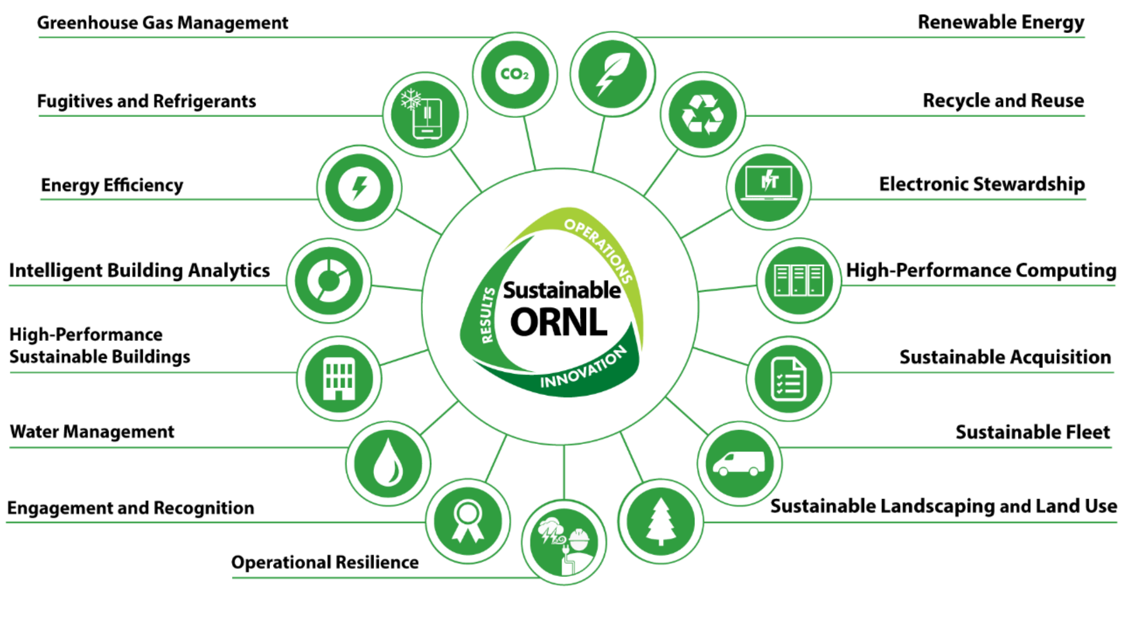


Figure 5.3. Sustainable ORNL focus areas (roadmaps) for fiscal year 2023

Sustainable ORNL awards

In 2023, R&D World and the Federal Laboratory Consortium recognized sustainability efforts at ORNL with the following awards:

- R&D World R&D 100 Awards (details **here**)
- Additively Manufactured Thermally Conductive Collimators for Neutron Instrumentation
- OpeN-AM: A Platform for Operando Neutron Diffraction Measurements of Additive Manufacturing
- Precise, Continuous, and High-Speed Manufacturing of Thermoplastic Composites Using Additive Manufacturing-Compression Molding, AM-CM
- Federal Laboratory Consortium 2023 Technology Transfer Awards (details **here**)
- Excellence in Technology Transfer: ORNL Spinoff's Food Waste Conversion Process
- State and Local Economic Development: Oak Ridge Reimagined: Nuclear Hub for a Carbon-Free Energy Future

Updates to federal sustainability guidance

Changes in federal government and DOE priorities resulted in a year of major transition and change in sustainability goals and priorities. DOE Order 436.1A, *Departmental Sustainability*, was issued in April 2023 and was added to the UT-Battelle prime contract later in FY 2023 (DOE 2023a). This order replaces DOE Order 436.1 (issued in May 2011) and includes a seven-page contractor requirements document (CRD) that is significantly more detailed that the one-page CRD associated with DOE Order 436.1. The CRD revisions demonstrate DOE's strengthening commitment to sustainable operations. Goals from Executive Order (EO) 14008, *Tackling the Climate Crisis at Home and Abroad* (EO 2021a); EO 14057, *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability* (EO 2021b); and EO 14072, *Strengthening the Nation's Forests, Communities, and Local Economies* (EO 2022), have been incorporated into DOE Order 436.1A. In 2023, ORNL completed an impact assessment on DOE Order 436.1A and developed an implementation plan for CRD compliance that includes action items for various organizations throughout the lab (e.g., Acquisition Management, Environmental Protection Services, Fleet Management). In FY 2022, the SSP instructions issued by the DOE Sustainability Performance Office were updated to capture requirements from EO 14008, the Energy Act of 2020 (EAct 2020), and EO 14057 as well as actions outlined in DOE's *Climate Adaptation and Resilience Plan and Sustainability Plan* (DOE 2021a). Updates in SSP guidance help to minimize and streamline reporting while addressing updated federal requirements.

ORNL Site Sustainability Plan

As required by DOE Order 436.1A, the ORNL FY 2024 SSP (ORNL 2024), which includes FY 2023 performance data, was completed and submitted to the DOE Sustainability Performance Office in December 2023. SSPs are used by DOE to outline various site contributions toward departmental sustainability goals as federal sites manage their buildings, vehicles, and overall operations to optimize energy and environmental performance, reduce waste, and cut costs. The ORNL FY 2024 SSP with FY 2023 performance data can be found **here**, and DOE's instruction document and template for submittal can be found **here**.

Summary of performance data for energy, water, and other federal sustainability performance goals

Table 5.1 summarizes ORNL's 2023 performance and progress toward meeting federal sustainability goals.

ORNL greenhouse gas and net-zero baseline

The sources of greenhouse gas (GHG) emissions at ORNL and the inventory for FY 2023 were reported and calculated via the SSP reporting process and are summarized in Figure 5.4. By far, the most significant components of GHG emissions at ORNL were the production and delivery factors associated with electrical power production, netting 76% of ORNL emissions in FY 2023. Over the past 15 years, GHG emission factors from electricity have improved slowly but steadily, but that is expected to change as the ORNL science mission continues to grow. Scope 1 emissions are direct GHG emissions from sources that are controlled or owned by an organization (e.g., emissions associated with fuel combustion in boilers, furnaces, or vehicles). Scope 2 emissions are indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling. Although scope 2 emissions physically occur at the facilities where they are generated, they are accounted for in an organization's GHG inventory because they are a result of the organization's energy use (EPA 2024a). The FY 2023 ORNL scope 1 and scope 2 GHG inventory was 237,169 $MTCO_2e$ (net after renewable energy credits [RECs]), an increase of 11% from FY 2022. Because the science mission at ORNL is growing and federal accounting guidance allows no GHG emissions exceptions or exclusions, regardless of mission, emissions are expected to increase in the near term.

Table 5.1. ORNL 2023 sustainability performance status and planned actions and contributions

DOE goal	Current performance status	Planned actions and contributions
Energy management		
Reduce EUI (Btu/GSF) in goal-subject buildings by 50% by the end of FY 2030.	ORNL's FY 2023 calculated EUI was 237,514 Btu/GSF. This is a cumulative reduction of 34.7% since FY 2003 and a reduction of 1.43% from the FY 2021 baseline but is an increase of 1.41% from FY 2022. ORNL continues to improve identification of energy-consuming facilities as the mission expands.	Continued EUI reduction for goal-subject facilities is considered attainable by concentrating on the best mix of ECM projects for energy savings and by incorporating net-zero strategies into all levels of lab planning efforts.
Achieve a net-zero emissions building portfolio by 2045 through building electrification and other efforts.	ORNL is currently investigating replacing dedicated fuel oil–powered boilers (not associated with the ORNL steam plant) with electric-powered boilers. A "mini-campus" would be made all electric if a project were pursued to replace the fuel oil–powered boiler with an electric-powered boiler.	ORNL is looking into the possibility of conducting an electrification study for the campus in the future.
Perform Energy Independence and Security Act Section 432 continuous (4-year cycle) energy and water evaluations.	FY 2023, the third year of the 4-year energy audit cycle, included 22 building audits to cover a quarter of the buildings that are qualified for audit inclusion.	ORNL will continue the current 4-year cycle of auditing and assessments to align with work priorities. In FY 2024, ORNL will conduct the final year of the 4-year energy audit cycle.
Meter individual buildings for electricity, natural gas, steam, and water to adhere to federal metering guidance.	In FY 2023, ORNL added 23 new advanced utility meters (including computational metering and electrical utility distribution metering), migrated 1 new data stream from other systems across the lab, and replaced 3 meters. ORNL meter installations included electrical, steam/hot water, natural gas, chilled water, and potable water.	ORNL will continue to use the metering-tracking process and plan for guidance in installation of additional advanced utility meters on all utilities per the new federal metering guidance.

Table 5.1. ORNL 2023 sustainability performance status and planned actions and contributions (continued)

DOE goal	Current performance status	Planned actions and contributions
Water management		
Reduce WUI for potable water (G/GSF).	Annual water consumption resulted in a WUI of 148.2 G/GSF in FY 2023, which is an increase of 8.7% from FY 2022, missing the 0.5% reduction goal compared with the previous year. Continued improvements in the identification of water-consuming facilities yielded a 1% decrease in GSF in support of the WUI calculation.	ORNL's WUI is subject to rise because of increased demands for cooling tower makeup water to support growth of high-performance computing systems. In conjunction with continued modernization activities that include the elimination of old facilities and the addition of new facilities, ORNL will consider more water-efficient systems and will maintain a focus on water management best practices to meet future WUI reduction goals.
Waste management		
Reduce nonhazardous solid waste sent to treatment and disposal facilities.	In FY 2023, ORNL's diversion rate for municipal solid waste reached 65.7%.	ORNL will continue to identify source reduction opportunities.
Reduce C&D materials and debris sent to treatment and disposal facilities.	In FY 2023, ORNL's C&D diversion rate for waste building materials and deactivation and decommissioning debris was 94.1%.	ORNL will continue to employ terms and conditions in construction contracts to manage construction waste and recycling. C&D recycle rates will vary as the proper characterization of debris dictates.
Fleet management		
Reduce petroleum consumption.	ORNL continues to optimize utilization, purchase vehicles with improved fuel economy and EVs when available, and purchase vehicles with anti-idling technology.	ORNL will launch a passenger-carrying vehicle-pooling project, encourage using the ORNL taxi service, and continue to replace fleet vehicles with improved–fuel economy vehicles.
Increase alternative fuel consumption.	Eighty percent of all ORNL vehicles are AFVs, and 88% of all replacements since FY 2020 have been AFVs or EVs. Also, 93% of light-duty vehicles operate on alternative fuels.	ORNL will continue to purchase AFVs and limit accessibility of non–alternative fuel at ORNL gas pumps.
Achieve 100% zero-emission vehicle acquisitions by 2035, including 100% zero-emission light-duty vehicle acquisitions by 2027.	ORNL is currently meeting the AFV requirement. If an AFV or EV has been available and has met mission requirements, it has been purchased or leased during the replacement process.	ORNL will continue the effort of replacing conventional vehicles with AFVs or EVs if available and if they meet the mission requirements.

Table 5.1. ORNL 2023 sustainability performance status and planned actions and contributions (continued)

DOE goal	Current performance status	Planned actions and contributions
Clean and renewable energy		
Achieve 100% carbon pollution–free electricity on a net annual basis by 2030, including 50% 24/7 CFE.	ORNL purchased 48,400 MWh RECs to supplement on-site renewable energy generation. The RECs represent 8.6% of the lab's electrical energy consumption, exceeding the 7.5% statutory requirement. TVA's specific percentage CFE with the 7.5% REC equivalent results in 58.5% CFE.	ORNL will remain compliant with the 7.5% renewable electric energy requirement of the Energy Policy Act (EPAct 2005) via REC purchases and will continue to explore innovative renewable energy projects. REC purchases will reflect significant mission growth in the near future and will transition to energy attribute certificates as ORNL works toward meeting CFE requirements. ORNL will continue to consider TVA's specific percentage CFE to better reflect grid-provided CFE.
Sustainable buildings		
Increase the number of ORNL-owned buildings that are compliant with the GPs for sustainable buildings.	ORNL's sustainable buildings inventory did not increase in FY 2023. ORNL has seven sustainable buildings that are GP certified.	In the next 2 years, ORNL plans to have at least two new buildings and to reassess the existing seven sustainable buildings to maintain the seven GP-certified buildings inventory.
Acquisition and procurement		
Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring all sustainability clauses are included as appropriate.	ORNL maintained 100% compliance in FY 2023. All subcontracts contain multistatutory terms and conditions that invoke requirements for sustainable acquisitions as defined in the UT-Battelle prime contract as flow-down requirements.	ORNL will continue its mission commitment to include all applicable federal acquisition regulation clauses and provisions in each new contract. ORNL will maintain compliance with DOE Order 436.1A and will assist with a future supply chain risk assessment.
Investments: improvement measures, workforce, and community		
Implement life cycle cost-effective efficiency and conservation measures with appropriated funds and/or performance contracts.	The ORNL Energy Efficiency and Sustainability program provides, on average, over $500,000/year toward ECMs. DOE has a current contract with Johnson Controls Inc. for an ORNL energy-savings performance contract project. The contract was issued July 31, 2008, with a term of 24 years and 7 months. It includes ECMs consisting of steam system decentralization, building management system improvements, advanced meter installations, energy-efficient lighting upgrades, and domestic water conservation.	An evaluation of ORNL ECMs needs to be performed to identify and install or implement ECMs that are life cycle cost-effective at the maximum level of funding available. ORNL plans on expanding the auditing process and integrating this process with the facility condition assessments. ORNL will then continue to investigate the best potential funding pathway strategies as the life cycle cost-effective ECM list grows.

Table 5.1. ORNL 2023 sustainability performance status and planned actions and contributions (continued)

DOE goal	Current performance status	Planned actions and contributions
Electronic stewardship		
Increase acquisition of sustainable electronics and promote sustainable information technology and end-of-life practices.	ORNL maintained 100% compliance in the acquisition of environmentally certified products. ORNL actively maintained power management features on 100% of all eligible devices in operation. Disposition of 100% of end-of-life electronics was performed through government reuse programs and certified recyclers.	ORNL plans to maintain 100% compliance with all electronic stewardship goals and categories. There are no foreseen obstacles to the goal.
Adaptation and resilience		
Implement climate adaptation and resilience measures.	In response to EO 14008 and DOE directives, ORNL submitted its vulnerability assessment and resilience plan in September 2022 along with a portfolio of actionable resiliency solutions. In FY 2023, ORNL updated the resiliency project status. One project was funded and completed in FY 2023.	Updates of the implementation status of ORNL's solutions will be reported annually to the Sustainability Performance Office.
Multiple categories		
Reduce scope 1 and scope 2 GHG emissions.	The FY 2023 scope 1 and scope 2 GHG inventory was 237,169 MTCO2e (net after RECs), a year-over-year increase of 11%. Purchased electricity (scope 2) comprised 76% of ORNL GHG emissions. EPA Emissions & Generation Resource Integrated Database emissions factors and rebounding from COVID-19 levels contributed to ORNL's scope 2 GHG increase.	Mission growth will limit the ability to reduce emissions in the next 5 years. However, forward-looking DOE priorities combined with net-zero initiatives will reverse the trend of higher emissions.
Reduce scope 3 GHG emissions.	The FY 2023 scope 3 GHG inventory was 25,536 MTCO2e, an 8% increase from FY 2022. Scope 3 activities at ORNL included distribution losses from purchased electricity and increased employee commuting and business travel.	Employee commuting and business travel categories are returning to pre–COVID-19 levels, which has reversed the scope 3 reductions of FY 2020 and FY 2021.

Acronyms:
AFV = alternative-fuel vehicle
C&D = construction and demolition
CFE = carbon pollution–free electricity
DOE = US Department of Energy
ECM = energy conservation measure
EO = executive order
EPA = US Environmental Protection Agency
EUI = energy use intensity
EV = electric vehicle
FY = fiscal year
G = gallon
GHG = greenhouse gas
GP = Guiding Principle
GSF = gross square foot
ORNL = Oak Ridge National Laboratory
REC = renewable energy credit
TVA = Tennessee Valley Authority
WUI = water use intensity

Figure 5.4. ORNL greenhouse gas inventory FY 2023 summary

The rate of progress toward achieving carbon pollution–free electricity (CFE) goals is expected to accelerate as the producers of CFE deploy clean energy strategies nationwide. Tennessee Valley Authority (TVA) is ORNL's wholesale electricity provider, and ORNL determines its CFE percentage from specific TVA data, which are usually a year or more old when they become available. ORNL will be able to extract a more relevant CFE percentage from TVA data as DOE works toward developing a process that reflects emissions factors associated with electricity production.

The FY 2023 scope 3 GHG inventory was 25,536 MTCO2e, an 8 percent increase from FY 2022. Employee commuting and business travel categories are returning to pre–COVID-19 levels. Federal priorities, programs, and initiatives including EOs 14008 and 14057 are expected to reduce GHG emissions significantly by 2030.

Pollution prevention

Source reduction efforts at ORNL include increasing the use of acceptable nontoxic or less-toxic alternative chemicals and processes while minimizing the acquisition of hazardous chemicals and materials via material substitution, operational assessments, and inventory management. In cases where the complete elimination of a particular hazardous material is not possible, a combination of actions is pursued, including controls to limit use, procurement alternatives, and recycling processes to mitigate the environmental impact. Sustainability is integrated across ORNL by procuring and using sustainable products with biobased and recycled content, including by using biobased foam handwash that is dispensed in limited amounts, using biobased and recycled-content paper towels in dispensers that limit single-use amounts, and upgrading aging transformers with new models that use biobased and biodegradable oils instead of mineral oils.

During 2023, UT-Battelle implemented 29 ongoing and new pollution prevention projects. These projects and ongoing reuse and recycle efforts eliminated more than 11.8 million kg of waste. Researchers at ORNL implement traditional recycling options when feasible and investigate new options when a need is identified. Moreover, ORNL recognizes the need to close the loop for recycled materials and supports these efforts by procuring materials with postconsumer recycled content and by performing research to support closing the loop for plastic recycling. Specifically, the DOE Manufacturing Demonstration Facility at ORNL works with industry to replace material disposability with renewability through research focused on closing the loop in the modern material supply chain. Through research, some conducted at ORNL, today's advanced manufacturing composite waste becomes tomorrow's valuable raw materials. (Details on composites recycling at ORNL are available **here**.) Researchers are investigating and deploying new processes that convert feedstocks used in advanced manufacturing into reusable materials. These efforts, including the development of processing and material technologies that provide automotive class A surface appearance and suitable mechanical properties for automotive body panels utilizing a thermoplastic matrix reinforced with discontinuous recycled carbon fibers (Figure 5.5), continue to close the recycling loop for plastics. (More details on these efforts can be found **here**.)

Efforts to further reduce and divert the amount of material going to the landfill also include the development of contract language requiring construction contractors to recycle as much construction debris as possible. Within ORNL, the extensive use of training, awareness, presentations, and outreach encourages source reduction and recycling by all associates.

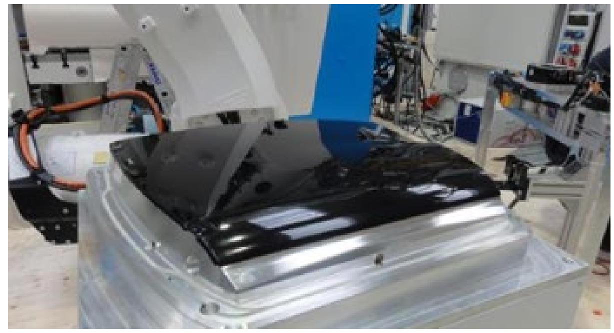


Figure 5.5. Recycled carbon fibers are being used in the development of nonwoven, discontinuous-fiber prepregs for thermoplastic compression molding of class A automotive body panels

Carbon pollution–free electricity

Electricity consumption is the largest contributor to ORNL GHG scope 2 emissions. CFE will be required to reach the goals of a net-zero energy economy, and the availability of CFE is largely dependent on electric utility suppliers. EO 14008 calls on electricity providers to reach annual CFE goals and to provide CFE by 2030, which will be a key step toward the attainment of net-zero operations that DOE is tracking via the SSP and reporting for federal sustainability goals.

DOE is still refining the methods for calculating and reporting meaningful CFE values at the site level. In FY 2022, ORNL's CFE percentage (41.3 percent) was calculated using defined methods based on regional data from EPA's Emissions & Generation Resource Integrated Database. In FY 2023, ORNL's CFE percentage (58.5 percent) was calculated using TVA's specific generation resource mix estimate (50.98 percent) for calendar year (CY) 2022 (the most recent data available) and the EPAct 2005 7.5 percent renewable electric energy requirement. TVA's estimated CFE percentage is higher than the regional percentage in the EPA database, and TVA directly supplies electricity to ORNL.

ORNL's ability to realize annual CFE target increases relies mainly on TVA's commitment to

CFE increases through FY 2030. TVA has projected that it will reach approximately 70 percent CFE by 2030. Because ORNL is a direct feed from TVA, the lab forecasts 70 percent CFE by FY 2029.

On December 7, 2023, DOE and TVA announced that they had signed a memorandum of understanding to provide ORNL, Y-12, and potentially other federal facilities in TVA's service territory with 100 percent locally supplied CFE by 2030. (The DOE press release is available **here**.) This would surpass the 2030 70 percent CFE commitment.

Sustainable ORNL Sustainability showcase projects for net-zero research

Net-zero initiatives do not operate in isolation. Rather, they work in conjunction with other priorities to reach a number of agency objectives. Throughout the ORNL campus, projects are evaluated on several sustainability priorities, including savings in energy, water, and cost from energy conservation measures, net-zero initiatives, and operational resilience. ORNL has an opportunity and a responsibility to lead by example and integrate climate and sustainability into all aspects of its operations. The goal is to develop a dynamic inventory of research and operational projects that represent opportunities to advance the ORNL campus toward net-zero strategies.

Each year, Sustainable ORNL makes funding available for projects that showcase creative measures that can improve ORNL's sustainability. In 2023, three showcase projects geared toward net-zero and energy-improvement research topics were chosen:

- 5600-5700-5800 complex sustainability and decarbonization using waste heat recovery from the Oak Ridge Leadership Computing Facility's high-performance computing data center
- Monitoring and replacement of a delinquent 250 gal natural gas water heater with a heat-pump water heater for a demonstration of carbon dioxide reduction and energy savings
- A pilot living laboratory demonstration of personalized heating and cooling management for efficient, grid-interactive buildings

Leadership-funded sustainability projects

ORNL leadership provided funding for three projects to aid in ORNL's GHG net-zero endeavors in FY 2023:

- Develop a design to allow migration of a legacy fuel oil boiler to an electric boiler at Building 7601. This replacement will reduce maintenance costs and ORNL's scope 1 GHG emissions. The replacement boiler will allow the facility and adjacent buildings to move toward net-zero GHG as ORNL's electricity supply moves closer to being completely carbon free.
- Purchase hardware and software needed to implement a vehicle-pooling program for ORNL's government fleet vehicles. Once implemented, fleet vehicles will be pooled in several locations across ORNL rather than being assigned to individuals or groups. This change will enable ORNL to right-size the fleet, thus decreasing scope 3 GHG emissions. Charging stations at the pooling locations will enable a smooth transition from internal combustion engine–powered vehicles to EVs.
- Accelerate the transition of lighting at ORNL to energy-efficient LED fixtures in support of the Energy Act of 2020. This additional funding enabled LED replacements beyond those that were originally scheduled for 2023.

Earth Day

Sustainable ORNL hosts an annual Earth Day celebration with engagement activities for staff and the community. ORNL celebrated Earth Day in 2023 for the first time since the start of the COVID-19 epidemic. "Sustainable ORNL 2023 Earth Day—Invest in our Planet" featured 28 vendors, an EV/hybrid car show, and an EV ride-and-drive event. ORNL also hosted three seminars during the week of Earth Day:

- "Growing Greener Communities through Tennessee Smart Yards," Dr. Andrea Ludwig, the University of Tennessee, April 17
- "Science and Society: Working Together for a Nature-Inclusive Energy Transition," Dr. David McCollum, ORNL senior R&D staff, April 20
- "The State of Sustainability in Tennessee," Chris Pianta, program manager, Tennessee Department of Environment and Conservation (TDEC) Office of Sustainable Practices

2023 Annual Sustainability Report

ORNL publishes the Annual Sustainability Report to share the benefits of committing to sustainable practices, such as energy conservation and the reduction of long-term risks due to carbon emissions (Figure 5.6). The report is available to the public to promote regional outreach and involvement. The current report and several past issues may be viewed **here**.

University of Tennessee/Pellissippi State Community College/ORNL transportation route

In August 2015, ORNL and the University of Tennessee partnered on a new bus route that connects the University of Tennessee's Knoxville campus, Pellissippi State Community College in west Knox County, and ORNL, providing transportation to staff, students, and faculty. The bus offers three round-trip routes each day to all three sites based on the University of Tennessee's semester schedules. The transportation route has grown with stops at ORNL's NTRC and Spallation Neutron Source (SNS) campuses and has expanded to year-round service with the exception of federal holidays and the week of Christmas. In 2023, ridership grew in the summer months with the influx of ORNL summer interns.

Figure 5.6. ***Annual Sustainability Report*** **cover for 2023 and sample pages**

Environmental justice

Environmental justice (EJ) is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies (EPA 2023). EJ is achieved when everyone enjoys the same degree of protection from environmental and health hazards and equal access to the decision-making process to have a healthy environment in which to live, learn, and work.

EJ principles are integrated into all ORNL programs and activities to comply with the following executive orders:

- EO 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (EO 1994)
- EO 14008, Tackling the Climate Crisis at Home and Abroad (EO 2021a)
- EO 14057, Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability (EO 2021b)

In keeping with a presidential memorandum accompanying EO 12898, NEPA evaluations for proposed actions at ORNL include an analysis of environmental effects, including human health–related, economic, and social effects on minority and low-income communities. No actions requiring NEPA evaluations were proposed for ORNL in 2023.

ORNL's Environmental Protection Services Division conducts environmental monitoring and sampling for the ORR-wide environmental surveillance program discussed in Chapter 6. The objectives of this program are to (1) characterize environmental conditions in areas outside facility boundaries on ORR and in areas adjacent to or near ORR and (2) ensure that doses to members of the public from radionuclides and chemicals released from ORR are not above established limits. Elements of the ORR-wide surveillance program include monitoring ambient air, external gamma exposure, water, fish, and food crops in several communities near ORR, including a historically minority community that borders ORR.

One of the most serious EJ concerns is climate change, which often has disproportionate adverse social, economic, and health effects on marginalized and underserved communities. ORNL uses its world-leading capabilities in supercomputing and large-scale experiments to advance understanding of climate change. ORNL's Climate Change Science Institute was formed in 2009 to integrate climate science activities across ORNL and to evaluate the interactions of climate change with human and natural systems. This research helps to develop adaptation and mitigation solutions at the intersection of climate, clean energy, national security, and EJ.

Native Americans are particularly vulnerable to environmental threats because of the crucial role that nature plays in their culture and their reliance on natural resources. To help ensure that plant species with cultural significance to the Eastern Band of Cherokee Indians and across the region are protected and preserved, ORNL participates in the Southeastern Appalachian Man and the Biosphere (SAMAB) Cooperative, a collaboration of land management agencies promoting sustainability. Core to SAMAB are five areas recognized internationally for their significance to the natural world: Great Smoky Mountains National Park, Mount Mitchell State Park, Grandfather Mountain, Coweeta Hydrologic Lab, and the ORNL National Environmental Research Park. The National Environmental Research Park, a major resource for conducting ecological studies, is a 20,000-acre research facility with over 1,100 plants, some of which hold rich cultural importance. This prompted ORNL's participation in the Culturally Significant Plant Species Initiative, a collaboration between the Eastern Band of Cherokee Indians and SAMAB focused on the sustainability, conservation, and management of plants with cultural significance to the Cherokee through education and increased access.

Other ORNL programs that invest in and engage with historically underserved communities while also contributing to a greener and more inclusive economy include the following:

- Collaborations and partnerships with tribal communities and universities, minority-serving institutions, and historically black colleges and universities to enhance the accessibility of ORNL resources to underrepresented entities
- Recruiting programs to attract staff from minority-serving institutions
- A comprehensive diversity, equity, inclusion, and accessibility plan that includes recruiting, onboarding, and career development strategies to close gaps in representation
- Community engagement and corporate giving programs to support local communities, including minority and underserved populations
- ORNL Small Business Programs Office initiatives to significantly increase opportunities for small, disadvantaged businesses to provide the goods and services that are used at ORNL

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) 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 (EISA 2007).

For the purposes of this provision, *development or redevelopment* is defined as follows:

> 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).

Because of the soil types (low permeability) and karst geology, conditions exist at ORNL that would allow for claiming technical infeasibility, as described in technical guidance from EPA (EPA 2009a). Clay soils have low infiltrative capacities, and the introduction of more water to the subsurface in a karst geology can accelerate the formation of sinkholes. As a result of these two geological conditions at ORNL, the use of subsurface infiltration to address EISA-438 is being pursued on a limited basis. Instead, mitigation strategies are being pursued (e.g., installation of water quality systems and devices to improve water quality and strategies that would allow for additional evapotranspiration for streams and their associated buffer zones).

Implementing this revised approach to EISA-438 compliance, as opposed to claiming technical infeasibility, demonstrates ORNL's commitment to environmental stewardship. If projects take place in existing contaminated areas or where an area approach is not feasible, technical infeasibility is claimed to prevent potential movement of contamination within soil or groundwater.

When possible, this environmental stewardship approach is implemented on an area basis at ORNL. Addressing EISA-438 on an area basis, instead of a project-by-project basis, allows for the following:

- Storm water runoff from adjacent areas can be diverted around developed areas to keep water quality high.
- Water quality structures and devices can be installed to handle runoff from developed areas, therefore reducing the number of water quality structures and devices to be installed and maintained.
- Individual projects are not burdened with the costs associated with addressing EISA-438 requirements.

In 2023, no water quality improvements for projects subject to EISA-438 were completed.

5.2.1.6. Emergency Preparedness and Response

The UT-Battelle Emergency Management Program supplies the resources and capabilities to provide emergency preparedness and emergency response services. The on-site emergency management organization provides emergency call answering and dispatch, emergency medical care and transport, firefighting capability, technical rescue services, and hazardous materials release mitigation. Emergency management 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 execution of the procedures and plans. Emergency responders to expanding and complex incidents are supported by an emergency operations center consisting of laboratory leaders and SMEs. An environmental SME is a member of the emergency response organization. The environmental SME participates in real events, drills, and exercises to ensure that environmental requirements are met and that environmental impacts are mitigated.

5.2.1.7. Environmental Management System Performance Evaluation

ISO 14001 includes requirements to monitor, measure, analyze, and regularly evaluate the performance of the EMS. EMS performance evaluations ensure that goals and objectives are being met and that opportunities to continually improve are identified.

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. SBMS includes requirements for management system owners 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 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, an internal EMS assessment is performed annually to ensure that the UT-Battelle EMS continues to conform to ISO 14001:2015 requirements. An independent internal audit conducted in 2023 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. Environmental Management System for Isotek

Isotek has developed and implemented an EMS for the Uranium-233 Disposition Project that reflects the elements and framework found in the ISO 14001:2004 standard (ISO 2004) and satisfies the applicable requirements of DOE Order 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 Uranium-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 Uranium-233 Disposition Project has a well-established recycling program that is implemented at all Isotek-managed facilities and includes Building 3017, the Building 3019 Complex, Building 2026, and Building 3137. Materials Isotek currently recycles 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 to continually improve the EMS.

5.3. Compliance Programs and Status

During 2023, UT-Battelle, UCOR, and Isotek operations were conducted to comply with contractual and regulatory environmental requirements. Table 5.2 summarizes environmental audits conducted at ORNL in 2023. The following discussions summarize the major environmental programs and activities carried out at ORNL during 2023 and provide an overview of the compliance status for the year. Summary information on 2023 noncompliances at ORNL is also available under Federal Services Registry ID number 110002040201 on EPA's Enforcement and Compliance History Online website **here**.

5.3.1. Environmental Permits

Table 5.3 lists the environmental permits that were in effect in 2023 at ORNL.

Table 5.2. Summary of regulatory environmental audits, evaluations, inspections, and assessments conducted at ORNL, 2023

Date	Reviewer	Subject	Issues
March 8–9	TDEC	Hazardous Waste Compliance Evaluation Inspection (including UT-Battelle, Transuranic Waste Processing Center, and UCOR)	0
March 9	City of Oak Ridge	CFTF Wastewater Pretreatment Permit Inspection	0
June 7	KCDAQM	Hardin Valley Campus Clean Air Act Inspection	0
June 21–23	TDEC	Biennial NPDES Permit Inspection	0
July 27	City of Oak Ridge	CFTF Wastewater Pretreatment Permit Inspection	0
August 9	TDEC	TWPC Clean Air Act Inspection	0
August 10	TDEC	CFTF Clean Air Act Inspection	0

Acronyms:
CFTF = Carbon Fiber Technology Facility
KCDAQM = Knox County Department of Air Quality Management
TDEC = Tennessee Department of Environment and Conservation
TWPC = Transuranic Waste Processing Center
UCOR = United Cleanup Oak Ridge LLC

Table 5.3. Environmental permits in effect at ORNL in 2023

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	Operating Permit, NTRC	22-0941	DOE	UT-B	UT-B
CAA	Operating Permit, TRU	071009P	DOE	UCOR	UCOR
CAA	Construction Permit, 3525 Area Off Gas System	971543P	DOE	UT-B	UT-B
CAA	Permit-by-Rule, TRU emergency generators	R80800	DOE	UCOR	UCOR
CAA	Title V Major Source Operating Permit, ORNL	578132	DOE	UCOR	UCOR
CAA	CFTF CAA Operating Permit (Conditional Major)	474951	DOE	UT-B	UT-B

Table 5.3. Environmental permits in effect at ORNL in 2023 (continued)

Regulatory driver	Permit title/description	Permit number	Owner	Operator	Responsible contractor
CAA	Construction Permit, NTRC	C-21-0941-02-01	DOE	UT-B	UT-B
CAA	CAA Title V Operating Permit for Isotek operations at ORNL	576448	DOE	Isotek	Isotek
CAA	Construction Permit, CFTF	980167	DOE	UT-B	UT-B
CAA	Construction Permit, SNS 8915 Upgrade	980182	DOE	UT-B	UT-B
CWA	ORNL NPDES Permit (ORNL sitewide wastewater discharge permit)	TN0002941	DOE	DOE	UT-B, UCOR, Isotek
CWA	Industrial and Commercial User Wastewater Discharge Permit (CFTF)	1-12	UT-B	UT-B	UT-B
CWA	General NPDES Permit for Storm Water Discharges Associated with Craft Resources Support Facility Construction Activities	TNR136355	DOE	UT-B	UT-B
CWA	General NPDES Permit for Storm Water for ORNL Experimental Gas Cooled Reactor Parking Lot	TNR136470	DOE	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	DOE	UCOR
CWA	Notice of Coverage Under the General NPDES Permit for Storm Water for TRC Project	TNR136285	DOE	UT-B	UT-B
RCRA	Hazardous Waste Transporter Permit	TN1890090003	DOE	UT-B	UT-B, UCOR
RCRA	Hazardous Waste Corrective Action Permit	TNHW-164	DOE	DOE/all	DOE/all
RCRA	Hazardous Waste Storage and Treatment Permit	TNHW-145	DOE	DOE/ UCOR	UCOR
RCRA	Hazardous and Mixed Waste Storage Permit	TNHW-178	DOE	DOE/UT-B	UT-B
PCB	PCB Risk Based Agreement between UT-B and EPA	TN1890090003	DOE	UT-B	UT-B
PCB	PCB Risk Based Agreement between UCOR and EPA	TN1890090003	DOE	UCOR	UCOR
CWA	ARAP—Construction of a New Outfall Consisting of a Headwall and Riprap Apron	NR2203.208	DOE	UT-B	UT-B
CWA	ARAP—Installation of a New Effluent Flow Monitoring Station with a Parshall Flume and New Outfall Line[a]	NR2203.188	DOE	UT-B	UT-B

Table 5.3. Environmental permits in effect at ORNL in 2023 (continued)

Regulatory driver	Permit title/description	Permit number	Owner	Operator	Responsible contractor
CWA	Tennessee Operating Permit, No-Discharge Wastewater Collection System for New GEARS Facility	SOP-22033	DOE	UT-B	UT-B
MBTA	US Fish and Wildlife Service Permit for Canada Geese	MB836291	UT-B	UT-B	UT-B
TCA 70	TWRA Scientific Collection Permit for Sunfish and Catfish	TWRA 1630	UT-B	UT-B	UT-B
TCA 70	TWRA Scientific Collection Permit for Canada Geese	TWRA 1631	UT-B	UT-B	UT-B
CWA	General NPDES Permit for Storm Water Discharges Associated with Stable Isotope and Production Research Center Site Prep	TNR136958	DOE	UT-B	UT-B
CWA	General Permit for Storm Water Discharges Associated with the ORNL 6000E Parking Lots	TNR137306	DOE	UT-B	UT-B
CWA	ARAP—Fifth Creek Culvert Maintenance Activities	NR2103.308	DOE	UT-B	UT-B
CWA	ARAP—Bank Armoring and Vegetative Stabilization for Jones Island Road Project [a]	NR2303.026	DOE	UT-B	UT-B
CWA	ARAP—Construction of Intake and Outfall Structures at NPDES Outfall 302	NR2303.163	DOE	UT-B	UT-B

[a] *Permit terminated during 2023.*

Acronyms:

ARAP = Aquatic Resources Alteration Permit
CAA = Clean Air Act
CFTF = Carbon Fiber Technology Facility
CWA = Clean Water Act
DOE = US Department of Energy
EPA = US Environmental Protection Agency
GEARS = Global Evaluation, Analysis, Research, and Security
Isotek = Isotek Systems LLC
MBTA = Migratory Bird Treaty Act of 1918
NPDES = National Pollutant Discharge Elimination System
NTRC = National Transportation Research Center
ORNL = Oak Ridge National Laboratory
PCB = polychlorinated biphenyl
RCRA = Resource Conservation and Recovery Act
SNS = Spallation Neutron Source
TCA 70 = T.C.A. 70-2-213
TRC = Translational Research Capability
TRU = transuranic
TWRA = Tennessee Wildlife Resources Agency
UCOR = United Cleanup Oak Ridge LLC
UT-B = UT-Battelle LLC

5.3.2. National Environmental Policy Act/National Historic Preservation Act

The NEPA process is used to evaluate the potential environmental impact of proposed federal activities and to examine alternatives to those actions. UT-Battelle, UCOR, 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 5.4 summarizes NEPA activities conducted at ORNL during 2023.

During 2023, UT-Battelle and UCOR 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, DOE has approved generic categorical exclusion determinations that cover proposed bench-scale and pilot-scale research activities and generic categorical exclusions that cover proposed nonresearch activities (e.g., maintenance activities, facilities upgrades, personnel safety enhancements). A categorical exclusion is one of a category of actions defined in 40 *Code of Federal Regulations* (CFR) Part 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 Preservation Act (NHPA 1966) is achieved and maintained at ORNL in conjunction with NEPA compliance. The scope of proposed actions is reviewed in accordance with the *Cultural Resource Management Plan* (Souza et al. 2001).

Table 5.4. National Environmental Policy Act activities, 2022–2023

Types of NEPA documentation	Number of instances
UT-Battelle LLC	
Environmental Assessments	0
Approved under general actions or generic CX determinations[a]	65
Project-specific CX determinations[b]	0
UCOR	
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

5.3.3. Clean Air Act Compliance Status

The Clean Air Act (CAA 1970), 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 Rad-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. The most recent sitewide UT-Battelle Title V Major Source Operating Permit was issued in December 2023. The Title V Major Source Operating Permit for the 3039 stack, operated by UCOR, was issued in January 2022. 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, a family of poisonous, highly reactive gases defined collectively as a criteria pollutant by EPA (EPA 2024b), are monitored continuously at one location. Samples are collected continuously from 8 major radionuclide sources and periodically from 14 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. In December 2022, an operating permit was issued by Knox County for two emergency generators located at NTRC. The CFTF operates under a conditional major operating permit issued to UT-Battelle by TDEC in 2022.

In summary, no UT-Battelle, Isotek, or UCOR CAA violations or exceedances occurred in 2023. Section 5.4. provides detailed information on 2023 activities conducted by UT-Battelle in support of the CAA.

5.3.4. Clean Water Act Compliance Status

The Clean Water Act (CWA 1972) is the primary federal statute governing the restoration, maintenance, and protection of the integrity of the nation's waters. The CWA establishes several major integrated regulatory programs, standards, and plans, including the National Pollutant Discharge Elimination System (NPDES) program, national and local pretreatment standards, Dredge or Fill Discharge Permit Program, Sewage Sludge Use and Disposal Program, and water quality management.

The CWA is the basis for comprehensive federal and state programs to protect the nation's waters from pollutants. (See Appendix C for water quality reference standards.) As a part of the CWA, EPA developed the NPDES permit program to address water pollution by regulating point sources that discharge pollutants to US waters. 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 permit program to the State of Tennessee.

The pretreatment program is a component of the NPDES program. This program is designed to reduce the level of toxic pollutants discharged by industry and other nondomestic wastewater sources into municipal sewer systems and treatment facilities. Local municipalities with approved pretreatment programs control sources of nondomestic discharges through permitting and are responsible for conducting inspections, sampling, and enforcement in Tennessee.

Wastewater discharges from ORNL facilities are subject to regulation by EPA and the TDEC Division of Water Resources. DOE received a renewed ORNL NPDES permit in May 2019 from TDEC. Several conditions in the permit were appealed, and others were addressed in permit modifications issued in December 2022 and February 2023. Another minor modification was scheduled to become effective on March 1, 2023, but some conditions were appealed and remained unresolved in 2023. An NPDES permit renewal application was submitted to TDEC in June 2023, and until a new permit is issued, the February 2023 permit, which expired December 31, 2023, has been administratively extended.

In 2023, compliance with the ORNL NPDES permit was calculated based on a total of 1,736 laboratory analyses and field measurements. One *Escherichia* coliform exceedance occurred in June 2023 at X01 (Sewage Treatment Plant) due to an operational issue with the disinfection system ozone diffuser. The diffuser has since been fixed. The wastewater treatment facilities achieved a numeric permit compliance rate of 99.9 percent in 2023 (see Table 5.5). The CFTF achieved 100 percent compliance with the UT-Battelle City of Oak Ridge Industrial and Commercial User Discharge Permit in 2023.

Table 5.5. National Pollutant Discharge Elimination System (TN0002941) compliance at ORNL, January through December 2023

Effluent parameters[a]	Number of numeric noncompliances	Number of compliance measurements[b]	Percentage of compliance[c]
X01 (Sewage Treatment Plant)			
IC_{25} static renewal 7-day chronic *Ceriodaphnia dubia* (%)[d]	0	1	100
IC_{25} static renewal 7-day chronic *Pimephales promelas* (%)[d]	0	1	100
Ammonia, as N (summer)	0	27	100
Ammonia, as N (winter)	0	25	100
Carbonaceous biological oxygen demand	0	52	100
Dissolved oxygen	0	52	100
Escherichia coliform (col/100 mL)	1	53	98.1
Peracetic acid	0	0	100
pH (standard units)	0	52	100
Total suspended solids	0	52	100
Carbonaceous biological oxygen demand	0	52	100
IC_{25} static renewal 7-day chronic *Ceriodaphnia dubia* (%)[d]	0	1	100
IC_{25} static renewal 7-day chronic *Pimephales promelas* (%)[d]	0	1	100
Oil and grease	0	4	100
pH (standard units)	0	52	100
Temperature (°C)	0	52	100
X16 through X27 (12 instream monitoring locations)			
Total residual oxidant	0	288	100
X28 and X29 (two additional instream monitoring locations)			
Peracetic acid	0	0	100
Hydrogen peroxide	0	0	100

[a] *Only permit parameters with a numerical limit are listed.*
[b] *Total number of readings taken in the year by approved method for the given parameter.*
[c] *Percentage compliance = 100 − [(number of noncompliances/number of samples) × 100].*
[d] *The inhibition concentration (IC_{25}) is the concentration (as a percentage of full-strength wastewater) that reduces survival or reproduction of the test species by 25 percent when compared to a control treatment.*

5.3.5. Safe Drinking Water Act Compliance Status

ORNL's water distribution system is designated as a "nontransient, noncommunity" public water system by the TDEC Division of Water Supply. TDEC's water supply rules—Chapter 0400-45-01, "Public Water Systems" (TDEC 2020)—set limits for biological contaminants and for chemical activities and chemical contaminants. TDEC requires sampling for the following constituents to demonstrate compliance with state and federal regulations:

- Residual chlorine
- Bacteria (total coliform)
- Disinfectant by-products (trihalomethanes and haloacetic acids)
- Lead and copper (required once every 3 years)

The fifth Unregulated Contaminant Monitoring Rule (UCMR 5), published on December 27, 2021, requires sample collection and analyses for 30 chemical contaminants in 2023, 2024, and 2025 using methods developed by EPA and consensus organizations. Sample collection at ORNL for UCMR 5 began in 2023 and will continue through 2026. Samples were taken five times in 2023 (January, April, July, October, and December) at the entry point of the distribution system.

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 2023, sampling results for ORNL's water system residual chlorine levels, bacterial constituents, and disinfectant by-products were all within acceptable limits. Sampling for lead and copper is not required until 2024.

5.3.6. Resource Conservation and Recovery Act Compliance Status

The hazardous waste program under the Resource Conservation and Recovery Act (RCRA 1976) 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 2023, 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 2023.

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 5.6. In 2023, UT-Battelle and UCOR were permitted to transport hazardous wastes under the EPA ID number issued for ORNL activities. TNHW-164 is a set of conditions pertaining to the current status of all solid waste management units and areas of concern at ETTP, ORNL, and the Y-12 Complex. The corrective action conditions require that the solid waste management units and areas of concern be investigated and, as necessary, remediated.

Reporting is required for hazardous waste activities on 12 active waste streams at ORNL, some of which involve mixed wastes. The quantity of hazardous/mixed waste generated at ORNL in 2023 was 795,473 kg, of which 590,990 kg was mixed wastewater.

Table 5.6. ORNL Resource Conservation and Recovery Act operating permits, 2023

Permit number	Storage and treatment/description
	Oak Ridge National Laboratory
TNHW-178	Building 7651 Mixed Waste Container Storage Unit Building 7652 Hazardous Waste Container Storage and Treatment Unit Building 7653 Chemical Waste Container Storage Unit Building 7654 Mixed Waste Container Storage and Treatment Unit
TNHW-145	Building 7572 Contact-Handled Transuranic Waste Storage Facility Building 7574 Transuranic Storage Facility 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 Building 7831F Flammable Storage Unit[a] 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 Macroencapsulation Treatment[a] T-2 Solidification/Stabilization Treatment[a] T-3 Amalgamation Treatment[a] T-4 Groundwater Absorption Treatment[a] T-5 Size Reduction[a] T-6 Groundwater Filtration Treatment[a] T-7 Neutralization[a] T-8 Oxidation/Deactivation[a] T-9 Puncturing Potentially Pressurized Containers[a]
	Oak Ridge Reservation
TNHW-164	Hazardous Waste Corrective Action Document

[a] *Treatment methodologies within Transuranic Waste Processing Center facilities.*

ORNL generators treated 4,108 kg of hazardous waste by elementary neutralization. The quantity of hazardous/mixed waste treated in permitted treatment facilities at ORNL in 2023 was 591,524 kg. This includes waste treated by macroencapsulation, size reduction, and stabilization/solidification as well as wastewater treatment at the Process Waste Treatment Complex (PWTC). In 2023, 203,112 kg of hazardous/mixed waste was shipped off-site to commercial treatment, storage, and disposal facilities. In March 2023, the TDEC Division of Solid Waste Management conducted a hazardous waste compliance evaluation inspection of the following:

- ORNL generator areas
- Used-oil collection areas
- Universal waste collection areas
- RCRA-permitted treatment, storage, and disposal facilities
- Hazardous waste training records
- Site-specific contingency plans
- Hazardous waste reduction plan
- Active mutual aid and memorandums of agreement with local authorities
- Waste determinations
- RCRA records

TDEC also reviewed the Hazardous Waste Transporter Permit and hazardous waste manifests. No violations were observed.

In June 2023 DOE and UT-Battelle operations at the HVC changed generator category from a very small quantity generator to a small quantity generator. HVC does not generate mixed waste. Hazardous wastes are accumulated in satellite accumulation areas or in less-than-180-day accumulation areas. Reporting is required for hazardous waste activities in nine active waste streams at HVC. During 2023 HVC generated 1,630 kg of hazardous waste and shipped 1,367 kg of hazardous waste for treatment and disposal.

CFTF was categorized as a very small quantity generator in 2023, meaning that less than 100 kg of hazardous waste was generated per month.

In 2023, no hazardous/mixed wastes were generated, accumulated, or shipped by DOE or UT-Battelle from the Jones Island Road 0800 Area, Property Sales, or the DOE Office of Scientific and Technical Information.

5.3.7. ORNL RCRA-CERCLA Coordination

The *Federal Facility Agreement for Oak Ridge Reservation* (DOE 1992) 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 2022 for ORNL's solid waste management units and areas of concern were consolidated with updates for ETTP, the Y-12 Complex, and ORR and were reported to TDEC, DOE, and EPA Region 4 in January 2023.

Periodic updates on proposed construction and demolition activities of 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 construction and demolition projects and facilities that warrant CERCLA oversight. The goal is to ensure that modernization efforts do not adversely affect future CERCLA environmental remediation actions or the effectiveness of previously completed CERCLA environmental remediation actions.

5.3.7.1. RCRA Underground Storage Tanks

Underground storage tanks (USTs) containing petroleum and hazardous substances are regulated under RCRA Subtitle I (40 CFR 280). EPA has granted TDEC the authority to regulate USTs containing petroleum under TDEC Rule 400-18-01 (TDEC 2021a); however, EPA still regulates hazardous-substance USTs.

ORNL has two USTs registered with TDEC under Facility ID 0-730089. These USTs are in service (for petroleum storage) and meet the current UST standards. TDEC did not conduct any compliance inspections in 2023.

5.3.8. CERCLA Compliance Status

CERCLA, also known as Superfund, was passed in 1980 and was amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA 1986). Under CERCLA, a site is investigated and remediated if it poses significant risk to health or the environment. The EPA National Priorities List is a comprehensive list of sites and facilities that have been found to pose a sufficient threat to human health or the environment to warrant cleanup under CERCLA.

In 1989, ORR was placed on the National Priorities List. In 1992, the ORR Federal Facility Agreement became effective among EPA, TDEC, and DOE and established the framework and schedule for developing, implementing, and monitoring remedial actions (RAs) on ORR. UCOR operates the on-site CERCLA Environmental Management Waste Management Facility (EMWMF) 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 these 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 Substances Control Act (TSCA 1976). PCB waste generation, transportation, and storage at ORNL are reported under EPA ID TN1890090003. In 2023, ORNL contractors operated five PCB waste storage areas. When longer-term storage was necessary, PCB/radioactive wastes were stored in RCRA-permitted storage buildings at ORNL. One of the PCB waste storage areas was operated at a UT-Battelle facility in the Y-12 Complex. The continued use of authorized PCBs in electrical systems and equipment (e.g., transformers, capacitors, rectifiers) is regulated at ORNL. Most of the equipment at ORNL that required regulation under the Toxic Substances Control Act 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 materials, 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 in paint, adhesives, electrical wiring, or floor tile, are identified at ORNL. No new unauthorized uses of PCBs were identified during 2023.

5.3.10. Emergency Planning and Community Right-to-Know Act Compliance Status

The Emergency Planning and Community Right-to-Know Act (EPCRA 1986) 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 Emergency Response Information System (E-Plan), which is an electronic database managed by the University of Texas at Dallas and funded by the US Department of Homeland Security. The State of Tennessee Emergency Response Commission has access to ORNL EPCRA data via the E-Plan system.

Table 5.7 describes the main elements of EPCRA. UT-Battelle complied with these requirements in 2023 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.

In 2023, ORNL had no releases of extremely hazardous substances as defined by EPCRA. Releases of toxic chemicals that were greater than the reportable threshold quantities designated in Section 313 are discussed in Section 5.3.10.2.

Table 5.7. 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, 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

5.3.10.1. Safety Data Sheet/Chemical Inventory (EPCRA 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 2023, there were 44 hazardous and 39 extremely hazardous substances at ORNL that met EPCRA reporting criteria.

Private-sector lessees were not included in the 2023 submittals. Under the terms of their leases, lessees must evaluate their own inventories of hazardous and extremely hazardous chemicals and 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.

In 2023, ORNL exceeded the reporting threshold for nitrate compounds and reported on their manufacture. Nitrate compounds were coincidentally manufactured 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 with USDA. In 2023, UT-Battelle personnel had 22 permits and agreements for the receipt, movement, or controlled release of regulated articles.

5.3.12. Wetlands

Wetland delineations are conducted to facilitate compliance with TDEC and US Army Corps of Engineers wetland protection requirements. In

2023, four wetlands were delineated on the ORNL campus. Two of these delineations helped projects avoid wetland impacts, and two were conducted to include in Aquatic Resources Alteration Permits.

5.3.13. Radiological Clearance of Property at ORNL

DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2020), 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 Order 458.1 established requirements for clearance of property from DOE control and for public notification of clearance of property.

5.3.13.1. Graded Approach to Evaluate Material and Equipment for Release

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
- 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; samples from those items undergo 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 required by DOE Order 458.1 (DOE 2020) 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 Order 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 2023, UT-Battelle cleared more than 19,930 items through the excess items and property sales processes. A summary of items requested for release through these processes is shown in Table 5.8.

Table 5.8. Excess items requested for release or recycling, 2023

Item	Process knowledge	Radiologically surveyed
Release request totals for 2023		
Totals	18,201	1,729
Recycling request totals for 2023		
Cardboard (lb)	314,012	
Scrap metal (nonradiological areas) (tons)	421.06	

5.3.13.2. Authorized Limits Clearance Process for Spallation Neutron Source and High Flux Isotope Reactor Neutron Scattering Experiment Samples

The 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 Order 458.1 (DOE 2020) 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 licensing regulations). Implementation of the clearance limits involves using unique instrument screening and methods to predict sample activity to provide an efficient and defensible process to release neutron scattering experiment samples to researchers without further DOE control.

In 2023, ORNL cleared a total of 11 samples from neutron scattering experiments using the sample authorized limits process. All 11 samples were from HFIR. No samples were cleared from SNS in 2023 using the sample authorized limit process.

5.4. Air Quality Program

Permits issued by the State of Tennessee convey the clean air requirements that are applicable to ORNL. These permits and the results of 2023 air monitoring activities are summarized in the following sections.

5.4.1. Construction and Operating Permits

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 radiological air 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 for operations at ORNL. DOE and UT-Battelle also maintained a valid minor source operating permit with the Knox County Department of Air Quality Management for the NTRC facilities, which are in Knox County.

The CFTF was constructed at an off-site location in the Horizon Center Business Park in Oak Ridge, Tennessee. UT-Battelle applied for and received two construction permits for construction of the CFTF (Permit No. 965013P in 2012 and Permit No. 967180P in 2014). The initial start-up of the CFTF occurred in March 2013. The most recent Conditional Major Source Operating Permit for the facility was issued in September 2023 (Permit No. 474951).

DOE/UCOR has one non-Title V Major Source Operating Permit for one emission source at TWPC (Permit No. 071009P and Permit-by-Rule R80800). During 2023, no permit limits were exceeded. Isotek has a Title V Major Source Operating Permit (576448) for the Radiochemical Development Facility (Building 3019 Complex). During 2023, no permit limits were exceeded. UCOR was issued a Title V Major Source Operating Permit (569768) on September 18, 2015, for the Building 3039 Process Off-Gas and Hot Cell Ventilation System. Construction Permit 974744 was issued on November 19, 2018, to implement several proposed modifications to the Title V Operating Permit, and Significant Modification #1 to the Title V Operating Permit was issued on April 5, 2019, incorporating those modifications. The current operating permit (578132) was issued in July 2022. During 2023, no permit limits were exceeded.

5.4.2. National Emission Standards for Hazardous Air Pollutants—Asbestos

Numerous facilities, structures, facility components, and pieces of equipment at ORNL contain asbestos-containing material. UT-Battelle's Asbestos Management Program manages the compliance of work activities involving the removal and disposal of asbestos-containing material. This program includes notifications to TDEC for all demolition activities and required renovation activities, approval of asbestos work authorization requests, implementation of engineering controls and work practices, inspections, air monitoring, and waste tracking of asbestos-contaminated waste material. During 2023, no deviations or releases of reportable quantities of asbestos-containing material occurred.

In 2023, activities related to the Asbestos Management Program included the following:

- No Notification of Demolition or Asbestos Renovation Application submittals were required for the projects contracted or for the removal work activities performed during the calendar year.
- The revised friable asbestos removal annual estimates CY 2023 letter was submitted in November 2023 to modify CY 2023 annual estimates, as required, with quantities of 1,005 ft, 35 ft^2, and 7 ft^3.
- The estimates of friable asbestos removal for CY 2024 (1,185 ft, 285 ft^2, and 50 ft^3) were submitted in December 2023.
- During 2023, a total of 98 asbestos work authorizations were completed for asbestos removal work activities primarily involving pipe insulation and floor tile materials.

5.4.3. Radiological Airborne Effluent Monitoring

Radioactive airborne discharges at ORNL are subject to Rad-NESHAPs 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 (^3H), adsorbable gases (e.g., iodine), and nonadsorbable gases (e.g., noble gases).

The major radiological emission point sources for ORNL consist of the following eight stacks. Seven are located in Bethel and Melton Valleys, and one, the SNS Central Exhaust Facility stack, is located on Chestnut Ridge (Figure 5.7):

- 2026 Radioactive Materials Analytical Laboratory
- 3020 Radiochemical Development Facility
- 3039 central off-gas and scrubber system, which includes the 3500 cell ventilation system, isotope area cell ventilation system, 3025/3026 cell ventilation system, 3042 ventilation system, and 3092 central off-gas system
- 4501 Radiochemistry Laboratory Area 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 2023, there were 14 minor point/group sources, and emission calculations/estimates were made for each of them.

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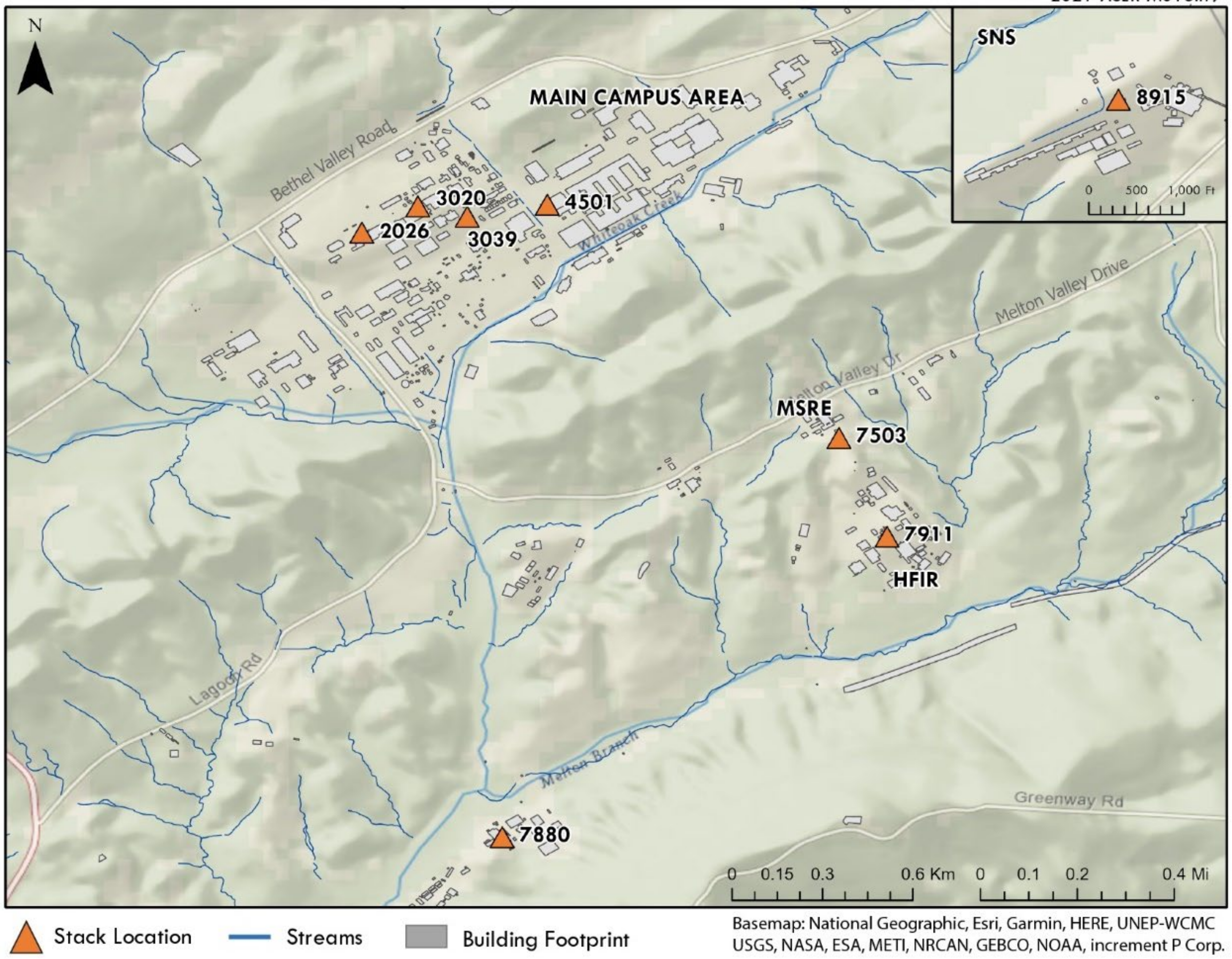

Acronyms:
HFIR = High Flux Isotope Reactor *MSRE = Molten Salt Reactor Experiment* *SNS = Spallation Neutron Source*

Figure 5.7. Locations of major radiological emission points at ORNL, 2023

5.4.3.1. Sample Collection and Analytical Procedure

Three of the major point sources (stacks 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).

Each sampling system generally comprises a multipoint in-stack sampling probe, a sample transport line, a particulate filter, activated charcoal cartridges (or canister), a silica gel cartridge (if required), flow measurement and totalizing instruments, a sampling pump, and a return line to the stack. The 2026 (Radioactive Materials Analytical Laboratory), 4501 (Radiochemistry Laboratory), 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 2026, 4501, and 7911 sampling systems have the same components as the ANSI 1969 sampling systems used for the four major point sources but use stainless-steel-shrouded probes instead of multipoint in-stack sampling probes. The 7911 sampling system also includes 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., 41Ar) 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 (40 CFR 60, Appendix A-1, Method 2) 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. Results obtained from the effluent flow rate totalizer and from EPA Method 2 are compared annually for the 7880 stack. 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 were calculated using a fixed stack flow rate. A fixed stack flow rate was used because the stack velocity at the sampling level was at or below the sensitivity of standard methods for measuring the velocity, and therefore stack flow rates could not be determined. The reduction in velocity was 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 to 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). The 3039 stack velocity was successfully measured with new equipment in November 2019 and in July 2020. Both results were below the fixed stack flow rate; the stack velocity result obtained in 2020 was used for emission calculation purposes in 2023.

In addition to the major sources, ORNL has several 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 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 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 and canisters, particulate filters, and silica gel traps are collected weekly to biweekly. The use of charcoal cartridges (or canisters) 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 composited quarterly or semiannually and are analyzed for alpha-, beta-, and gamma-emitting isotopes. At stack 7880, the filters are collected monthly and analyzed for alpha-, beta-, and gamma-emitting isotopes. The sampling system on stack 7880 requires no other type of radionuclide collection media. Monthly sampling provides a better opportunity for quantification of the low-concentration isotopes. Silica gel traps are used to capture water vapor that may contain ^{3}H. Analysis is performed weekly to biweekly. At the end of the year, the sample probes for all 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. Contaminant deposits are not expected to 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 not more often than every 3 years unless particulate emissions increase, detectable radionuclides in the sample media increase, or process modifications occur.

The data from the charcoal cartridges or canisters, 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 2023 are presented in Appendix G.

Historical trends for ^{3}H and ^{131}I are presented in Figures 5.8 and 5.9. For 2023, 3H emissions totaled about 1,319 Ci (Figure 5.8), comparable to what was seen in 2022; ^{131}I emissions totaled 0.17 Ci (Figure 5.9), an increase from what was seen in 2022. For 2023, of the 404 radionuclides (excluding radionuclides with multiple solubility types) 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 27 percent, and ^{138}Cs, which contributed about 39 percent to the total ORNL dose.

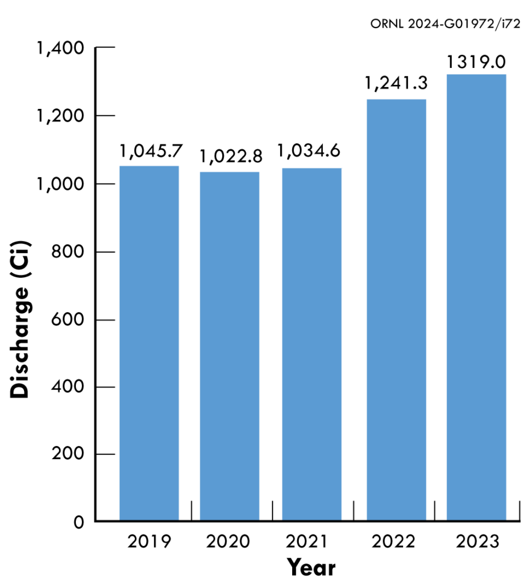

Figure 5.8. Total curies of ^{3}H discharged from ORNL to the atmosphere, 2019–2023

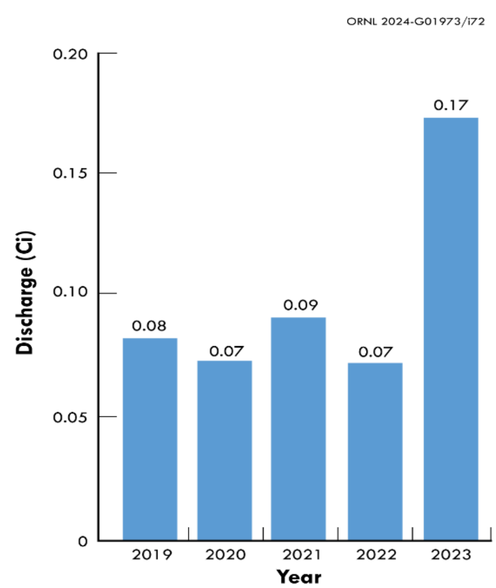

Figure 5.9. Total curies of ^{131}I discharged from ORNL to the atmosphere, 2019–2023

Emissions of ^{212}Pb result from research activities and from the radiation decay of legacy material stored on-site and from areas containing ^{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 3000 and 4000 area laboratory hoods. Emissions of ^{138}Cs result from Radiochemical Engineering Development Center research activities and HFIR operations. For 2023, ^{212}Pb emissions totaled 5.31 Ci, ^{138}Cs emissions totaled 2,190 Ci, and ^{41}Ar emissions totaled 1,040.5 Ci (Figure 5.10).

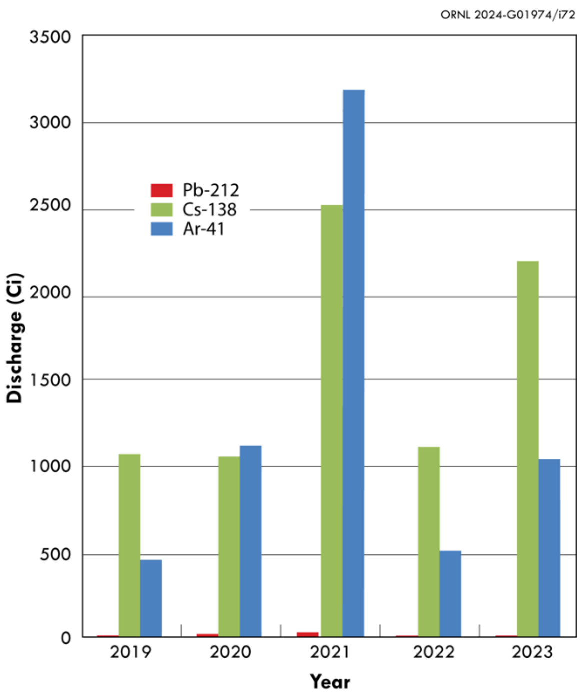

Figure 5.10. Total curies of ^{41}Ar, ^{138}Cs, and ^{212}Pb discharged from ORNL to the atmosphere, 2019–2023

The calculated radiation dose to the maximally exposed individual (MEI) from all radiological airborne release points at ORR during 2023 was 0.6 mrem. The dose contribution to the MEI from all ORNL radiological airborne release points was 15 percent of the ORR dose. This dose is well below the Rad-NESHAPs standard of 10 mrem and is equal to approximately 0.2 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.)

5.4.4. Stratospheric Ozone Protection and Hydrofluorocarbon Phasedown

As required by the CAA Title VI Amendments of 1990 and in accordance with 40 CFR 82, actions have been implemented to comply with the prohibition against intentionally releasing ozone-depleting substances during maintenance activities performed on refrigeration equipment. In 2017, EPA enacted major revisions to the stratospheric ozone rules to include the regulation of substitutes for ozone-depleting substances as part of 40 CFR 82 Subpart F. The revisions became effective January 1, 2018, for the 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. On October 1, 2021, EPA began implementing the hydrofluorocarbons phasedown requirements of the American Innovation and Manufacturing Act (AIM 2020), which seeks to reduce hydrofluorocarbon consumption and production to 15 percent of a 2011–2013 baseline by 2036. (*Phasedown of Hydrofluorocarbons: Establishing the Allowance Allocation and Trading Program under the AIM Act* [EPA 2022a] is available **here**.) Sitewide use of hydrofluorocarbons is being evaluated to understand future effects of AIM Act phasedowns.

5.4.5. Ambient Air

Station 7 in the ORNL 7000 maintenance area is the site-specific ambient air monitoring location. During 2023, the sampling system at Station 7 was used to quantify levels of ^{3}H; 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 ^{3}H as tritiated water. The silica gel was collected biweekly or weekly, depending on ambient humidity, and was composited quarterly for ^3H analysis. Station 7 sampling data (Table 5.9) were compared with the derived concentration standards (DCSs) for air established by DOE as guidelines for controlling exposure to members of the public (DOE 2021b). During 2023, average radionuclide concentrations at Station 7 were less than 1 percent of the applicable DCSs in all cases.

Table 5.9. Radionuclide concentrations measured at ORNL air monitoring Station 7, 2023[a]

Parameter	Concentration (pCi/mL)[b]
Alpha	3.4×10^{-9}
^7Be	2.7×10^{-8}
Beta	1.8×10^{-8}
^{40}K	1.9×10^{-9}
^3H[c]	6.6×10^{-6}
$^{233/234}U$	2.9×10^{-11}
$^{235/236}U$	0
^{238}U	2.8×10^{-11}

[a] *Except for ^3H, each concentration value is based on a single result from annual composites of low-volume filters.*

[b] *1 pCi = 3.7×10^{-2} Bq.*

[c] *Silica gels are composited quarterly for ^3H analysis. The ^3H concentration is the calculated annual average.*

5.5. ORNL Water Quality Program

NPDES Permit TN0002941—issued to DOE for the ORNL site, reissued by the State of Tennessee in 2019, and modified in 2022 and again in 2023—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, and storm water) and requirements for developing and implementing a water quality protection plan (WQPP). The permit calls for a WQPP to "efficiently utilize the facility's financial resources to measure its environmental impacts."

Rather than prescribing rigid monitoring schedules, the ORNL WQPP is flexible and focuses on significant findings. It is implemented using an adaptive management approach whereby results of investigations are routinely evaluated and strategies for achieving goals are modified based on those evaluations. The goals of 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 DOE and was approved by TDEC in 2008, and WQPP monitoring was initiated in 2009. The WQPP originally incorporated several control plans that were required under the previous NPDES permit, including a biological monitoring and abatement plan, a chlorine control strategy, a storm water pollution prevention plan, a non–storm water best management practices plan, and a radiological monitoring plan. Radiological monitoring requirements were removed in the February 2023 permit modification, but some radiological monitoring is still performed to comply with DOE Order 458.1.

To prioritize the stressors and contaminant sources that may be of greatest concern to water quality and to define conceptual models to guide any special investigations, the WQPP strategy was defined using EPA's *Stressor Identification Guidance Document* (EPA 2000). 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).
3. 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 White Oak Creek (WOC) watershed.

Monitoring and investigation data collected under the ORNL WQPP are analyzed, interpreted, reported, and compared with past results at least annually. A summary of significant findings is reported in the *Annual Site Environmental Report*, and a more comprehensive report of findings is submitted to TDEC on an annual basis. This information is used to assess 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.

5.5.1. Treatment Facility Discharges

The ORNL Sewage Treatment Plant (STP) and the ORNL PWTC appropriately treat the various R&D, operational, and domestic wastewaters generated by site staff and research activities. Both are permitted to discharge treated wastewater and are monitored under NPDES Permit TN0002941, issued by TDEC to DOE for the ORNL site. The ORNL NPDES permit requirements include monitoring the two ORNL wastewater treatment facility effluents for conventional and water quality–based constituents and for effluent toxicity with numeric parameter-specific compliance limits established by TDEC as determined to be necessary. 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 Section 5.3.4 (Table 5.5). Compliance with permit limits for ORNL wastewater treatment facilities was 99.9 percent in 2023.

Toxicity testing provides an assessment of any potential harmful effects from the total combined constituents in discharges from ORNL wastewater treatment facilities. The NPDES permit has required testing of effluents from the STP for toxicity to aquatic species since 1986, and effluents from the PWTC have been tested since it went into operation in 1990. Test species have been Ceriodaphnia 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. In past years, the STP and PWTC have shown isolated indications of effluent toxicity, 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 chronic toxicity from the ORNL STP and PWTC. In 2023 no toxicity was observed in any of the tests at either of the wastewater treatment facilities. In addition, the TDEC Division of Water Resources performed an NPDES permit compliance evaluation inspection at ORNL in 2023, which included a supplementary toxicity test at both the STP and PWTC, and no toxicity was observed in the results from either test.

5.5.2. Residual Bromine and Chlorine Monitoring

ORNL receives potable water from the City of Oak Ridge Department of Public Works, which uses chlorine as a final disinfectant. On the ORNL site, potable water is used for drinking, sanitary, and housekeeping purposes as well as for research processes and in cooling systems. After the water is used, residual chlorine remains and can be toxic to fish and other aquatic life if discharged to surface water. Residual chlorine in wastewater routed to the STP is generally consumed in reactions with other substances within the collection and treatment system, and any residual chlorine in wastewater routed to the PWTC is removed by final activated carbon filtration.

The NPDES permit requires monitoring total residual oxidant (TRO) levels at 12 different instream locations twice a month. In addition, oxidant levels at outfalls with potential chlorine/bromine sources are routinely monitored via the WQPP TRO control strategy (also referred to as the chlorine control strategy). The NPDES permit establishes an action level of 1.2 g/day for TRO loading at all outfalls. A root cause analysis is performed for action level exceedances, and corrective actions are taken to reduce chlorine/bromine loading to less than 1.2 g/day.

In 2023, TRO was monitored twice a month at outfalls that receive cooling tower discharges and once-through cooling water. Less frequent monitoring was conducted at other outfalls (semimonthly, monthly, quarterly, or semiannually if flow was present). A total of 388 TRO measurements were taken at 25 locations, in addition to 288 semimonthly instream measurements. TRO was detected at or above the end-of-pipe action level on 19 occasions during 2023 but was never detected at any of the 12 instream monitoring points (Table 5.10).

Table 5.10. Overview of 2023 chlorine control strategy

Total residual oxidant sampling events	676
Below detection (<0.05 mg/L)	604
Instream total residual oxidant exceedances	0
Outfall detections	19
Outfall action level detections (>1.2 g/day)	19
Number of outfalls with action level detections	6

5.5.2.1. Monitoring Results and Corrective Actions

Actions in response to point-source TRO monitoring include source investigations, source elimination, addition of pretreatment dechlorination systems, emergency repairs, and dechlorination system adjustments. Inspections of the sodium sulfite tablet feeders are also conducted to ensure that they are refilled and in good condition and that any fouled tablets are removed for disposal. In addition, as a storm water best management practice, potential residual chlorine/bromine sources or leaks are dechlorinated prior to discharge in the WOC watershed to reduce risk of harm to aquatic life and the environment.

Table 5.11 summarizes 2023 TRO detections greater than 1.2 g/day and any additional investigation actions or repairs.

Table 5.11. Total residual oxidant mitigation summary: emergency repairs, 2023

Outfall	Date	TRO (mg/L)	Flow (gpm)	Load (g/day)	Receiving stream	Downstream water kilometer	Instream monitoring point	Notes
210	3/16/2023	2.2	40	477.51	WOC	WCK 4.1	X18	Once-through cooling liquid dechlorination system was inoperable in 2023 due to pump failure. Dechlorination was facilitated with sodium sulfite tablets.
210	4/21/2023	2.0	25	269.82	WOC	WCK 4.1	X18	
210	6/29/2023	0.3	25	36.52	WOC	WCK 4.1	X18	
210	7/24/2032	1.8	15	147.18	WOC	WCK 4.1	X18	
210	9/18/2023	0.3	20	30.53	WOC	WCK 4.1	X18	
210	11/27/2023	1.7	45	417.00	WOC	WCK 4.1	X18	
210	12/7/2023	1.2	35	228.94	WOC	WCK 4.1	X18	
211	7/24/2023	0.4	45	98.12	WOC	WCK 4.4	X22	Once-through cooling is present in this drainage network. Flows are dechlorinated at the end of the pipe with tablets.
231	11/27/2023	1.3	120	850.35	WOC	WCK 4.4	X25	Sodium sulfite tablets placed in a bucket at outfall.
231	12/22/2023	0.1	20	7.63	WOC	WCK 4.4	X25	
267	1/6/2023	0.1	25	13.63	FFK	FFK 0.1	X20	Source unknown but suspected as coming from drainage in Building 3144.
267	5/17/2023	1.2	3	18.81	FFK	FFK 0.1	X20	
267	8/21/2023	0.1	5	2.73	FFK	FFK 0.1	X20	
267	10/16/2023	0.8	15	67.05	FFK	FFK 0.1	X20	
314	1/6/2023	0.1	45	24.53	WOC	WCK 4.4	X26	Foundation sump pumping of chlorinated water, which was redirected and dechlorinated with tablets.
314	1/27/2023	0.7	20	76.31	WOC	WCK 4.4	X26	
314	5/26/2023	0.3	1	1.64	WOC	WCK 4.4	X26	Cooling tower tablet dechlorination failure. Tablets replaced.
363	7/10/2023	1.5	20	163.53	FFK	FFK 0.1	X20	Cooling tower blowdown dechlorination system failure. Sodium sulfite tablets are placed at the end of pipe.
363	8/21/2023	1.6	20	173.34	FFK	FFK 0.1	X20	

Acronyms:
FFK = Fifth Creek kilometer
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 per DOE Order 458.1. Table 5.12 details the analyses performed on samples collected in 2023 at 2 treatment facility outfalls, 4 instream monitoring locations, and 16 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 2023, dry-weather grab samples were collected at 11 of the 16 category outfalls targeted for sampling. Five category outfalls were not sampled because no discharge was present during sampling attempts.

The two ORNL treatment facility outfalls that were monitored for radioactivity in 2023 were the STP outfall (Outfall X01) and the PWTC outfall (Outfall X12). The four instream locations that were monitored were the WOC headwaters, X13 on Melton Branch, X14 on WOC, and X15 at White Oak Dam (WOD) (Figure 5.11). At each treatment facility outfall and instream monitoring location, monthly flow-proportional composite samples were collected using dedicated automatic water samplers.

A DCS for each radioisotope is used to evaluate discharges of radioactivity from DOE facilities (DOE 2021b). 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 met or exceeded 4 percent of the relevant DCS concentration in dry-weather discharges from Outfalls X01, X12, 085, 207, 302, and 304 (Figure 5.12). In 2023, no dry-weather discharges from sampled outfalls had an annual mean radioactivity concentration greater than 100 percent of a DCS.

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 5.13 through 5.17. Because discharges of radioactivity are somewhat correlated to stream flow, annual flow volumes measured at the WOD monitoring station are given in Figure 5.18. Discharges of radioactivity at WOD in 2023 were similar to discharges during other recent years, particularly when differences in annual flow volume are considered, and continue to be generally lower than in the years preceding completion of the waste area caps in Melton Valley (substantially complete by 2006).

No wet-weather sampling was conducted in 2023 due to changes in the NPDES permit.

Table 5.12. Radiological outfall and instream monitoring conducted at ORNL, 2023

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	Annually	X								
Outfall 080[a]	Annually									
Outfall 081	Annually	X		X						
Outfall 085	Monthly	X	X			X				
Outfall 203[a]	Annually									
Outfall 207	Monthly	X	X							
Outfall 211	Annually	X	X			X				
Outfall 234[a]	Annually									
Outfall 281	Quarterly	X		X						
Outfall 282	Annually	X								
Outfall 302	Monthly	X	X	X		X	X	X	X	X
Outfall 304	Monthly	X	X	X		X	X	X	X	X
Outfall 365	Annually	X								
Outfall 368[a]	Annually									
Outfall 383	Annually	X		X						
Outfall 484[a]	Annually									
WOCHW	Monthly	X	X	X	X	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 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
WOCHW = White Oak Creek headwaters
WOD = White Oak Dam

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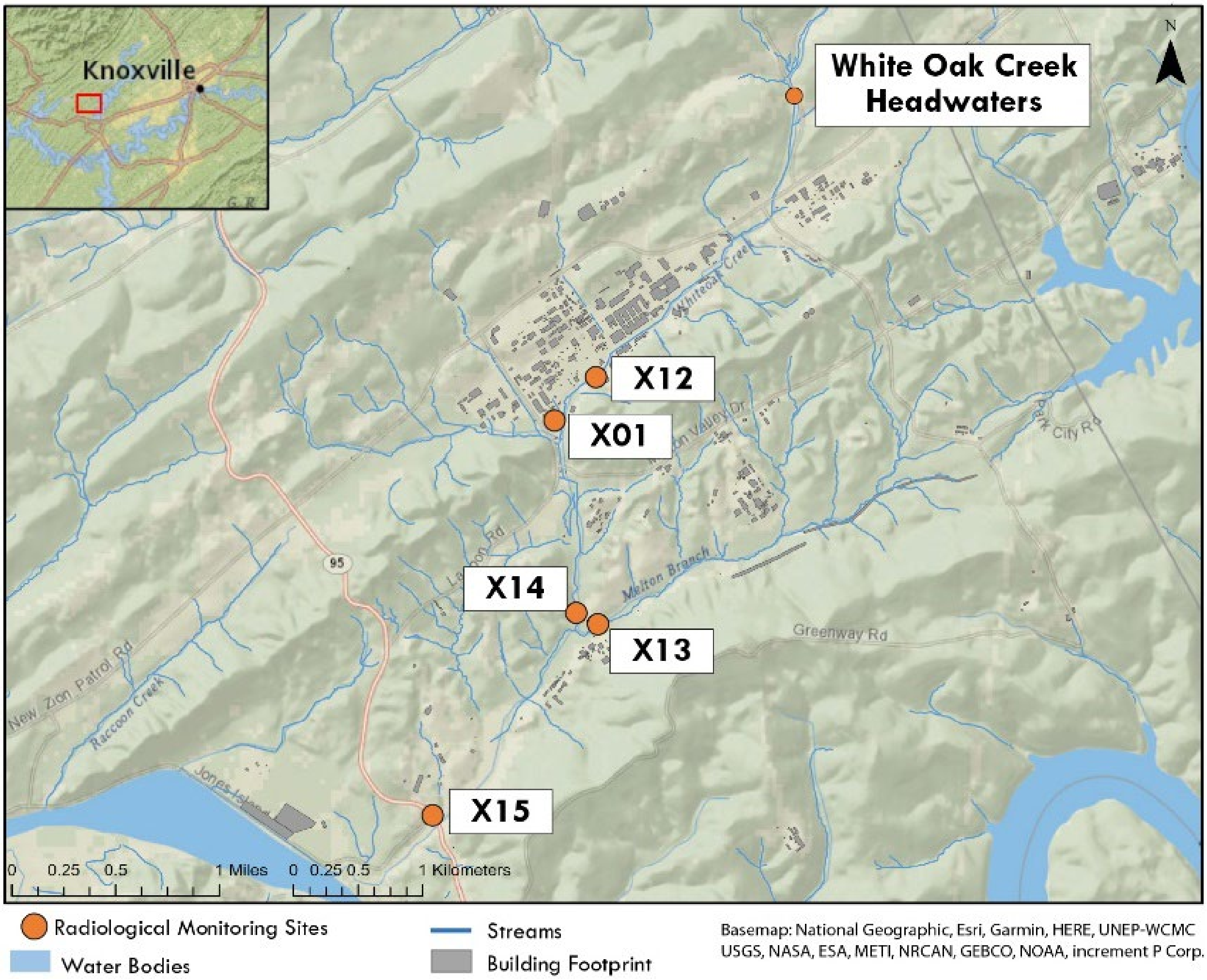

Figure 5.11. Selected surface water, National Pollutant Discharge Elimination System, and reference sampling locations at ORNL

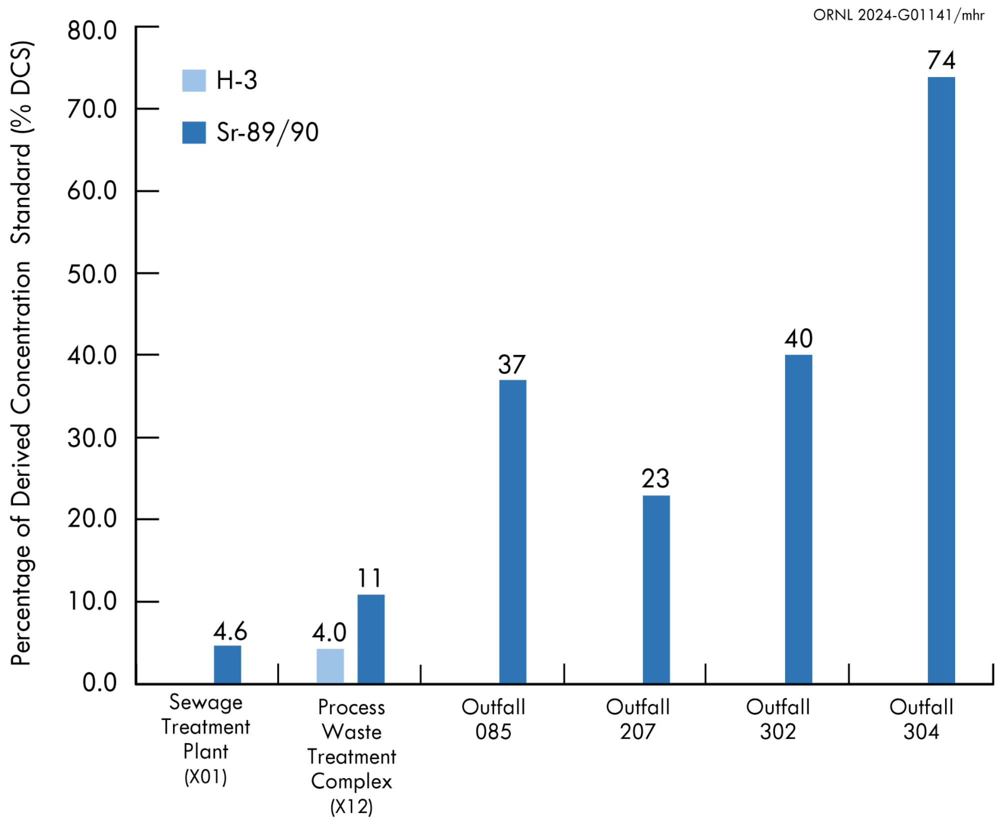

Figure 5.12. Outfalls and instream locations at ORNL with average radionuclide concentrations greater than 4 percent of the relevant derived concentration standards, 2023

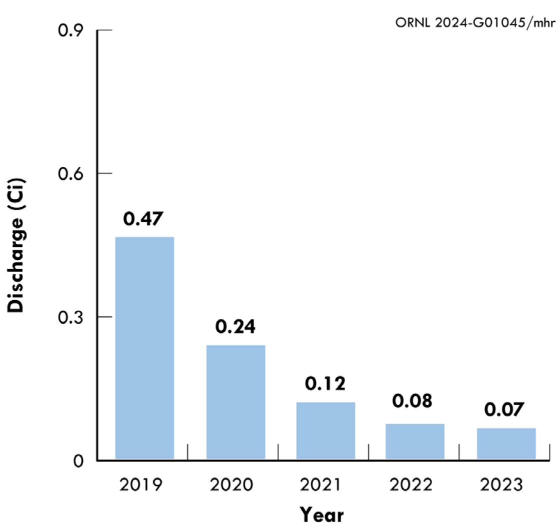

Figure 5.13. Cesium-137 discharges at White Oak Dam, 2019–2023

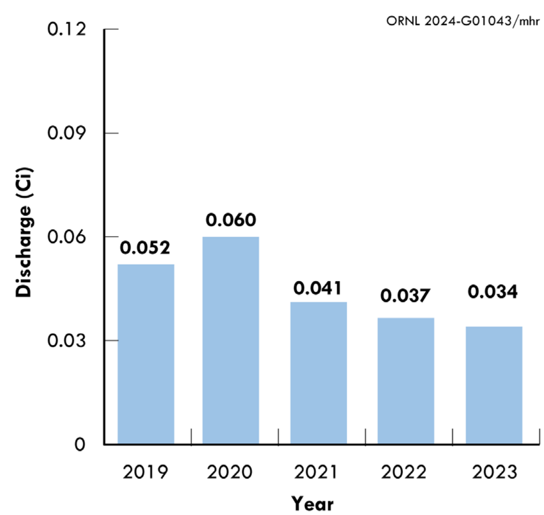

Figure 5.14. Gross alpha discharges at White Oak Dam, 2019–2023

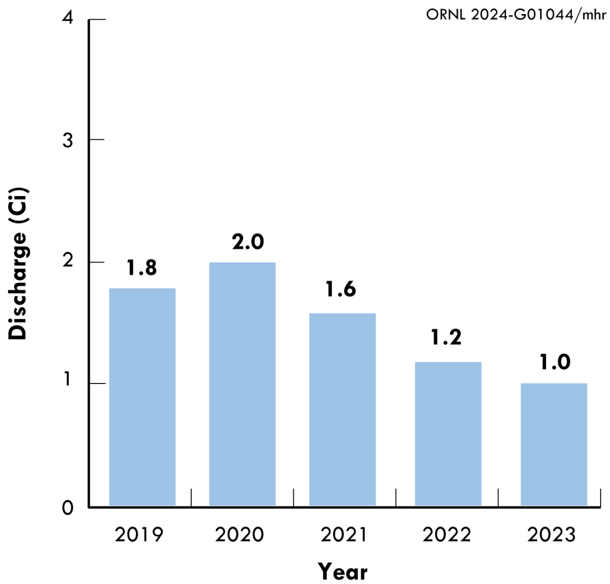

Figure 5.15. Gross beta discharges at White Oak Dam, 2019–2023

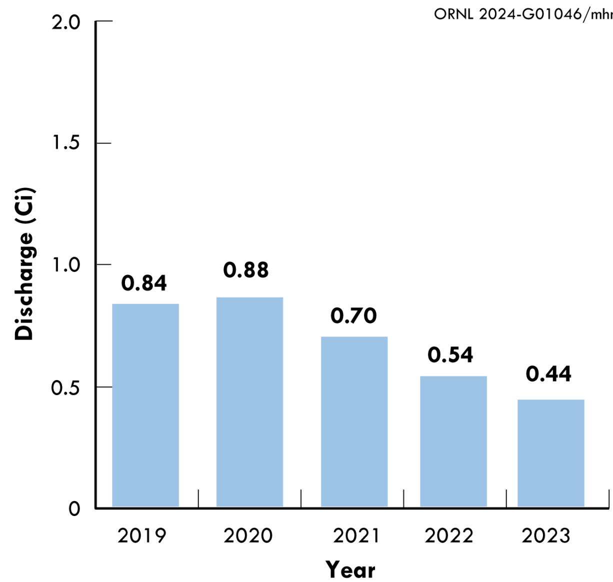

Figure 5.16. Total radioactive strontium discharges at White Oak Dam, 2019–2023

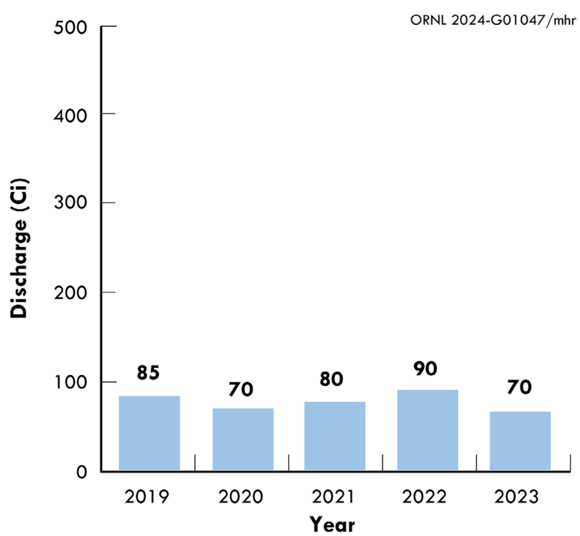

Figure 5.17. Tritium discharges at White Oak Dam, 2019–2023

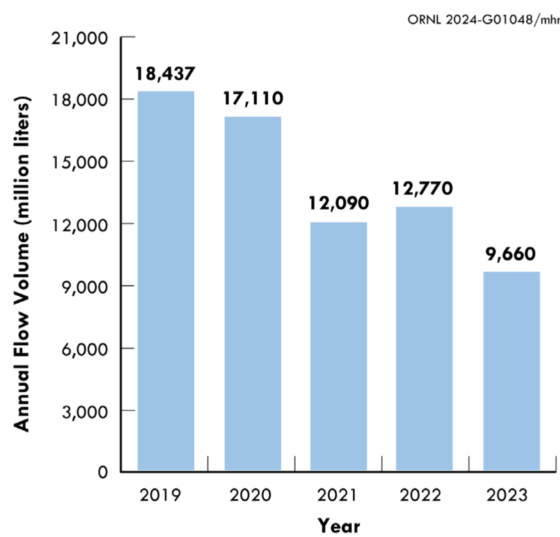

Figure 5.18. Annual flow volume at White Oak Dam 2019–2023

5.5.4. Mercury in the White Oak Creek Watershed

During the mid-1950s, mercury (Hg) was used for pilot-scale isotope separation work in Buildings 3592, 4501, and 4505 and in spent-fuel reprocessing in Building 3503. By 1963, this work had transferred to Y-12. Buildings 4501 and 4505, located east of Fifth Creek and north of WOC, are still active research facilities. In the 1990s two settling ponds for process wastewaters from these buildings were removed, and discharges were rerouted to the PWTC for treatment. Figure 5.19 depicts Outfalls 211 and 207 and associated storm drain connections that are potential legacy Hg sources.

In 1996, the Building 4501 foundation sump was found to contain legacy Hg because of its volatility and from its use and spills in the 1950s. The foundation sump discharged to storm Outfall 211 (Figure 5.19) on WOC; a smaller foundation sump in the building discharged to Outfall 263 on Fifth Creek. By 2008 the foundation sump had been rerouted to the PWTC, and by 2011, an Hg pretreatment system had been installed on the larger sump. Discharge from the foundation sumps in Buildings 4501 and 4500N and from the smaller sump in Building 4501 had also been rerouted along with the smaller sump and a 4500N foundation sump to the PWTC. Outfall 211 and Outfall 363 storm piping still receives other sources of storm water, cooling water, and steam condensate discharges. Buildings 3592 and 3503 were demolished under the CERCLA remedial process in 2011 and 2012, respectively; their footprints and associated storm water drains remain in the Outfall 207 storm water drainage system. Because of the persistence of elemental Hg, its volatility, and the complexity of its interactions in piping and soil, legacy Hg continues to be monitored and assessed at these storm outfalls.

Legacy Hg associated with process infrastructure has also been found in other areas, such as north of the Fifth Street and Central Avenue intersection and in the Outfall 304 drainage area. Storm water exchange with process leaks has occurred in the past.

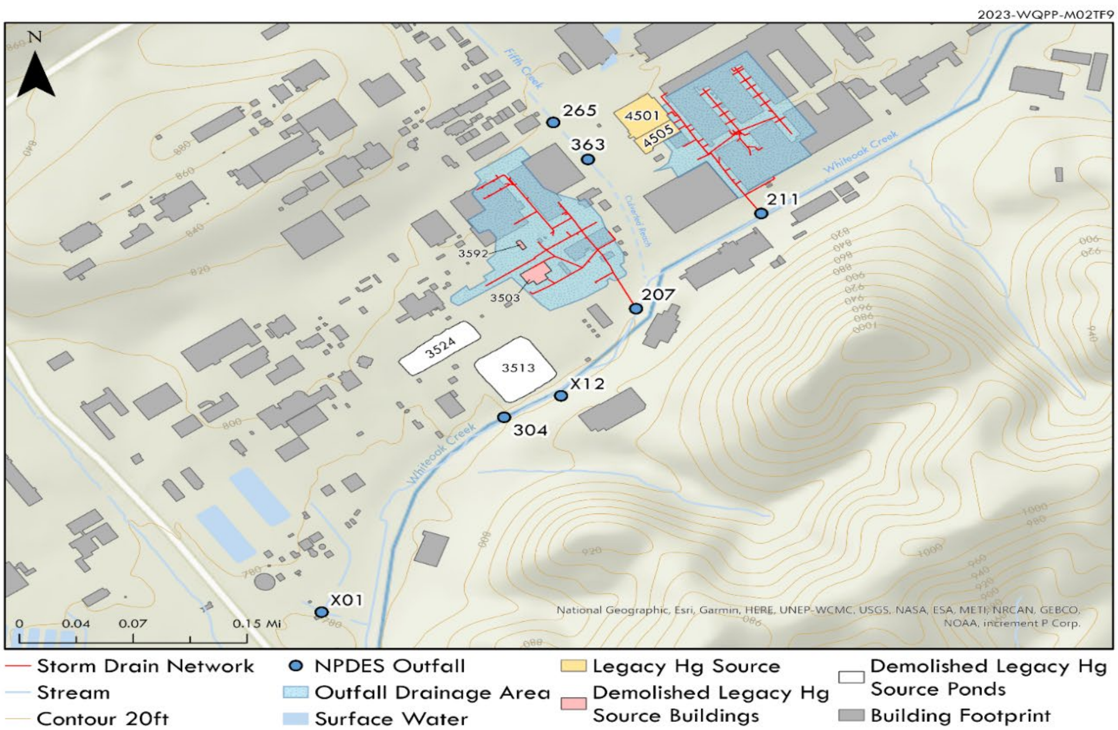

Figure 5.19. Outfalls and associated storm drain connections that are potential mercury sources, 2023

5.5.4.1. Mercury in Ambient Water

Aqueous Hg monitoring in WOC continued in 2023 with quarterly grab sampling at five instream sites: White Oak Creek kilometer (WCK) 1.5, WCK 2.3, WCK 3.4, WCK 4.1, and WCK 6.8 (Figure 5.20). Samples were collected to be representative of seasonal base flow conditions (dry weather, clear flow). Historical sampling results show that Hg concentrations are typically higher under those conditions.

In 2023, the average concentration of Hg in WOC upstream from ORNL (WCK 6.8) was less than 3 ng/L, and the highest value was 3.5 ng/L. Waterborne Hg concentrations in WOC downstream of ORNL (Figure 5.21) were above Tennessee recreational-use water quality criteria (WQCs) from 1997 to 2007 but declined abruptly in 2008 as a result of actions to reduce Hg discharges to WOC at Outfall 211 (sump reroutes to the PWTC) and to reduce Hg discharges from the PWTC. Since 2008, the results from WQPP Hg monitoring have met Tennessee Hg WQCs for recreational use (51 ng/L), with only a few exceptions. Applying recreational-use WQCs to the WOC watershed is very conservative because the watershed is on ORR and is not accessible to the public. In general, ambient concentrations have remained low since 2008, with a few exceptions. In 2023, Hg concentrations were well below WQCs at all the instream sites that were monitored (Figure 5.21). The average aqueous Hg concentration at WOD (WCK 1.5) was 27.45 ng/L compared with 16.33 ng/L in 2022.

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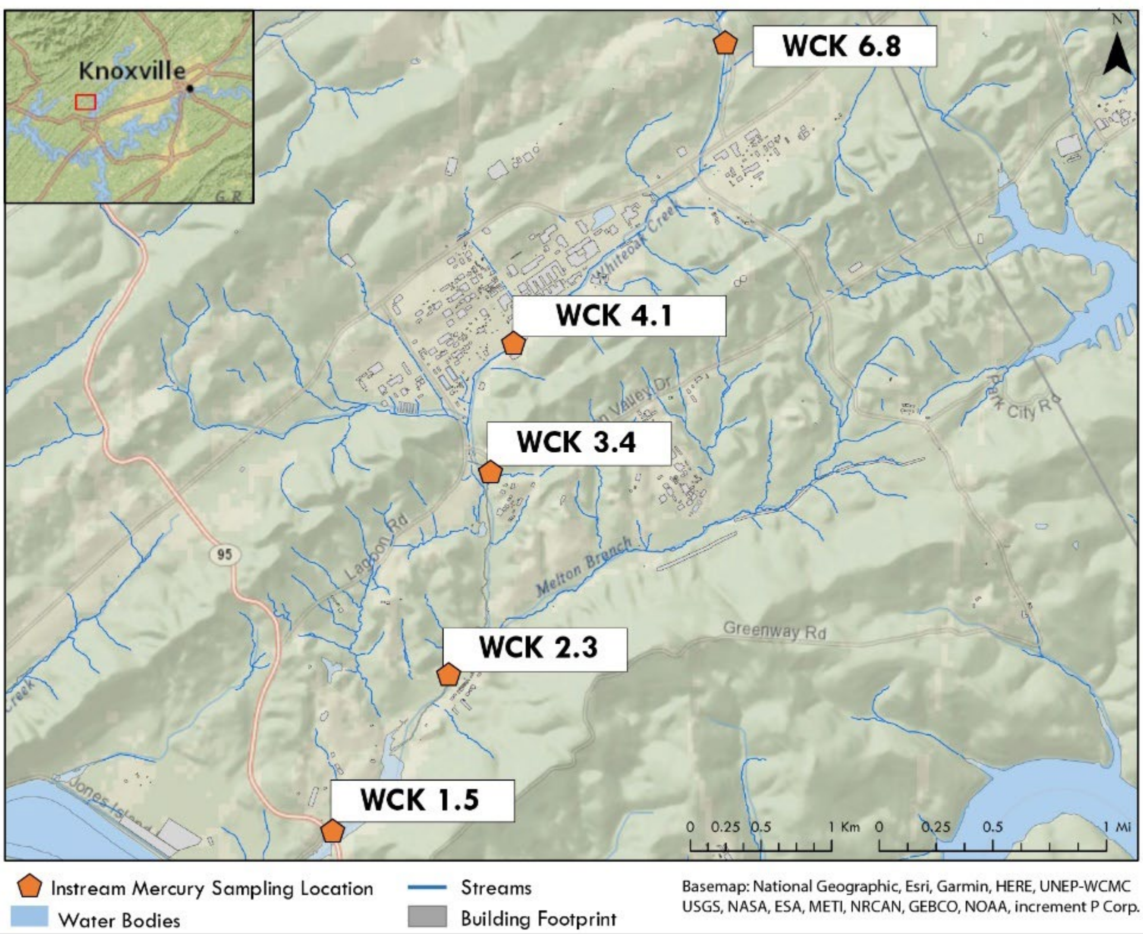
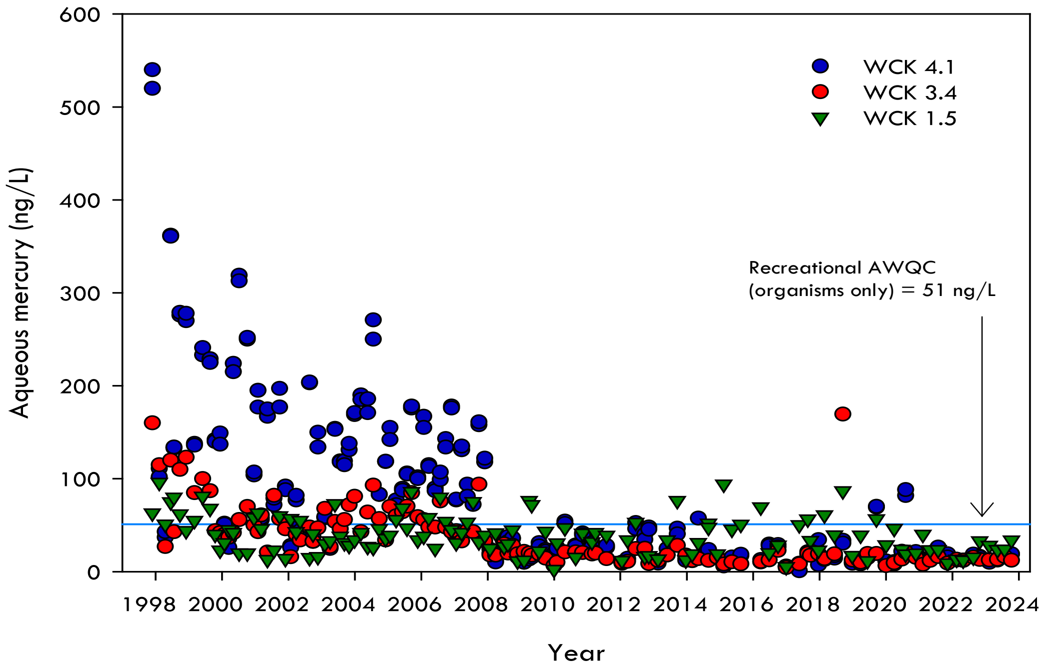


Figure 5.20. Instream mercury monitoring and data locations, 2023



Note: *The blue line at 51 ng/L shows the recreational water quality criteria for water and organisms.*

Acronym: *WCK = White Oak Creek kilometer AWQC = ambient water quality criterion*

Figure 5.21. Aqueous mercury concentrations of grab samples at sites in White Oak Creek downstream from ORNL, 1998–2023

5.5.4.2. Water Quality Protection Plan Mercury Investigation—Treatment Plants

The STP and the PWTC (Outfalls X01 and X12, respectively) are monitored quarterly for Hg, and results are reported to TDEC in monthly discharge monitoring reports required by the NPDES permit. Twenty-four-hour composite samples are taken at both locations, and flow rates are measured and recorded.

Concentrations of Hg in discharges from the STP (X01) averaged 2.0 ng/L in 2023, and Hg concentrations in discharges from the PWTC (X12) averaged 48.75 ng/L. Trends in total Hg concentrations are shown in Figure 5.22 for the STP (Outfall X01) from 2012 to 2023 and in Figure 5.23 for the PWTC (Outfall X12) from 2009 to 2023.

The 2023 quarterly dry-weather sampling at X01 and X12 was coordinated with Hg sampling at instream locations WCK 4.4 (upstream of the two treatment plant outfalls), WCK 3.4 (7500 Bridge monitoring station downstream of the ORNL central campus and both wastewater treatment plant outfalls), and WCK 1.5 (X15) at WOD. These data are presented in Figure 5.24.

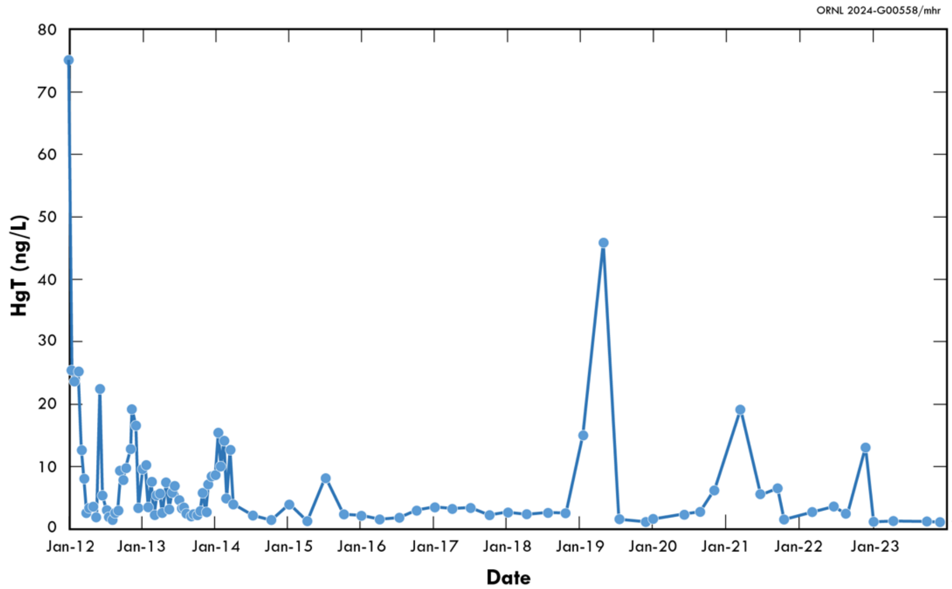


Figure 5.22. Total mercury concentrations in discharges to Outfall X01 from the Sewage Treatment Plant, 2012–2023

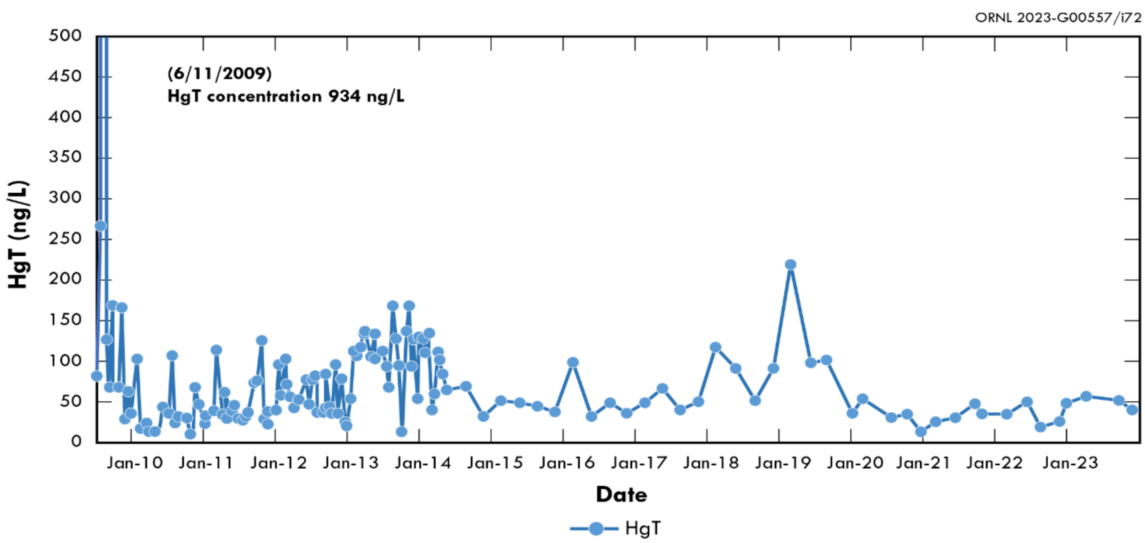


Figure 5.23. Total mercury concentrations in discharges to Outfall X12 from the Process Waste Treatment Complex, 2009–2023

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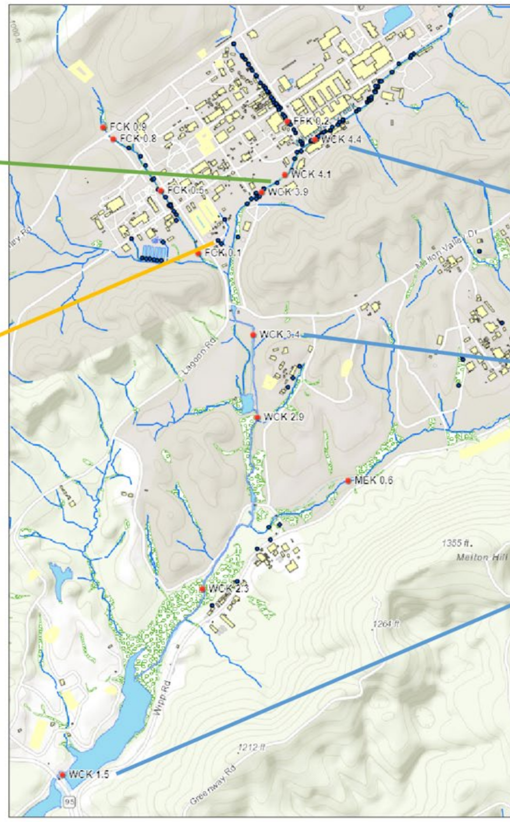
Treatment Plant
24 h composites HgT

Outfall X12 (PWTC)	
Date	HgT (ng/L)
01/10/23	48
04/12/23	56
09/06/23	51
11/28/23	40

Outfall X01 (STP)	
Date	HgT (ng/L)
01/10/23	1.9
04/12/23	3.0
09/06/23	1.79
11/28/23	1.31



Instream
24 h composites
HgT (51 ng/L WQC)

WCK 4.4	
Date	HgT (ng/L)
01/10/23	2.1
04/12/23	15.0
09/06/23	13.6
11/28/23	21.5

WCK 3.4 (7500 Bridge)	
Date	HgT (ng/L)
01/10/23	6.3
04/12/23	9.1
09/06/23	14.4
11/28/23	11.6

WCK 1.5 (White Oak Dam)	
Date	HgT (ng/L)
01/10/23	15
04/12/23	17
09/06/23	27
11/28/23	18.2

Acronyms:
PWTC = Process Waste Treatment Complex
STP = Sewage Treatment Plant
WCK = White Oak Creek kilometer
WQC = water quality criteria

Figure 5.24. Coordination of treatment plant sampling with instream sampling sites at ORNL, 2023

5.5.4.3. Legacy Outfall Point Source and Non–Point Source Investigation

Legacy Hg outfalls are investigated as part of the WQPP to better delineate Hg sources and to prioritize future abatement actions. WQPP Hg monitoring includes both point source outfalls and non–point source storm water runoff but focuses mainly on several outfalls in the central part of the main ORNL campus known to be contaminated with legacy Hg.

In 2023 most of the WQPP dry-weather Hg monitoring was conducted along WOC and portions of Fifth Creek at Outfalls 207, 211, 265, 304, and 363 (Figure 5.19). As in past years, 2023 WQPP legacy Hg monitoring focused on Outfalls 207 and 211, which generally show the highest Hg concentrations. In 2023, discharged water volumes, and therefore Hg fluxes, from Outfall 211 were higher than those from Outfall 207. This is consistent with previous volume and flux measurements from these locations. Figures 5.25 and 5.26 show trends in dry-weather Hg sampling from Outfalls 207 and 211, respectively. In 2023, point source Hg investigations and monitoring (if flow was present) were also performed at Outfalls 265, 304, and 363, where Hg has been detected at levels of interest in the past likely due to the prevalence of Hg used historically in nearby buildings and from other legacy sources in these areas. In 2023, no dry-weather flow was recorded at Outfall 265, and the average dry-weather Hg concentrations at Outfalls 304 and 363 were low (4.94 and 45.3 ng/L, respectively).

WQPP non–point source Hg monitoring was also undertaken in 2023. Semiannual wet-weather sampling at Outfalls 207, 211, 265, 304, and 363 was completed. Trends in wet-weather unfiltered Hg sampling results at Outfalls 207 and 211 are presented in Figures 5.27 and 5.28, respectively. In 2023, the average wet-weather sampling results were approximately 8.25 ng/L at Outfall 265, 8.65 ng/L at Outfall 304, and 21.85 ng/L at Outfall 363. Dry- and wet-weather Hg fluxes at Outfalls 207 and 211 either declined in 2023 or were comparable to fluxes in previous years (Figures 5.25–5.28).

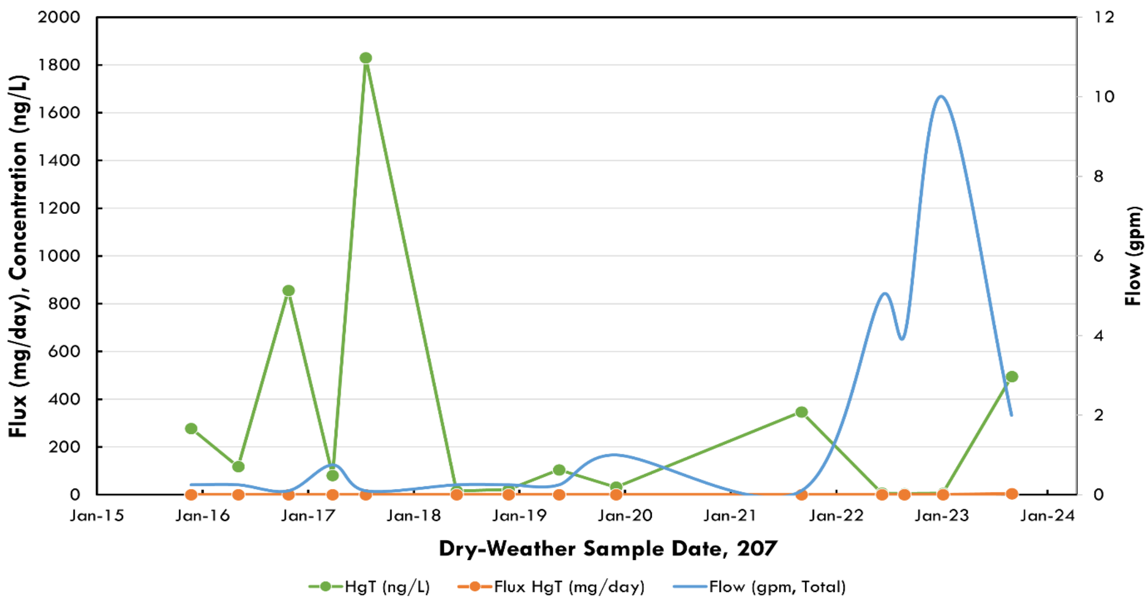


Figure 5.25. Outfall 207 dry-weather flow rate, total mercury concentration (unfiltered), and flux, 2016–2023

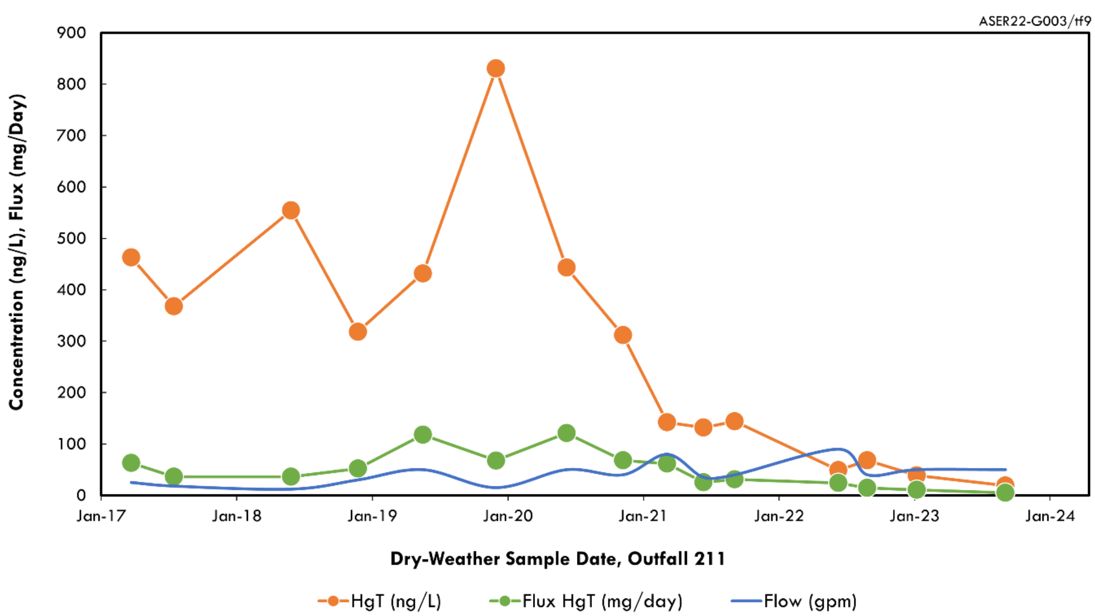


Figure 5.26. Outfall 211 dry-weather flow rate, total mercury concentration (unfiltered), and flux, 2017–2023

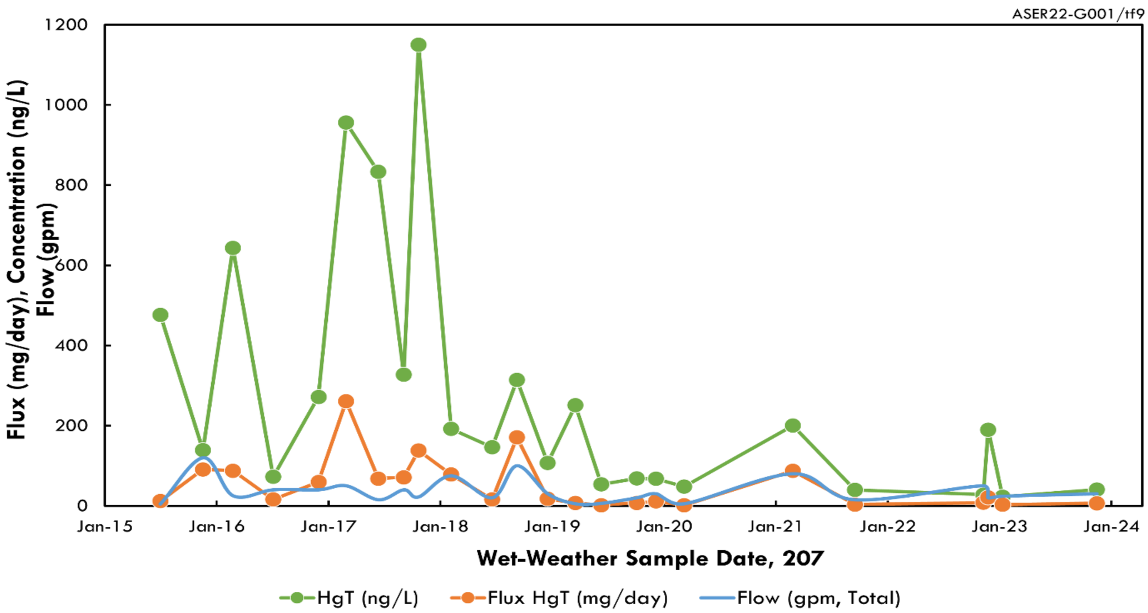


Figure 5.27. Outfall 207 wet-weather flow rate, total mercury concentration (unfiltered), and flux, 2015–2023

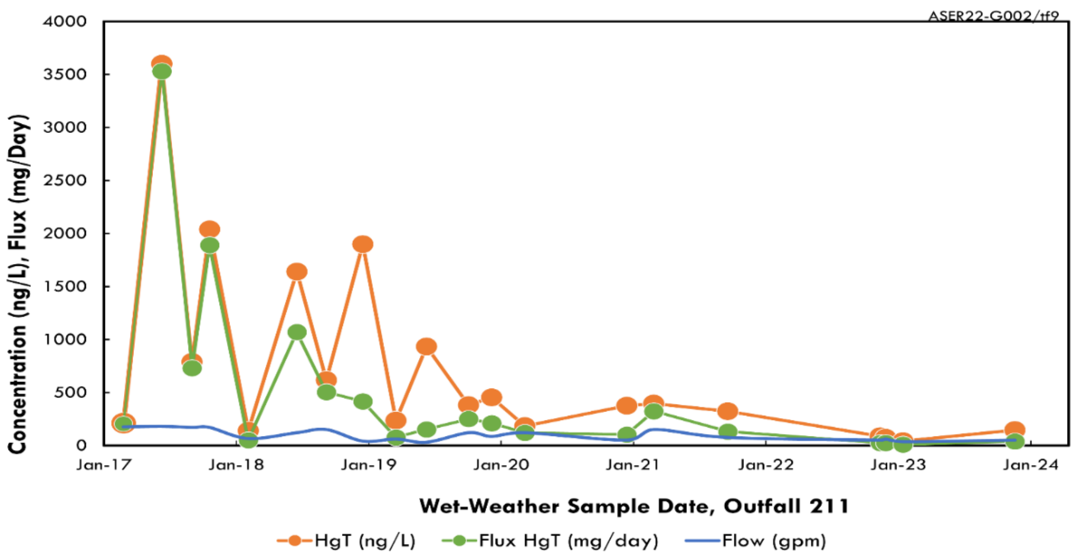


Figure 5.28. Outfall 211 wet-weather flow rate, total mercury concentration (unfiltered), and flux, 2017–2023

5.5.5. Storm Water Surveillances and Construction Activities

Storm water drainage areas at ORNL are inspected semiannually in accordance with WQPP requirements. These areas encompass typical office, industrial, and research settings with surface features such as laboratories, support facilities, paved areas, and grassy lawns. ORNL maintains a robust safety materials management system, ensuring proper tracking, handling, and storage of materials to mitigate potential impacts to storm water. Additionally, ORNL adheres to various regulations governing materials handling, storage, and disposal and waste management, minimizing the risk of environmental release. ORNL also has a storm water best management practice plan that outlines approved actions and guidance to minimize storm water runoff impacts.

Although outdoor materials are temporarily located throughout the ORNL campus, most movement and storage activities occur in the 7000 Area, which is situated on the east end of the site and houses craft and maintenance shops. Smaller outdoor storage areas are dispersed across the site, including loading docks and material delivery areas at laboratory and office buildings. Outdoor materials typically are finished metal items; equipment awaiting use, disposal, or repair; aging infrastructure; and construction equipment and materials, as observed during field inspections. Results of drainage area inspections are documented in electronic map files by the Water Quality Protection group.

Any construction project exceeding 1 acre is required to be permitted under the Tennessee General NPDES Permit for Storm Water Discharges Associated with Construction Activity, necessitating routine inspections by Tennessee-certified erosion and sedimentation control inspectors throughout the project duration. As a best management practice, ORNL mandates routine inspections by Tennessee-certified erosion and sedimentation control inspectors for subcontracted construction projects that are smaller than 1 acre and not covered under the Tennessee General NPDES Permit for Storm Water Discharges Associated with Construction Activity.

Storm water discharges from current ORNL research laboratory operations contain minimal pollutants primarily originating from ongoing site construction, grounds maintenance, and utility operations. Despite being an active cleanup site with legacy contamination regulated under CERCLA and the Atomic Energy Act for radiological constituents, historical storm water pollutants at ORNL have been limited.

5.5.6. Biological Monitoring

Biological monitoring programs conducted at ORNL in 2023 included bioaccumulation studies in the WOC watershed; benthic macroinvertebrate monitoring in WOC, First Creek, and Fifth Creek; and fish community monitoring in WOC and its major tributaries. The following sections summarize the biological monitoring programs at ORNL and the results for 2023.

5.5.6.1. Bioaccumulation Studies

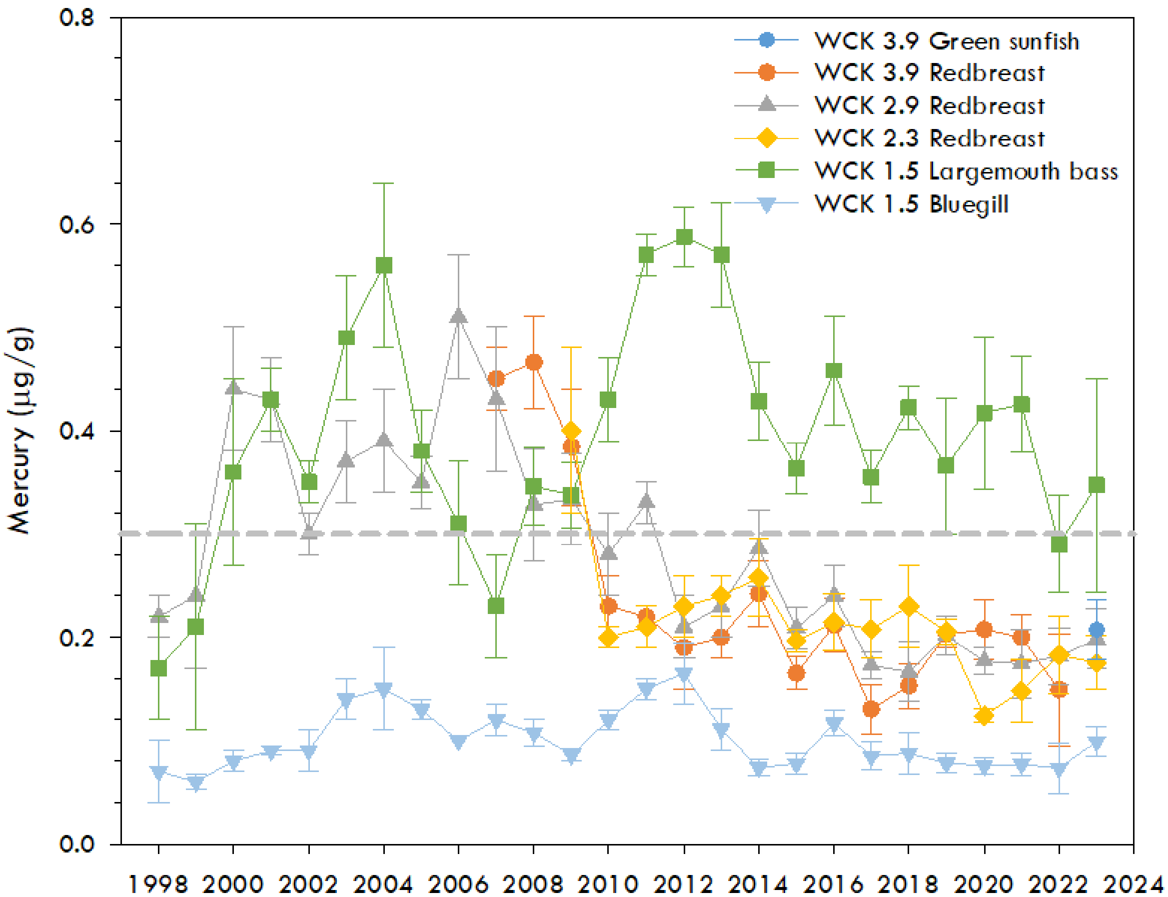
Bioaccumulation tasks for the biological monitoring and abatement plan address two NPDES permit requirements at ORNL: (1) evaluate whether Hg at the site is contributing to streams at a level that will adversely affect fish and other aquatic life or that will violate the recreational criteria and (2) monitor the status of PCB contamination in fish tissue in the WOC watershed. Concentrations of Hg in fish in the WOC watershed are monitored annually and are evaluated relative to the EPA ambient water quality criterion (AWQC) of 0.3 µg/g in fish fillets, a concentration considered protective of human health and the environment. Concentrations of PCBs in fish fillets are also monitored annually and are evaluated relative to TDEC fish advisory limits.

Bioaccumulation in fish

Mercury concentrations in fish have been below human health risk thresholds (e.g., EPA-recommended fish-based AWQCs [0.3 µg/g for Hg]) in the stream portions of WOC for a decade due to actions taken in 2007 to treat the water in a Hg-contaminated sump (Figure 5.29). In 2023, Hg concentrations in fish collected throughout WOC remained similar those seen in 2022. In 2023, Hg concentrations in bluegill and redbreast sunfish samples collected throughout the WOC watershed remained below the AWQC for Hg in fish; Hg concentrations in largemouth bass samples from WCK 1.5 were slightly above this AWQC. Largemouth bass are larger, longer-lived fish at the top of the food web and are therefore expected to have higher Hg concentrations than other sunfish species, but longer-term trends suggest a significant decrease in Hg concentrations over the past decade in this species.

In 2023, PCB concentrations (defined as the sum of Aroclors 1248, 1254, and 1260) in fish collected throughout the WOC watershed remained within historical ranges at all stream sites, averaging below 0.4 µg/g (Figure 5.30).

While these concentrations are above concentrations seen in fish collected from reference sites off ORR, there are no federal guidelines for fish advisories for PCBs. PCB advisories may consider either acute, chronic noncancer, or chronic cancer health risks, which leads to a wide range of difference across states (Cleary et al. 2021). Most recently the AWQC has been used to calculate the fish tissue concentration triggering impairment and a total maximum daily load; this concentration is 0.02 µg/g in fish fillets (TDEC 2010 a,b,c). The average PCB concentrations in fish in WOC (and across ORR) exceed this conservative guideline (Figure 5.30), but recent work has shown that PCB concentrations have generally been declining in WOC sites at rates of up to approximately 1 percent per year through natural attenuation (Matson et al. 2022). Work to mitigate sources of PCBs within ORNL facilities (Section 5.5.7) may increase these attenuation rates.

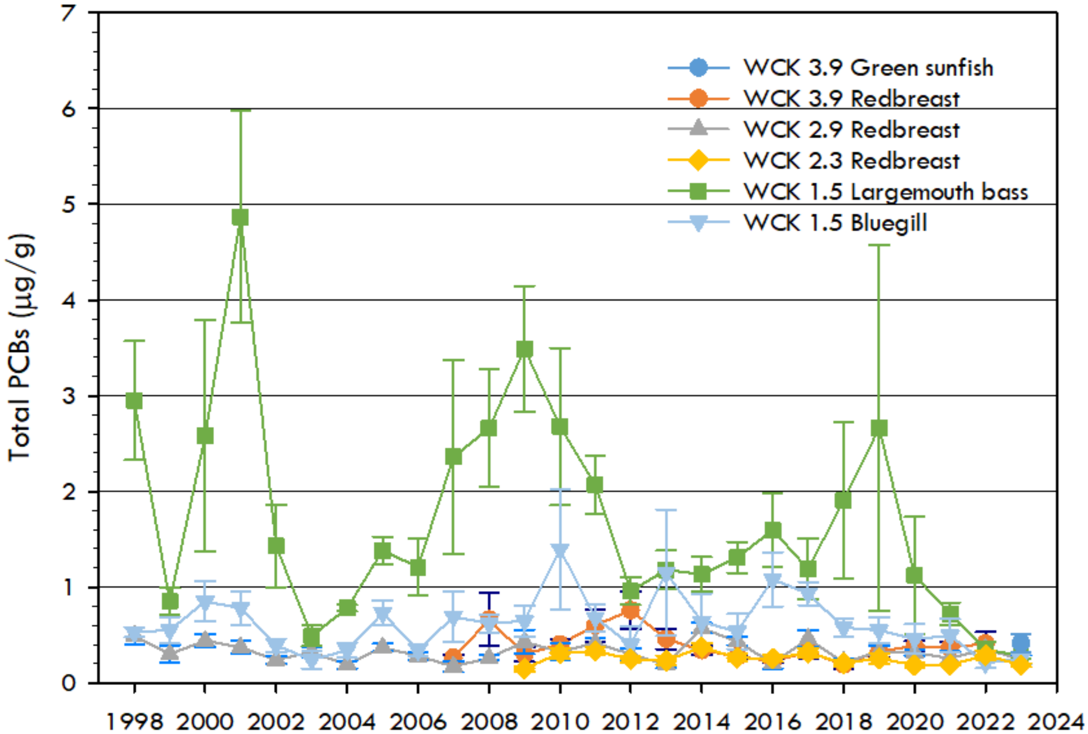


Notes:

1. *Mean concentrations of mercury (± standard error, n = 6) in tissue taken from sampled fish.*
2. *The dashed grey line at 0.3 µg/g indicates the US Environmental Protection Agency ambient water quality criterion for mercury in fish tissue.*

Acronym: *WCK = White Oak Creek kilometer*

Figure 5.29. Mean mercury concentrations in muscle tissue of sunfish and bass sampled from the White Oak Creek watershed, 1998–2023



Note: *Mean total PCB concentrations (± standard error, n = 6) found in fish fillets.*
Acronyms: *PCB = polychlorinated biphenyl* *WCK = White Oak Creek kilometer*

Figure 5.30. Mean total PCB concentrations in fish sampled from the White Oak Creek watershed, 1998–2023

5.5.6.2. Benthic Macroinvertebrate Communities

Monitoring of benthic macroinvertebrate communities in WOC, First Creek, and Fifth Creek continued in 2023. 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 have been collected annually following TDEC protocols since 2009 and following protocols developed by ORNL staff since 1987. The protocols developed by ORNL staff provide a long-term record (37 years) of spatial and temporal trends in invertebrate communities from which the effectiveness of pollution abatement and remedial actions taken at ORNL can be evaluated. 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.

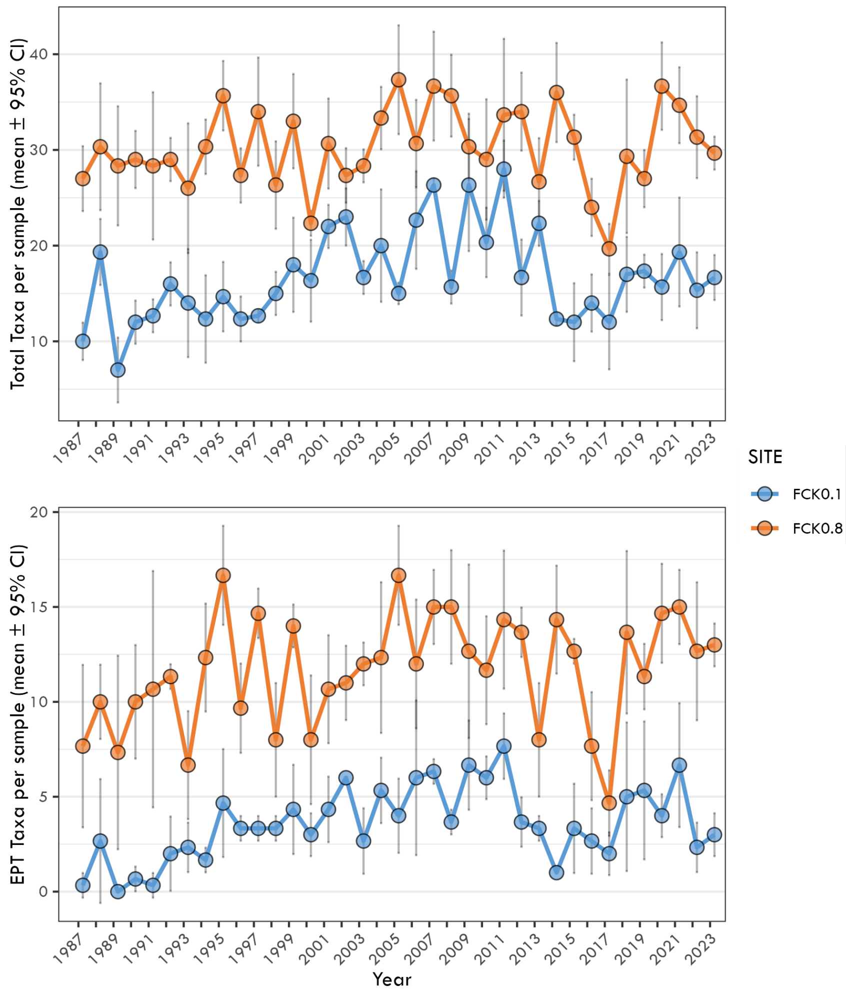
General trends in the results obtained using ORNL protocols indicated significant recovery in benthic macroinvertebrate communities since 1987, but community characteristics suggest that ecological impairment remains (Figures 5.31, 5.32, and 5.33). Total taxonomic richness (i.e., the number of different species per sample) and richness of the pollution-intolerant taxa (i.e., the number of different mayfly, stonefly, and caddisfly species per sample or Ephemeroptera, Plecoptera, and Trichoptera [EPT] taxa richness) continued to be lower at downstream sites relative to respective upstream reference sites.

In lower First Creek (First Creek kilometer [FCK] 0.1), total taxa richness increased gradually in the 1990s and 2000s but was then lower for

4 years beginning in 2014 (Figure 5.31). Total taxa richness then increased at FCK 0.1 from 2018 to 2023, reaching values not observed prior to 2014. 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 (Figure 5.31). After 2021, when values were the highest they had been in the past 10 years, EPT taxa richness values in 2022 and 2023 fell to pre-2018 levels. In upper First Creek (FCK 0.8), which serves as a reference for FCK 0.1, total taxa richness and EPT taxa richness declined for 3 consecutive years, from 2015 to 2017, before rebounding in 2018. Since 2018, total taxa richness and EPT taxa richness at FCK 0.8 both increased and have returned to pre-2015 levels (Figure 5.31). Low EPT taxa richness values observed over a 6-year period (2012 to 2017) at FCK 0.1 were mirrored only in some years at FCK 0.8 (i.e., EPT taxa richness was low at both sites in 2013, 2016, and 2017). This suggests that while climate or hydrological change may have influenced conditions within the entire stream (both FCK 0.1 and FCK 0.8), a more localized change may have also occurred 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. The increases in EPT taxa richness at both sites in 2023, while slight, suggest conditions may be improving, though further monitoring is necessary to determine whether the previously mentioned decline was due to an acute or a longer-term impact to the system.

Total taxa richness at Fifth Creek kilometer (FFK) 0.2 increased in the late 1980s and early 1990s and then was fairly consistent until decreasing significantly between 2007 and 2008 (Figure 5.32), suggesting that conditions changed at the site during that time. Total taxa richness returned to predecline levels over a period of about 5 years and then decreased again over a 4-year period (2018 to 2021) until increasing slightly in 2022 and 2023 (Figure 5.32). EPT taxa richness at FFK 0.2 increased slowly from the late 1980s to early 2000s before decreasing for several years (~2003–2011). From 2011 to 2018, EPT taxa richness remained steady at about five EPT taxa per sample but decreased in 2019 and remained low in 2020 and 2021 before increasing in 2022 back to five EPT taxa per sample. In 2023, EPT taxa richness increased again to the highest value seen since 2002 (seven EPT taxa per sample). It is not known whether this increase will persist in future years or instead reflects interannual variation in invertebrate community composition. Total and EPT richness values at FFK 1.0 (which serves as a reference for FFK 0.2) increased between 2022 and 2023 and have remained higher than at FFK 0.2 since sampling began in 1987.

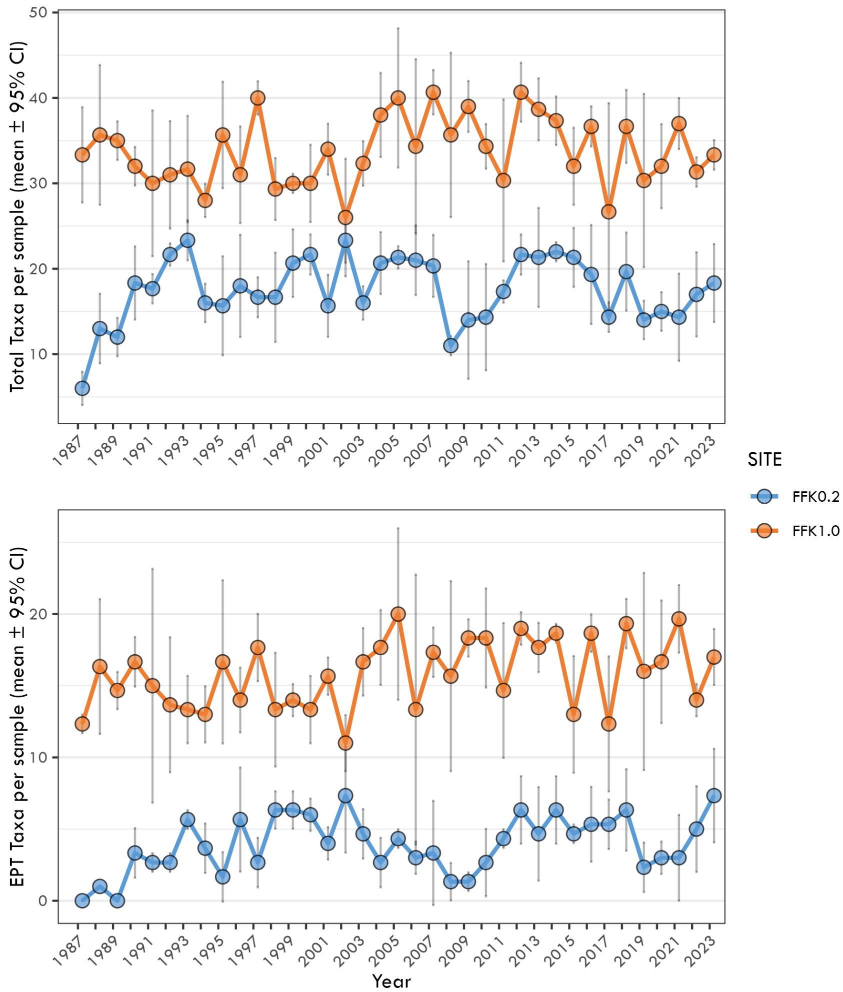
Invertebrate metric values for WCK 2.3 and WCK 3.9 remained within the ranges of values found since the late 1990s and early 2000s, although total taxa richness and EPT taxa richness were lower at WCK 2.3 and WCK 3.9 over the past 8 to 9 years. The total taxa richness and EPT taxa richness at WCK 2.3 and WCK 3.9 continued to be notably lower than at the reference sites. Neither total nor EPT taxa richness at WCK 3.9 has rebounded following the large decline that began in 2015, and while increased richness values were observed in 2021, these values stabilized at a lower level in 2022 and 2023. The cause of the initial decline in 2015 and what has prevented recovery are unknown, though changes in the chemical and physical conditions at WCK 3.9 may be contributing to these observed patterns. Since 2001 (except for one sampling event in 1987), Walker Branch kilometer (WBK) 1.0 has served as an additional reference site for WOC main-stem sites downstream of Bethel Valley Road (Figure 5.33). Comparisons of WCK 6.8 with WBK 1.0 show that communities in WCK 6.8 represent ideal reference conditions. Additionally, the comparison of WBK 1.0 with downstream sites in WOC shows that those WOC communities remain impaired.



__Note:__ Taxonomic richness (number of taxa per sample), 1987–2023. FCK 0.8 serves as a reference site.
Top: Total taxonomic richness.
Bottom: Taxonomic richness of the pollution-intolerant taxa Ephemeroptera, Plecoptera, and Trichoptera (EPT).

Acronyms:
CI = confidence interval
FCK = First Creek kilometer

Figure 5.31. Benthic macroinvertebrate communities in First Creek, 1987–2023



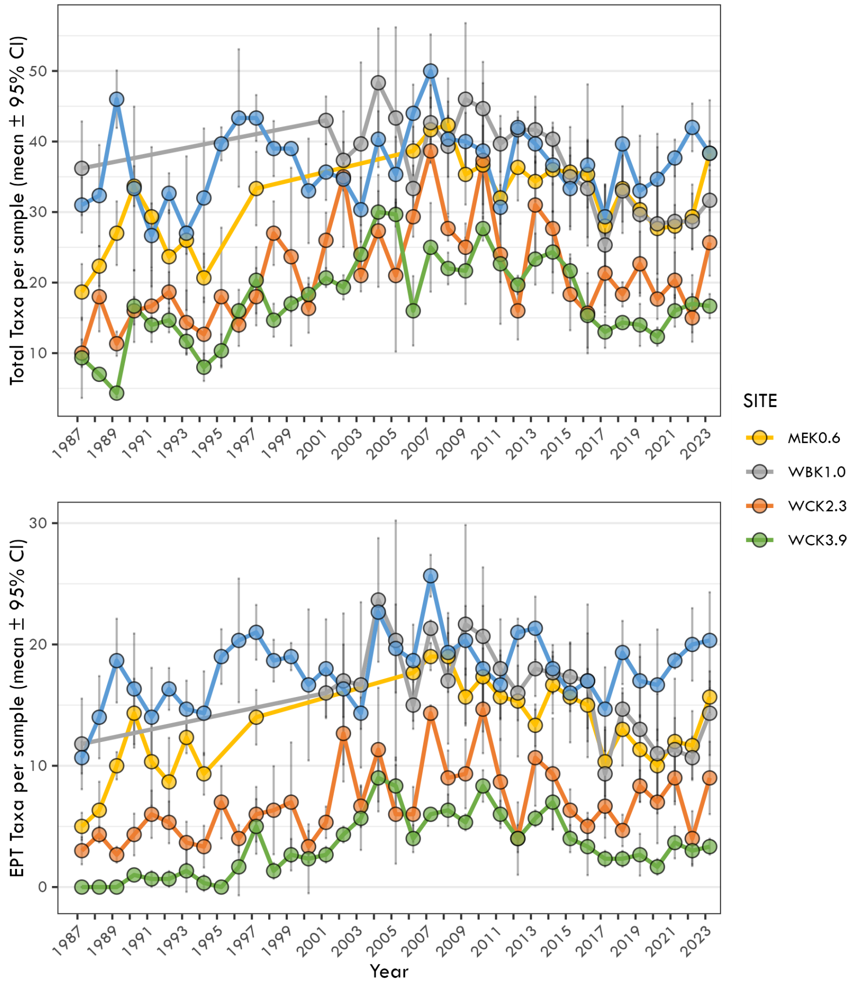
Note: *Taxonomic richness (number of taxa per sample), 1987–2023. FFK 1.0 serves as a reference site.*
Top: Total taxonomic richness.
Bottom: Taxonomic richness of the pollution-intolerant taxa Ephemeroptera, Plecoptera, and Trichoptera (EPT).

Acronyms:

CI = confidence interval

FFK = Fifth Creek kilometer

Figure 5.32. Benthic macroinvertebrate communities in Fifth Creek, 1987–2023



Note: *Taxonomic richness (number of taxa per sample), 1987–2023. WCK 6.8 and WBK 1.0 serve as reference sites.*

Top: Total taxonomic richness.

Bottom: Taxonomic richness of the pollution-intolerant taxa Ephemeroptera, Plecoptera, and Trichoptera (EPT).

Acronyms:

CI = confidence interval

MEK = Melton Branch kilometer

WBK = Walker Branch kilometer

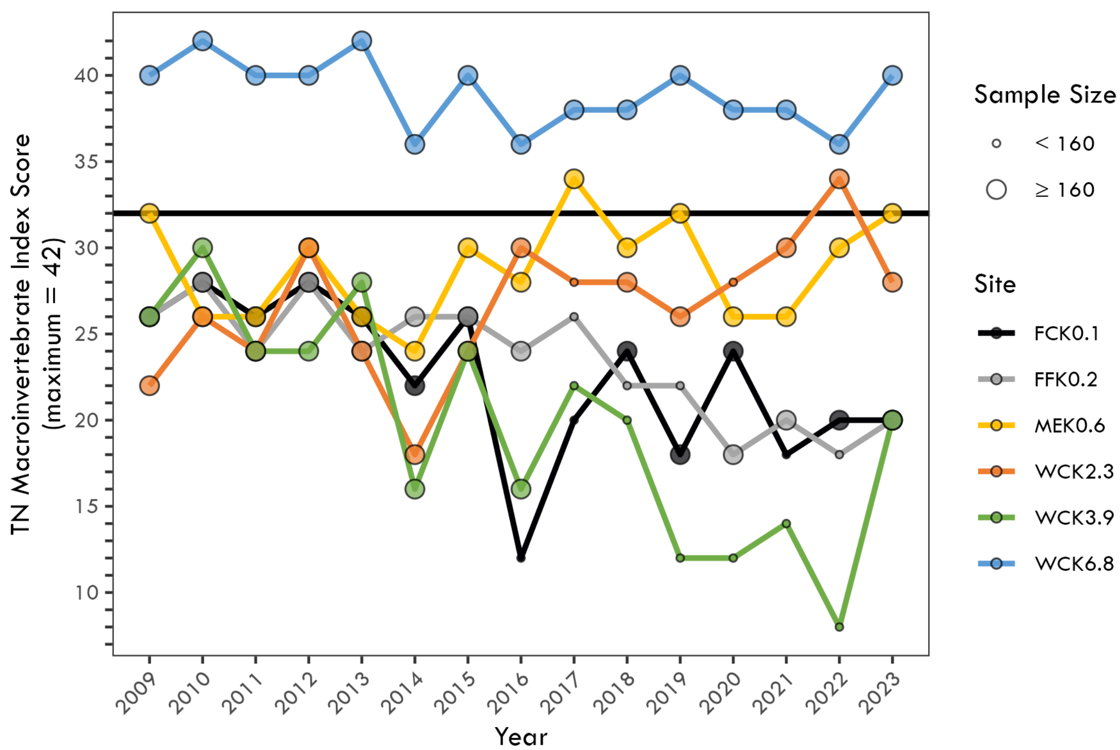
WCK = White Oak Creek kilometer

Figure 5.33. Benthic macroinvertebrate communities in Walker Branch, Melton Branch, and White Oak Creek, 1987–2023

Macroinvertebrate metrics for Melton Branch (MEK 0.6) suggested that total taxa and EPT taxa richness continued to be similar to those in reference sites in 2023, particularly WBK 1.0 (Figure 5.33). However, other invertebrate community metrics at MEK 0.6, such as the 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. For the past 8 years (2016–2023), EPT density has generally been lower in MEK 0.6 than in WCK 6.8 and WBK 1.0, whereas the density of pollution-tolerant species (oligochaetes and chironomids [worms and nonbiting midges]) was higher in MEK 0.6 than in those two reference sites.

Based on TDEC protocols (TDEC 2021b), scores for the TDEC Tennessee Macroinvertebrate Index (TMI) in 2023 rated the invertebrate communities at the reference site, WCK 6.8, and MEK 0.6 as passing biocriteria guidelines, while scores from FCK 0.1, FFK 0.2, and WCK 3.9 were below these guidelines (Figure 5.34, Table 5.13). Scores improved at two of the four sites (WCK 3.9 and FFK 0.2), remained the same at one site (FCK 0.1), and declined at one site (WCK 2.3).

Low TMI scores in FCK 0.1, FFK 0.2, WCK 2.3, and WCK 3.9 were primarily due to low values for EPT percentage and EPT taxa richness (Table 5.13). However, all these sites had low percentages of oligochaetes and chironomids and thus received high scores for this category. WCK 6.8 received the highest attainable scores for all categories except for total taxa richness (Table 5.13).



Note: *The black horizontal line shows the threshold for Tennessee Macroinvertebrate Index scores. The values above the threshold are passing scores; those below are not.*

Acronyms:

FCK = First Creek kilometer | *MEK = Melton Branch kilometer*
FFK = Fifth Creek kilometer | *WCK = White Oak Creek kilometer*

Figure 5.34. Temporal trends in Tennessee Department of Environment and Conservation Tennessee Macroinvertebrate Index scores for White Oak Creek watershed streams, August sampling, 2009–2023

Table 5.13. Tennessee Macroinvertebrate Index metric values, metric scores, and index scores for White Oak Creek, First Creek, Fifth Creek, and Melton Branch streams, August 22, 2023[a,b]

Site	Metric values							Metric scores							TMI[c]
	Taxa rich	EPT rich	EPT (%)	OC (%)	NCBI	Cling (%)	TN Nuttol (%)	Taxa rich	EPT rich	EPT (%)	OC (%)	NCBI	Cling (%)	TN Nuttol (%)	
WCK 2.3	26	5	29	22.4	5.3	44.8	53.6	4	2	4	6	4	4	4	28
WCK 3.9	14	3	37.4	12.9	5.1	12.3	38	2	0	4	6	4	0	4	20
WCK 6.8	29	14	55.6	3.7	2.9	76.6	13.1	4	6	6	6	6	6	6	40 [pass]
FCK 0.1	12	1	0	3.5	5.8	25.7	19.3	2	0	0	6	4	2	6	20
FFK 0.2	14	6	22.7	3.2	5.2	28.6	53.2	2	2	2	6	4	2	2	20
MEK 0.6	28	10	31.4	3.3	4.5	44.8	36.2	4	4	4	6	6	4	4	32 [pass]

[a] *TMI metric calculations and scoring and index calculations are based on TDEC protocols for Ecoregion 67f (TDEC 2021b)*

[b] *Taxa rich = taxa richness; EPT rich = taxa richness of mayflies, stoneflies, and caddisflies; EPT = EPT abundance excluding Cheumatopsyche spp.; OC = percent abundance of oligochaetes (worms) and chironomids (nonbiting midges); NCBI = North Carolina Biotic Index; Cling = percent abundance of taxa that build fixed retreats or otherwise attach to substrate surfaces in flowing water; TN Nuttol = percent abundance of nutrient-tolerant organisms.*

[c] *TMI is the total index score. Higher index scores indicate higher quality conditions. A score of ≥32 is considered to pass biocriteria guidelines.*

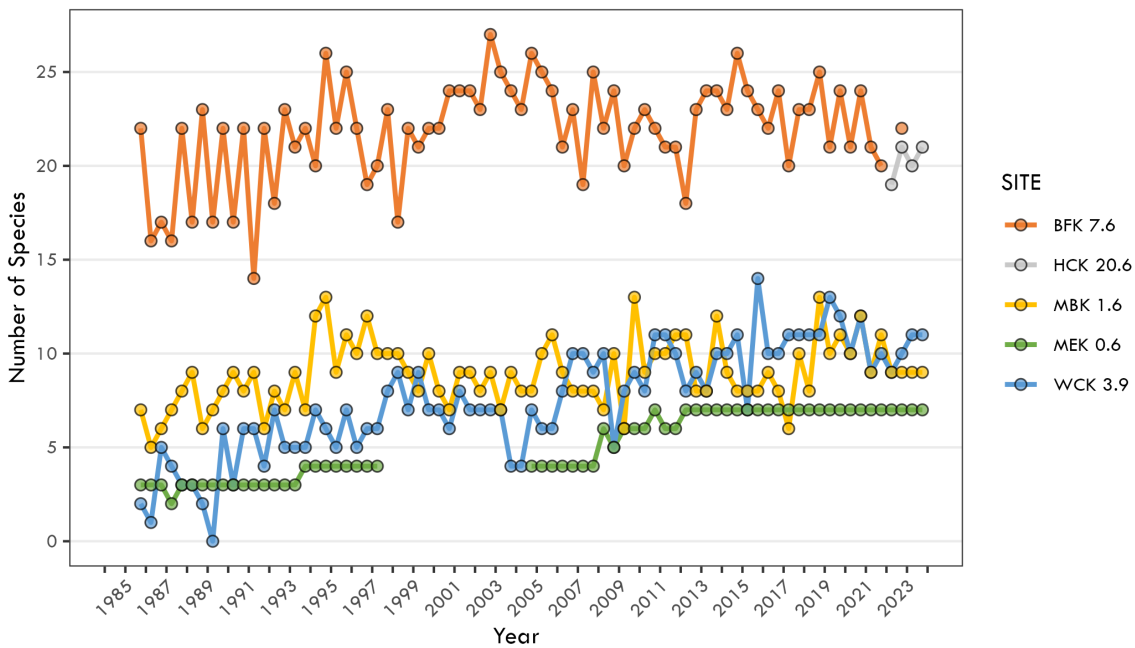
Acronyms:

EPT = Ephemeroptera, Plecoptera, and Trichoptera
FCK = First Creek kilometer
FFK = Fifth Creek kilometer
MEK = Melton Branch kilometer
NCBI = North Carolina Biotic Index
OC = percent abundance of oligochaetes (worms) and chironomids (nonbiting midges)
TDEC = Tennessee Department of Environment and Conservation
TMI = Tennessee Macroinvertebrate Index
TN Nuttol = nutrient-tolerant organism
WCK = White Oak Creek kilometer

5.5.6.3. Fish Communities

Monitoring of the fish communities in WOC and its major tributaries continued in 2023. 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 Hinds Creek) were also sampled as reference sites for comparison.

In the WOC watershed, the fish community continued to be slightly degraded in 2023 compared with communities in reference streams. Sites closest to outfalls within the ORNL campus had lower species richness (number of species) (Figure 5.35) and fewer pollution-sensitive species than a slightly larger reference site and more closely resembled values found in a smaller reference reach. WOC sites also had more pollution-tolerant species and elevated densities (number of fish per square meter) of pollution-tolerant species compared with 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 continued to be negatively affected by ORNL effluent in 2023 relative to reference streams and upstream sites.



Note: *BFK 7.6 was not surveyed in the spring of 2022 or in 2023 because of lack of access to the site.*

Acronyms:

BFK = Brushy Fork kilometer

HCK = Hinds Creek kilometer

MBK = Mill Branch kilometer

MEK = Melton Branch kilometer

WCK = White Oak Creek kilometer

Figure 5.35. Fish species richness (number of species) in upper White Oak Creek and lower Melton Branch compared with two reference streams, Brushy Fork and Mill Branch, 1985–2023

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 seven such native species. Continuing reproduction has been noted for six 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. This is likely due to numerous structures located within the watershed that act as barriers to upstream fish migration. In response, introductions to supplement the small populations of those fish species were continued at sites within the watershed until 2019.

One exception to the apparent difficulty of expansion is the striped shiner (*Luxilus chrysocephalus*), which has expanded into upper Melton Branch, upper WOC, and lower First Creek, although established populations have not been observed in all those locations. The introductions have enhanced species richness at almost all sample locations within the watershed. This may indicate 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 in the Clinch River below White Oak Lake.

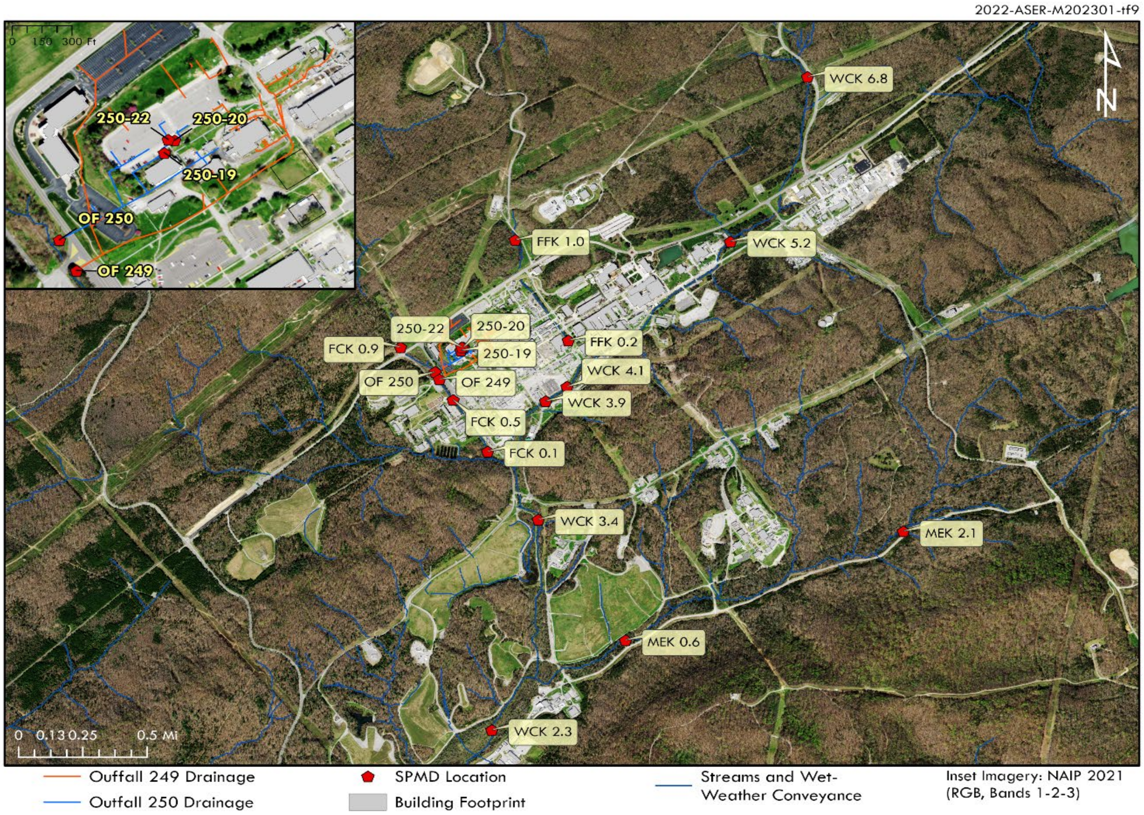
5.5.7. Polychlorinated Biphenyls in the White Oak Creek Watershed

The original objective of the PCB investigation in the WOC watershed was to identify the stream reaches, outfalls, or sediment areas that were contributing to elevated PCB levels. Past ORNL PCB monitoring efforts have identified upper parts of First Creek, particularly the storm drain network leading to Outfall 250, as sources of PCBs to the WOC watershed. Because PCBs are hydrophobic and do not readily dissolve in water, concentrations in samples from the WOC watershed analyzed by conventional methods have historically been below detection limits. However, PCB concentrations in largemouth bass in White Oak Lake have been above levels recommended by TDEC and EPA for frequent consumption, confirming elevated levels at this site. Because fish are mobile, source identification is not possible from the data.

Semipermeable membrane devices (SPMDs), thin plastic sleeves filled with oil in which PCBs are soluble, have proven to be useful tools to identify sources of PCBs. Because SPMDs are deployed at a given site for 4 weeks and have a high affinity for PCBs, they overcome the limitations associated with conventional analytical methods and allow for a time-integrated semiquantitative index of the relative PCB concentrations in the water column (compared to a snapshot value that would be obtained from a conventional surface water grab sample).

The most recent PCB monitoring was done in 2022, when SPMDs were deployed in the same locations monitored in 2009 and 2010 (Figure 5.36) to determine whether changes in PCB sources had occurred. Forage fish were also collected at three sites in First Creek to examine PCB exposure to biota in the stream. Spatial patterns from the 2022 SPMD deployment were very similar to those from the 2009 and 2010 deployments, with First Creek being the greatest contributor to aqueous PCBs in the WOC watershed (Figure 5.37). The Outfall 250 storm drain network, particularly the location at 250-19, remained the greatest contributor of PCBs to the First Creek watershed. PCB concentrations in forage fish in First Creek decreased with downstream distance from this outfall. While SPMDs are semiquantitative, allowing for a relative assessment of PCB sources to the stream, the overall concentrations in the SPMDs were comparable to those in previous years, suggesting no major changes have occurred in aqueous PCB concentrations in the WOC watershed over the past decade.

The upper reaches of the Outfall 250 storm drain network lie beneath an area where two buildings with known PCB materials were once located. A closed-circuit television investigation of the Outfall 250 storm drain system has been initiated.



Acronyms:

FCK = First Creek kilometer
FFK = Fifth Creek kilometer
MEK = Melton Branch kilometer
OF = outfall
SPMD = semipermeable membrane device
WCK = White Oak Creek kilometer

Figure 5.36. Locations of monitoring points for First Creek source investigations, 2009 and 2022

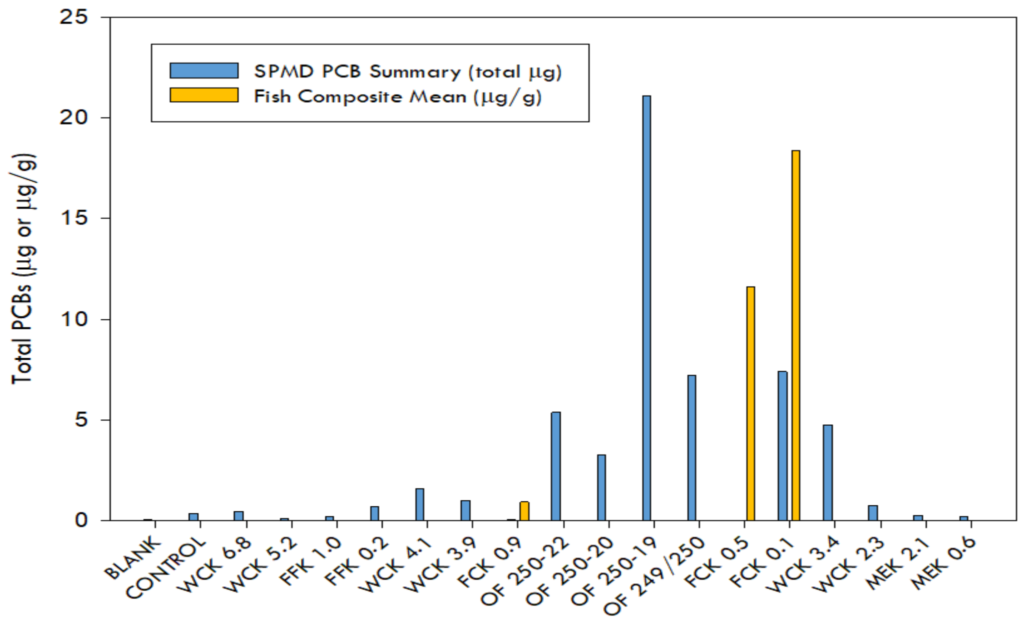


Figure 5.37. Total polychlorinated biphenyl content (µg) in semipermeable membrane devices in the White Oak Creek watershed and in First Creek forage fish composite samples (*n* = 3), 2022

5.5.8. Oil Pollution Prevention

Requirements for the prevention of oil discharges at specific nontransportation-related facilities are set forth in 40 CFR 112, "Oil Pollution Prevention." These requirements were originally published in Section 311 of the Federal Water Pollution Control Act, now the CWA, in 1973. Discharge includes any spilling, leaking, pumping, pouring, emitting, emptying, or dumping but excludes permitted discharges (e.g., via an NPDES permit). To contain oil discharges and to prevent them from reaching navigable waters or adjoining shorelines, these facilities are required to develop and implement spill prevention, control, and countermeasure (SPCC) plans and to provide annual training for oil-handling personnel.

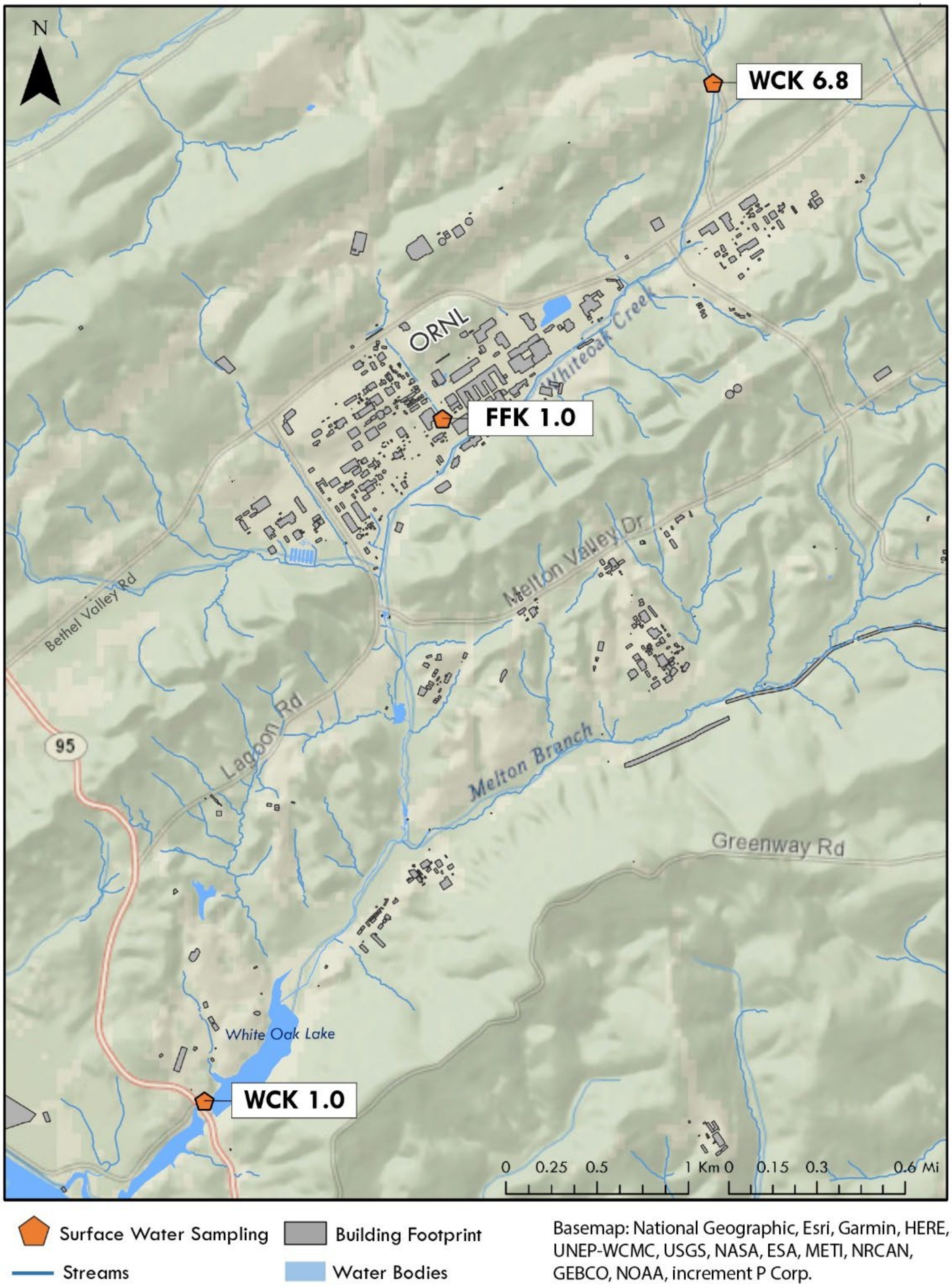
Currently, separate SPCC plans are implemented for the ORNL site and for the HVC, which is located off ORR. An SPCC plan is not required for the CFTF, which is off the ORNL campus in the Heritage Center Business Park. The ORNL SPCC and HVC SPCC plans were revised in 2023. Inventories for both SPCC plans are maintained electronically in the ORNL geographic information system and are updated throughout each year as SPCC inventories change. No regulatory actions related to oil pollution prevention were taken at ORNL or HVC in 2023.

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 5.38) 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 5.14. Monitoring at WCK 1.0 is conducted monthly for radiological parameters and quarterly for Hg under the ORNL WQPP (Section 5.5.4); therefore, those parameters are not duplicated by this program. Radiological monitoring at WCK 6.8 is also conducted monthly under the ORNL WQPP and therefore is not included in the ORNL surface water monitoring program.

ORNL 2021-G00715/mhr
2021-EPSDM013.tf9



Acronyms: *FFK = Fifth Creek kilometer* *WCK = White Oak Creek kilometer*

Figure 5.38. ORNL surface water sampling locations, 2023

Table 5.14. ORNL surface water sampling locations, frequencies, and parameters, 2023

Location[a]	Description	Frequency and type	Parameters
WCK 1.0[b]	White Oak Lake at WOD	Quarterly, grab	Volatiles, PCBs, field measurements[c]
WCK 6.8[d]	WOC upstream from ORNL	Quarterly, grab	PCBs, field measurements[c]
FFK 0.1	Fifth Creek just upstream of WOC (ORNL)	Semiannually, grab	Gross alpha, gross beta, total radioactive strontium, gamma scan, ^{3}H, 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 WOC and the Clinch River).*

[b] *For this location, radiological parameters and mercury are monitored under another program (the WQPP) and therefore are not included in this program.*

[c] *Field measurements consist of dissolved oxygen, pH, and temperature.*

[d] *Radiological monitoring is performed at this location as part of the WQPP.*

Acronyms:
FFK = Fifth Creek kilometer
ORNL= Oak Ridge National Laboratory
PCB = polychlorinated biphenyl
WCK = WOC kilometer
WOC = White Oak Creek
WOD = White Oak Dam
WQPP = water quality protection plan

Samples are collected and analyzed for general water quality parameters and are screened for radioactivity at all locations (as part of this program or the WQPP). Samples are further analyzed for specific radionuclides when general screening levels are exceeded. Samples from WCK 1.0 are analyzed for volatile organic compounds (VOCs) and PCBs. Samples from WCK 6.8 are also analyzed for PCBs. The State of Tennessee has designated use classifications for all surface water bodies in the state. Each classification has different WQCs to protect water bodies according to their designated uses. WCK 6.8 and WCK 1.0 are classified for freshwater fish and aquatic life. Tennessee WQCs associated with these classifications are used as references where applicable (TDEC 2019). The Tennessee WQCs do not include criteria for radionuclides. Four percent of the DOE DCS (DOE 2021b) is used for radionuclide comparison.

No radionuclides were reported above 4 percent of the DCS at the Fifth Creek location (FFK 0.1) in 2023. Beta activity and $^{89/90}Sr$ 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 the DCS were reported for samples collected at the upstream WOC sampling location (WCK 6.8). The other radionuclide results from WCK 6.8 and from samples collected at WOD (before WOC empties into the Clinch River) are discussed in Section 5.5.3.

Low estimated concentrations of Aroclors 1254 and 1260 were detected in the August 2023 sample collected at WCK 1.0. PCBs were not detected in any other 2023 samples from this location. Since 2017, PCBs have been detected on only two other occasions at WCK 1.0: Aroclor 1254 was detected at a low estimated concentration in September 2022, and in 2021 Aroclors 1254 and 1260 were detected in one sample, also at low estimated concentrations.

Two VOCs were detected in samples from WCK 1.0 during 2023: methylene chloride was detected in the sample collected in May, and acetone was detected in the samples collected in all four quarters. All VOC detections were at low estimated values. Methylene chloride was detected at a low estimated value in the associated May trip blank. Acetone was detected in the associated trip blanks at levels similar to those in the WCK 1.0 samples in three out of four quarters and was detected in one associated method blank. All VOCs detected in 2023 have previously been detected at WCK 1.0. In addition, acetone and methylene chloride have occasionally been detected in at least one on-site groundwater well in past monitoring. Acetone and methylene chloride are common laboratory contaminants.

5.5.10. Carbon Fiber Technology Facility Wastewater Monitoring

Wastewaters from activities at CFTF are discharged to the City of Oak Ridge sanitary sewer system under conditions established in City of Oak Ridge Industrial Wastewater Discharge Permit 1-12. Permit limits, parameters, and 2023 compliance status for this permit are summarized in Table 5.15.

Table 5.15. Industrial and commercial user wastewater discharge permit compliance at the ORNL Carbon Fiber Technology Facility, 2023

Effluent parameters	Permit limits		Permit compliance		
	Daily max. (mg/L)	Monthly ave. (mg/L)	Number of noncompliances	Number of samples	Percentage of compliance[a]
Outfall 01 (Underground Quench Water Tank)					
Cyanide	3.9	0.1	0	0	100
pH (standard units)	6–9	-	0	0	100
Outfall 02 (Electrolytic Bath Tank)					
pH (standard units)	6–9	-	0	1	100
Outfall 03 (Sizing Bath Tank)					
Copper	0.87	0.10	0	0	100
Zinc	1.24	0.60	0	0	100
Total phenol	4.20	-	0	0	100
pH (standard units)	6–9	-	0	0	100
Outfall 04 (Steam Stretcher Condensate)					
Copper	0.87	0.10	0	0	100
Zinc	1.24	0.60	0	0	100
Total phenol	4.20	-	0	0	100
pH (standard units)	6–9	-	0	0	100

[a] *Percentage compliance = 100 − (number of noncompliances/number of samples) × 100*

5.6. ORNL Groundwater Monitoring Program

Groundwater monitoring at ORNL was conducted under two sampling programs in 2023: OREM monitoring and DOE Office of Science (SC) surveillance monitoring. The OREM groundwater monitoring program was conducted by UCOR in 2023. The SC groundwater monitoring surveillance program was conducted by UT-Battelle.

5.6.1. Summary of US Department of Energy 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 on the ORNL site. Groundwater monitoring for baseline and trend evaluation in addition to measuring effectiveness of completed CERCLA RAs is conducted as part of the WRRP. The WRRP is managed by UCOR for the OREM program. The results of CERCLA monitoring for ORR for FY 2023, including monitoring at ORNL, are evaluated and reported in the *2024 Remediation Effectiveness Report* (DOE 2024) as required by the ORR Federal Facility Agreement.

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 a groundwater treatability study at the Bethel Valley 7000 Area VOC plume. This plume contains trichloroethylene 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. Post-treatment monitoring of the 7000 Area plume continues.

During FY 2023, post-remediation monitoring continued at Solid Waste Storage Area (SWSA) 3 to evaluate the effectiveness of the 2011 hydrologic isolation of the area that included construction of a multilayer cap and an upgradient storm flow and 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. 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 post-remediation groundwater-level suppression. Sampling and analysis to evaluate groundwater quality and contaminant concentrations were also conducted. Post-remediation 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 synoptic groundwater-level monitoring in 42 wells in addition to 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 2023 monitoring results showed that the cap was effectively enabling attainment of the groundwater-level goals established in the post-remediation completion report. Uncertainty regarding the elevation of bedrock at three monitoring wells was resolved by geophysical measurements that confirmed the groundwater elevation was at or below the bedrock surface. Drinking water standards are used as screening water quality concentrations to evaluate the site response to remediation. Concentrations of 90Sr, a signature contaminant at SWSA 3, decreased significantly in groundwater and at the adjacent surface water monitoring sites at Raccoon Creek and the Northwest Tributary. Groundwater data trend evaluation shows that 90Sr trends are decreasing to stable at the four monitoring wells where FY 2023 90Sr concentrations exceeded the 8 pCi/L maximum contaminant-level derived concentration. Concentrations of benzene, potentially from natural sources, exhibited a stable trend in one well and an increasing trend in a second well; FY 2023 maxima were 0.006 mg/L for the first well and 0.007 mg/L for the second well, which are slightly greater than the 0.005 mg/L maximum contaminant level. During FY 2023, as part of the 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 for exit pathway groundwater monitoring in western Bethel Valley. Groundwater monitoring near SWSA 3 and 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 *2024 Remediation Effectiveness Report for the US Department of Energy Oak Ridge Site, Oak Ridge, Tennessee, Data and Evaluations* (DOE 2024). To enhance exit pathway groundwater monitoring near the ORR property boundary at the Clinch River in western Bethel Valley, three deep boreholes were drilled and characterized. During FY 2021, Westbay multizone sampling systems were installed to enable discrete zone sampling in the carbonate bedrock units. The three new exit pathway multizone wells were sampled quarterly throughout FY 2023 to assess groundwater quality conditions near the DOE property boundary at the western end of Bethel Valley. Project documentation and monitoring results are presented in the remedial investigation completion report that was issued in August 2023 (DOE 2023c).

Groundwater monitoring continued at the ORNL 7000 Area during FY 2023 to evaluate treatability of the VOC plume at that site. Site characterization testing of the endemic microbial community showed that microbes present at that site are capable of fully degrading trichloroethylene 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 shows 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 with the performance goal of reducing ^{90}Sr in WOC.

Strontium-90 is a principal CERCLA contaminant of concern in surface water in WOC. The ROD established a 37 pCi/L goal for the annual average concentration of ^{90}Sr at the 7500 Bridge Weir. During FY 2023, this goal was not attained. Over the past several years, various problems have occurred in Bethel Valley that have caused the failure to meet the ^{90}Sr concentration goal. Belowground infrastructure deterioration related to process liquid wastewater handling in the aging ORNL Central Campus area allowed contaminant releases. Furthermore, treatment facility upset conditions during start-up of new treatment processes reduced the effectiveness of ^{90}Sr removal during part of FY 2021. OREM is investigating sources of groundwater ^{90}Sr contamination that seep directly into WOC as nonpoint discharges to the stream.

5.6.1.2. Melton Valley

The Melton Valley ROD (DOE 2000) established goals for reducing contaminant levels in surface water, reducing groundwater-level fluctuation within hydrologically isolated areas, and mitigating impacts to groundwater. 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 at ORNL during FY 2023 was about 51 in., which is about 3 in. less 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. At SWSA 6, groundwater quality monitoring that is substantively equivalent to the former RCRA monitoring continues. Several VOCs continue to be detected in wells along the eastern edge of the site at essentially stable concentrations.

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 strontium, ^{3}H, uranium, and VOCs have been detected intermittently in several of the multizone sampling locations. Groundwater in the exit pathway wells has high alkalinity and sodium and exhibits elevated pH. During FY 2020, 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 2024 *Remediation Effectiveness Report* (DOE 2024).

5.6.2. DOE Office of Science Groundwater Surveillance Monitoring

DOE Order 458.1 (DOE 2020) is the primary requirement for a sitewide 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 SC groundwater surveillance monitoring are reported in the following sections.

Exit pathway and active-sites groundwater surveillance monitoring points sampled during 2023 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 among locations, results were compared with 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 2021b). 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 2023, exit pathway groundwater surveillance monitoring was performed in accordance with the exit pathway sampling and analysis plan (Bonine 2013). Groundwater exit pathways at ORNL include areas from watersheds or subwatersheds 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 listed below. Figure 5.39 shows the locations of the exit pathway monitoring points targeted for sampling in 2023:

- The 7000/Bearden Creek Discharge Area Exit Pathway
- The East End Discharge Area Exit Pathway
- The Northwestern Discharge Area Exit Pathway
- The Southern Discharge Area Exit Pathway
- The WOC Discharge Area Exit Pathway

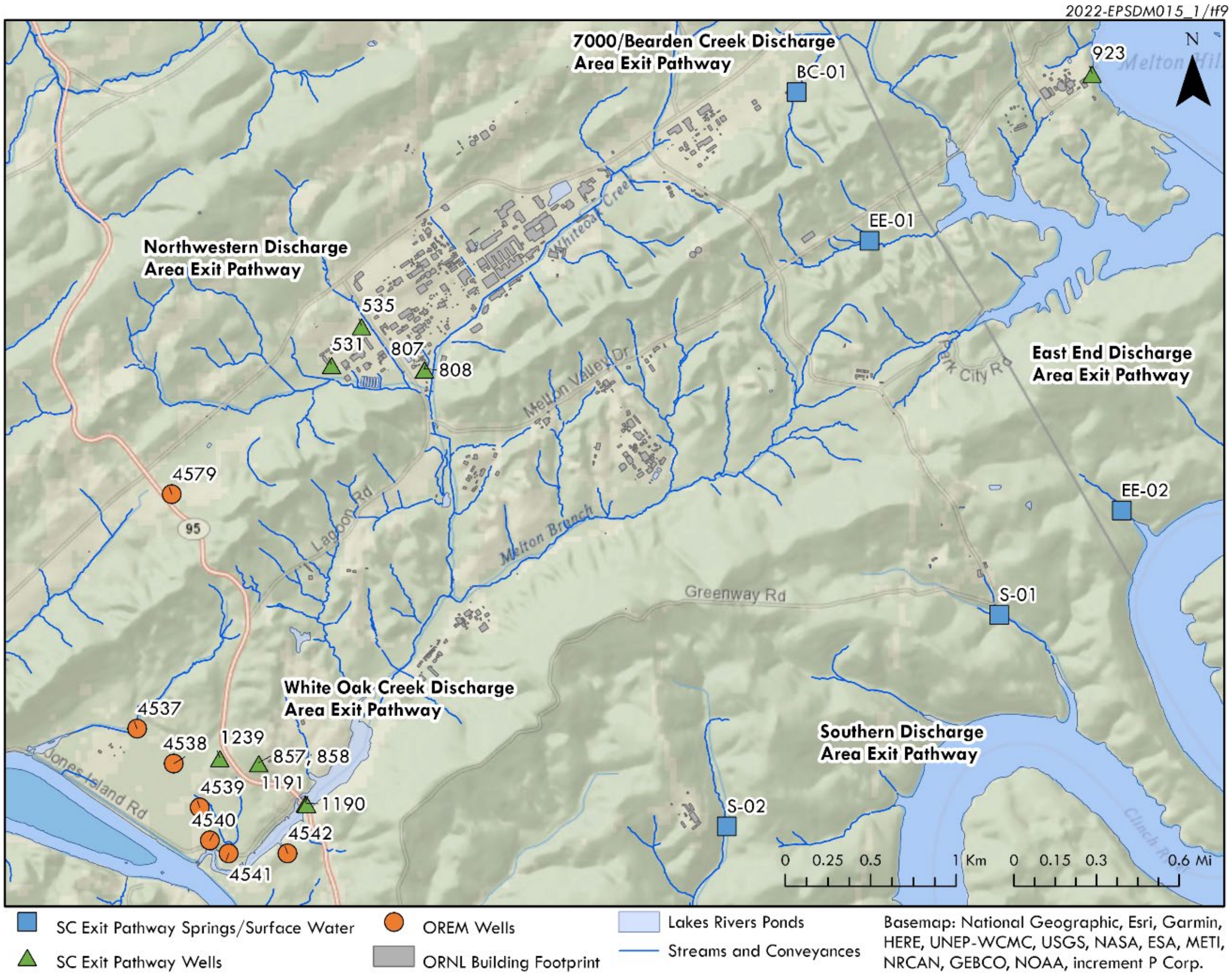
The efficacy of the exit pathway monitoring program was reviewed in late 2011. As a result, the groundwater monitoring program was modified through an optimization approach that included frequency analysis of parameters and their concentrations based on an exhaustive review of historical groundwater sampling data. The modification resulted in a staggered groundwater monitoring schedule and analytical suite selection. This approach was initiated in 2012. The groundwater monitoring that was conducted in 2023 is summarized in Table 5.16.

Unfiltered samples were collected. The organic suite comprised VOCs and semivolatile organic compounds; the metallic suite included heavy and nonheavy metals; and the radionuclide suite comprised gross alpha/gross beta activity, gamma emitters, $^{89/90}$Sr, and ^{3}H. In 2023, dry-season samples were collected in July through October, and wet-season samples were collected in March.

Exit pathway monitoring results

Table 5.17 summarizes radiological parameters detected in samples collected from exit pathway monitoring points during 2023. Metals are ubiquitous in groundwater exit pathways and so are not summarized in the table.

2022-EPSDM015_1/tf9



Acronyms:
OREM = DOE Oak Ridge Office of Environmental Management
ORNL = Oak Ridge National Laboratory
SC = DOE Office of Science

Figure 5.39. UT-Battelle exit pathway groundwater monitoring locations at ORNL, 2023

Table 5.16. Exit pathway groundwater monitoring conducted in 2023

Monitoring point	Season	
	Wet	Dry
7000 Bearden Creek Discharge Area		
BC-01	Radiological	Radiological
East End Discharge Area		
923	Radiological	Radiological
EE-01	Radiological	Radiological
EE-02	Radiological, organics, and metals	Not sampled[a]
Northwestern Discharge Area		
531	Radiological	Radiological
535	Radiological	Radiological, organics, and metals
807	Radiological	Radiological
808	Radiological	Radiological
Southern Discharge Area		
S-01	Radiological	Not sampled[a]
S-02	Radiological	Radiological, organics, and metals
White Oak Creek Discharge Area		
857	Radiological	Radiological, organics, and metals
858	Radiological	Radiological
1190	Radiological, organics, and metals	Radiological, organics, and metals
1191	Radiological, organics, and metals	Radiological, organics, and metals
1239	Radiological	Radiological

[a] *Locations EE-02 and S-01 (stream locations) were not sampled in the 2023 dry season because of lack of water flow.*

Table 5.17. Radiological parameters detected in 2023 exit pathway groundwater monitoring

Monitoring Location	Parameter	Concentration (pCi/L)		
		Wet season[a]	Dry season[a]	Reference value[b]
7000 Bearden Creek Discharge Area				
Spring BC-01	^{214}Bi	23.3	ND	40,000
Spring BC-01	^{137}Cs	2.31	ND	164
Spring BC-01	^{212}Pb	6.34	ND	292
Spring BC-01	^{214}Pb	21.1	ND	23,600
East End Discharge Area				
Well 923	Alpha	3.57	U1.24	15
Well 923	Beta	3.12	3.69	50
Well 923	^{214}Bi	7.62	ND	40,000
Well 923	^{40}K	U27.1	38	640
Stream EE-01	Alpha	U1.04	2.38	15
Stream EE-01	Beta	4.19	U0.917	50
Stream EE-01	^{214}Bi	11.6	ND	40,000
Stream EE-01	^{214}Pb	14.5	ND	23,600
Stream EE-02	Beta	3.68	NF	50
Stream EE-02	^{214}Bi	73.5	NF	40,000
Stream EE-02	^{212}Pb	6.6	NF	292
Stream EE-02	^{214}Pb	60.2	NF	23,600
Northwestern Discharge Area				
Well 531	Beta	U2.46	2.07	50
Well 531	^{214}Bi	8.85	ND	40,000
Well 807	Beta	2.72	2.54	50
Well 807	^{214}Bi	9.21	ND	40,000
Well 807	^{212}Pb	8.91	ND	292
Well 807	$^{89/90}$Sr	U0.951	1.54	68
Well 808	Beta	6.63	3.56	50
Well 808	^{214}Bi	5.91	ND	40,000
Well 808	^{212}Pb	8.01	ND	292
Well 808	$^{89/90}$Sr	1.92	U1.06	68
Southern Discharge Area				
Stream S-01	Beta	3.06	NF	50
Stream S-01	^{214}Bi	38	NF	40,000
Stream S-01	^{214}Pb	36.3	NF	23,600
Stream S-02	Beta	3.06	U1.18	50
Stream S-02	^{214}Bi	23.3	ND	40,000
Stream S-02	^{137}Cs	ND	5.43	164
Stream S-02	^{212}Pb	7.07	ND	292
Stream S-02	^{214}Pb	12	ND	23,600

Table 5.17. Radiological parameters detected in 2023 exit pathway groundwater monitoring (continued)

Monitoring Location	Parameter	Concentration (pCi/L)		
		Wet season[a]	Dry season[a]	Reference value[b]
White Oak Creek Discharge Area				
Well 857	Beta	U1.98	2.95	50
Well 858	Beta	3.64	4.1	50
Well 858	$^{89/90}$Sr	2.72	U0.544	68
Well 1190	Beta	U2.61	3.97	50
Well 1190	^{214}Bi	ND	6.06	40,000
Well 1190	^{3}H	10,400	13,400	20,000
Well 1191	Beta	253	240	50
Well 1191	^{214}Bi	6.51	9.08	40,000
Well 1191	$^{89/90}$Sr	76.3	123	68
Well 1191	^{3}H	8,170	8,030	20,000
Well 1239	Alpha	11.7	U0.224	15
Well 1239	Beta	4.01	U1.01	50
Well 1239	$^{89/90}$Sr	2.11	U0.155	68

[a] *NF = there was no flow at the spring or stream sampling location during sampling attempts*

ND = the analyte was not detected in the gamma scan that was performed

U = the analyte was measured but not detected above the practical quantitation limit/contractor-required detection limit

[b] *Current federal and state standards are used as reference values. If no federal or state standard exists for the analyte, 4 percent of the DOE derived concentration standard is used as the reference value.*

Exit pathway groundwater surveillance summary

Concentrations of metals and man-made radionuclides observed in groundwater exit pathway discharge areas in 2023 at ORNL were generally consistent with observations reported in past annual site environmental reports for ORR. Based on the results of the 2023 monitoring effort, there is no indication that current SC operations are significantly introducing contaminants to the groundwater at ORNL.

Nine radiological contaminants were detected in exit pathway groundwater samples collected in 2023. Gross beta and $^{89/90}$Sr were the only radiological parameters that exceeded reference values at any of the discharge areas. Consistent with previous monitoring, these parameters were observed at concentrations above their respective reference values in the WOC discharge area.

Cesium-137 was detected for the first time at two locations in 2023: in wet-season sampling at spring BC-01 (2.31 pCi/L) in the Bearden Creek Discharge Area and in dry-season sampling at S-02 (5.43 pCi/L) in the Southern Discharge Area. Although historic data at these locations do not include detections for comparison, both measured concentrations of ^{137}Cs were below the reference value. Lead-212 was detected for the first time at well 807 (8.91 pCi/L) in the Northwest Discharge Area in the wet-season sampling event.

Twenty-eight metallic parameters were detected in exit pathway groundwater samples collected in 2023. Only three metals, aluminum, iron, and manganese, were detected at concentrations exceeding reference values. These metals are commonly found in groundwater at ORNL.

No organic compounds were detected at concentrations above the analytical method practical quantitation limit in exit pathway groundwater monitoring during 2023. Three organic compounds were detected at estimated concentrations (i.e., concentrations between the method analytical detection level and the practical quantitation limit). Acetone was detected during wet-season monitoring in samples from well 1191 and spring/surface water monitoring point EE-02. Bis(2-ethylhexyl) phthalate was detected in the sample from well 535 in dry-season monitoring. Toluene was detected in samples from well 857 and EE-02 during wet-season monitoring and from well 1190 and S-02 during dry-season monitoring. Methylene chloride was detected at an estimated concentration below the detection limit during wet-season monitoring at EE-02. Acetone, methylene chloride, toluene, and some phthalate compounds are common laboratory contaminants (EPA 2014).

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 5.5.3 for a discussion of results.)

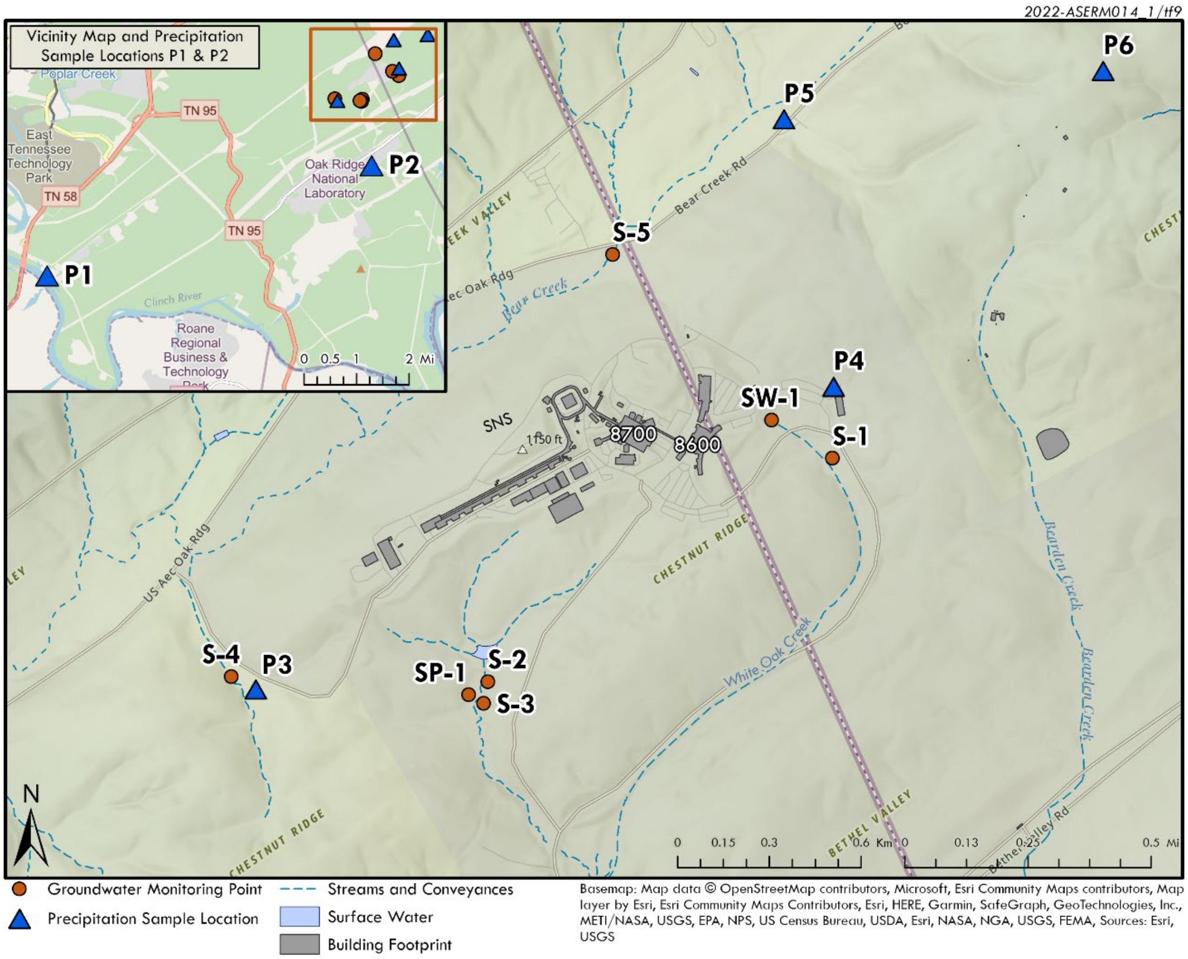
5.6.2.3. Active-Sites Monitoring—Spallation Neutron Source

Active-sites groundwater surveillance monitoring was performed in 2023 at the SNS site under the SNS operational monitoring plan (Bonine, Ketelle, and Trotter 2007) because of the potential for adverse impact on groundwater resources at ORNL should a release occur.

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 consistent with 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, 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 operational monitoring plan include maintaining compliance with applicable DOE contract requirements and environmental quality standards and providing 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. Since 2016, precipitation samples have also been collected for ^{3}H analysis at six of the springs, seeps, and surface water locations. Figure 5.40 shows the locations of the specific monitoring points sampled during 2023.



Acronyms:
P = precipitation monitoring point *S = spring* *SP = seep* *SW = surface water sampling area*

Figure 5.40. Groundwater and precipitation monitoring locations at the Spallation Neutron Source, 2023

In November 2011, the SNS historical ^{3}H data were evaluated to determine whether sampling could be optimized. The influence of flow condition on the proportion of ^{3}H 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. The results of the analysis indicate 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 ^{3}H detects to nondetects. The results of the statistical analysis of the April 2004–September 2011 data were the basis for the modified operational plan monitoring scheme implemented in 2012.

Quarterly sampling at each monitoring point continued in 2023. All sampling performed in 2023 was performed in conjunction with rainfall events, with samples being collected during rising or falling (recession) limb flow conditions. Table 5.18 shows the sampling and parameter analysis schedule followed in 2023.

Table 5.18. Spallation Neutron Source monitoring program schedule, 2023

Monitoring location	Quarter 1 January–March	Quarter 2 April–June	Quarter 3 July–September	Quarter 4 October–December
SW-1	^{3}H	^{3}H and expanded suite[a]	^{3}H	^{3}H
S-1	^{3}H	^{3}H	^{3}H	^{3}H and expanded suite[a]
S-2	^{3}H	^{3}H	^{3}H	^{3}H and expanded suite[a]
S-3	^{3}H	^{3}H and expanded suite[a]	^{3}H	^{3}H
S-4	^{3}H and expanded suite[a]	^{3}H	^{3}H	^{3}H
S-5	^{3}H	^{3}H and expanded suite[a]	^{3}H	^{3}H
SP-1	^{3}H	^{3}H	^{3}H	^{3}H and expanded suite[a]

[a] *The expanded suite includes gross alpha and gross beta activity, ^{14}C, and gamma emitters.*

Acronyms:
S = spring
SP = seep
SW = surface water sampling area

Spallation Neutron Source site results

Sampling at the SNS site occurred quarterly in 2023. Low concentrations of alpha and beta activities were detected at spring S-5. The alpha and beta activities detected at the S-5 monitoring location are attributed to CERCLA contaminants in Bear Creek Valley associated with legacy waste management practices at the Y-12 facility. Very low beta activity was detected at seep SP-1. Table 5.19 summarizes SNS sampling locations and radionuclide detections for 2023. Analytical results were compared with current federal or state standards or 4 percent of the DCS. Only alpha activity measured at the S-5 location exceeded its reference value in 2023.

In addition to SNS surface water sampling, precipitation monitoring for ^{3}H has been conducted at six locations since 2016. The precipitation sampling is conducted contemporaneously with the surface water sampling. Tritium can be an airborne constituent that is released from several DOE facilities at ORNL, from TVA reactor sites, and from commercial radiological waste processing facilities in the area. The precipitation sampling locations are shown in Figure 5.40, and the results are summarized in Table 5.20. Thirty-two sampling events have been conducted at each of the precipitation monitoring locations. The highest ^{3}H concentrations and frequencies of detection were at sample location P1, approximately 6 miles southwest of the SNS site. The second-highest concentrations and detection frequency occurred at location P4, which is located within 2,000 ft northeast of the SNS target facility. Tritium rainout from atmospheric ^{3}H releases from sources including DOE facilities, TVA facilities, and commercial radiological waste-handling and waste-processing facilities creates a regional background of ^{3}H in some surface water and groundwater samples.

Table 5.19. Radiological concentrations detected in samples collected at the Spallation Neutron Source, 2023[a]

Parameter	Concentrations (pCi/L)				Reference value[b]
	February	June	October	December	
SW-1[c]					
^{3}H	1,620		2,640	2,050	20,000
S-1[d]					
^{214}Bi			22.8		40,000
^{3}H	974		835	1,390	20,000
S-2[e]					
^{3}H	614	914	896	1,320	20,000
S-3[f]					
^{214}Bi	17.9			53.8	23,600
^{214}Pb	13.1			32.2	40,000
^{3}H	432	188	269	548	20,000
S-4[g]					
^{3}H	411		262	314	20,000
S-5[g]					
Alpha		18.4			15
Beta		15.7			50
^{3}H				323	20,000
SP-1[d]					
Beta			4.49		50
^{3}H	490	260	263	402	20,000

[a] *In addition to ^{3}H analyses, an extended suite of parameters was analyzed at each location during one 2023 sampling event. The extended suite includes gross alpha, gross beta, gamma scan, and ^{14}C. Results for ^{3}H and detected concentrations from the extended suite are listed in the table.*

[b] *Current federal and state standards are used as reference values. If no federal or state standard exists for a particular radionuclide, 4 percent of the derived concentration standard for a radionuclide is used.*

[c] *Analysis of extended suite completed in June.*

[d] *Analysis of extended suite completed in October.*

[e] *Analysis of extended suite completed in February and December.*

[f] *Analysis of extended suite completed in February.*

[g] *Analysis of extended suite completed in June.*

Acronyms: *S = spring SP = seep SW = surface water sampling area*

Table 5.20. Summary of precipitation ^3H monitoring results, 2016–2023

Sample location	Total samples	Total detects	Maximum detect (pCi/L)	Date of maximum detect	Date of most recent detect
P1	32	8	4,930	05/21/2016	12/23/2023
P2	32	2	1,070	05/21/2016	02/07/2018
P3	32	4	1,230	05/21/2016	06/27/2022
P4	32	8	3,560	10/07/2023	10/07/2023
P5	32	5	908	05/21/2016	10/07/2023
P6	32	3	1,240	02/07/2018	10/07/2023

5.6.2.4. Emerging Contaminant Assessment—Potential for Per- and Polyfluoroalkyl Substances in ORNL Area Groundwater

A group of fluorinated organic chemical compounds collectively referred to as per- and polyfluoroalkyl substances (PFAS) are contaminants of emerging concern. PFAS compounds are persistent in the environment, and some are known to bioaccumulate in humans or wildlife. They have been widely used in both consumer and industrial products, and traces have been detected in environmental media in many parts of the world.

Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) are the two PFAS compounds that have been produced in the largest amounts in the United States and that have been studied most. Through 2001, PFOS and other PFAS compounds were used in the manufacture of aqueous film-forming foams (AFFFs), and use of such foams, including in firefighting training activities, may have contributed to environmental releases. The information contained in this and the previous paragraph is summarized from EPA's *Technical Fact Sheet—Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA)* (EPA 2017).

On June 21, 2022, EPA published updated health advisories for PFOA and PFOS of 0.004 ng/L and 0.02 ng/L, respectively (EPA 2022b). These replaced the final health advisory of 70 ng/L for combined PFOA and PFOS that was issued in 2016. At the same time, the EPA also issued final health advisories for hexafluoropropylene oxide dimer acid and its ammonium salt (collectively referred to as GenX chemicals) and perfluorobutane sulfonic acid and the related compound potassium perfluorobutane sulfonate (together referred to as PFBS) of 10 ng/L and 2,000 ng/L, respectively.

In April 2022, EPA proposed the first CWA aquatic life criteria for PFAS (Table 5.21), which focus on PFOA and PFOS chemical groups. These draft recommendations reflect the latest peer-reviewed scientific knowledge regarding the toxicological effects of PFOA and PFOS on freshwater aquatic organisms.

Historically, firefighter training at ORNL included training in the use of AFFFs, and the foams that were used in past training activities may have contained PFAS compounds. The discharges of these foams are suspected to be the most significant potential source of PFAS in environmental media at ORNL. Most of the training was conducted at four locations: adjacent to the ORNL Fire Station (Building 2500), at the Fire Training and Test Facility (Building 2648), on the southeast corner of First Street and Bethel Valley Road (near where Building 2040 was later constructed), and at a location on the north side of Old Bethel Valley Road in the Bearden Creek watershed. A sampling and analysis plan has been developed and was implemented in 2023 to assess these areas for the presence of PFAS compounds in groundwater and in surface water bodies in these areas.

Table 5.21. Draft recommended freshwater aquatic life water quality criteria for PFOA and PFOS (EPA 2022c)

Criteria Component	Acute Water Column (CMC)	Chronic Water Column (CCC)	Invertebrate Whole-Body	Fish Whole-Body	Fish Muscle
PFOA magnitude	49 mg/L	0.094 mg/L	1.11 mg/kg ww	6.10 mg/kg ww	0.125 mg/kg ww
PFOS magnitude	3.0 mg/L	0.0084 mg/L	0.937 mg/kg ww	6.75 mg/kg ww	2.91 mg/kg ww
Duration	1 h average	4-day average	Instantaneous[a]		
Frequency	Not to be exceeded more than once in 3 years, on average	Not to be exceeded more than once in 3 years, on average	Not to be exceeded more than once in 10 years, on average		

[a] *Tissue data provide instantaneous point measurements that reflect integrative accumulation of PFOA or PFOS over time and space in aquatic life population(s) at a given site.*

Acronyms:
CCC = *criterion continuous concentration*
CMC = *criterion maximum concentration*
PFOA = perfluorooctanoic acid
PFOS = perfluorooctane sulfonate
ww = wet weight

The sampling and analysis plan also includes monitoring surface water locations in other parts of the ORNL campus, including former waste storage areas, to determine whether PFAS compounds from sources other than the use of AFFFs are present and are reaching surface water bodies. Surface water monitoring includes the use of passive sampling devices, which are deployed in stream environments for long periods (typically 4 weeks) and therefore can accumulate PFAS compounds and detect trace concentrations that might not be detectable with traditional water sampling techniques.

Neither groundwater nor surface water at ORNL is a direct source of drinking water. ORNL's water supply is municipal water purchased from the City of Oak Ridge. DOE owns the water distribution system on the ORNL site; limited sampling of the ORNL water distribution system for the presence of PFAS compounds was completed for 2023.

5.7. Quality Assurance Program

The UT-Battelle Quality Management System (QMS) has been developed to implement the requirements defined in DOE Order 414.1D, Quality Assurance (DOE 2011b). The methods used for successful implementation of the QMS rely on the integration and implementation of quality elements and 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 on 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 perform work safely and effectively. 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.
- Provide feedback.

In addition, EPSD has approved project-specific standard operating procedures for all activities controlled and maintained through the Enterprise Document and Records Management System.

Environmental sampling standard operating procedures developed for UT-Battelle environmental sampling programs provide detailed instructions on maintaining chain of custody; identifying, collecting, handling, and preserving samples; decontaminating equipment; and collecting 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 staff 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.

EPSD team leaders are responsible for identifying the training needs, qualifications, and requirements for staff who conduct sampling, data management, and reporting tasks associated with ORNL and ORR-wide environmental surveillance programs. Training status is routinely monitored by the division training officer, and notices of training needs or deficiencies are automatically sent to individual employees. The training program is supplemented by a division-wide required reading program. This program ensures that staff members have reviewed new or revised documents (e.g., procedures, lessons learned) that are applicable to their jobs.

5.7.3. Equipment and Instrumentation

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 and traceable standards to ensure measurement quality and traceability. The UT-Battelle Facilities and Operations Instrumentation and Control Services team tracks all equipment used in EPSD environmental monitoring programs through a maintenance recall program to ensure that equipment is functioning properly and within defined tolerance ranges.

5.7.3.1. Calibration

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 is performed annually to certify the Predictive Emissions Monitoring System for nitrogen oxides and oxygen. The purpose of a relative accuracy test audit is to provide a rigorous QA assessment in accordance with "Performance Specification 16" (EPA 2009b). The results of the QA tests are provided to TDEC quarterly, semiannually, or annually, as applicable.

5.7.3.2. Standardization

EPSD sampling procedures are maintained in the Enterprise Document and Records Management System 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 perform 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 5.2 lists environmental audits and assessments performed at ORNL in 2023 and the number of findings identified. EPSD also conducts internal assessments of UT-Battelle environmental monitoring activities. Surveillance results, recommendations, and completion of corrective actions, if required, are also documented and tracked in the UT-Battelle Assessment and Commitment Tracking System.

Independent audits, surveillances, and internal management assessments are performed at TWPC and Building 3019 to verify that requirements have been accurately specified and that activities that have been performed conform to expectations and requirements. Corrective actions at TWPC, if required, are documented and tracked using the UCOR Quality Assurance and Corrective Action Management Systems, and Isotek corrective actions for Building 3019 are tracked in its Assessment and Commitment Tracking System.

5.7.5. Analytical Quality Assurance

Laboratories that analyze environmental samples collected for EPSD environmental sampling programs are required to have documented QA/QC programs, trained and qualified staff, appropriately maintained equipment and facilities, and applicable certifications. The laboratories also participate in accreditation, certification, and performance evaluation programs such as the National Environmental Laboratory Accreditation Program (NELAP), Mixed Analyte Performance Evaluation Program (MAPEP), Discharge Monitoring Report Quality Assurance Study (DMRQA), and DOE Environmental Management Consolidated Audit Program (DOECAP), which evaluate laboratories according to stringent and widely accepted criteria for quality, accuracy, reliability, and efficiency. Any issues identified through accreditation or certification programs or through performance evaluation testing are addressed with analytical laboratories and are considered when determinations are made on data integrity. Blank and duplicate samples are submitted along with environmental samples to provide an additional check on analytical laboratory performance.

Environmental samples collected in support of EPSD environmental monitoring programs in 2023 were analyzed by one of two contracted commercial laboratories (GEL Laboratories or Eurofins) or by the UT-Battelle Radiochemical Materials Analytical Laboratory (RMAL) or the UT-Battelle Environmental Toxicology Laboratory. Contracts with analytical laboratories include statements of work that specify the scope of work, data deliverables, turnaround times, required methods, and detection limits.

GEL Laboratories, a contracted commercial radiochemistry and environmental laboratory in Charleston, South Carolina, holds more than 40 federal and state certifications, accreditations, and approvals, including for ISO 17025 (which contains general requirements for the competence of testing and calibration laboratories) and from the Department of Defense Environmental Laboratory Accreditation Program (DOD-ELAP), DOECAP, and NELAP. Four external audits were performed on-site in 2023. Ten internal audits focusing on analytical and support service activities were conducted to verify compliance with the requirements of the GEL QA/QC program and with client-specified terms. No issues were identified that would affect analytical data reported to clients. In 2023, GEL reported results from 5,331 performance test analyses (including DMRQA, MAPEP, DOECAP, and NELAP). Of these, 5,192 (97.4 percent) fell within acceptance ranges. Those that did not meet acceptance criteria were found to have no effect on data reported to clients.

Eurofins, a contracted environmental laboratory in Tacoma, Washington, is accredited, licensed, or approved by 11 third-party programs, including ISO 17025, DOD-ELAP, DOECAP, NELAP, and several state licensing or accrediting programs. In 2023, Eurofins participated in MAPEP and DMRQA, and all applicable test results were within acceptable ranges.

RMAL received ISO 17025:2017 (ISO 2017) accreditation in April 2023. Additionally, RMAL operates in compliance with the US Department of Defense/DOE *Consolidated Quality Systems Manual* (DOD/DOE 2018) and with the requirements of DOE 414.1D (DOE 2011b) and 10 CFR 830 Subpart A, "Quality Assurance Requirements." The UT-Battelle Chemical Sciences Division's QA plan also meets applicable requirements of the American Society of Mechanical Engineers' Nuclear Quality Assurance Program. In 2023, RMAL participated in several external audits, including the annual TDEC Waste Compliance Audit, the initial ISO 17025 accreditation audit performed by A2LA, and 10 internal assessments, that focused on adherence to approved analytical methods, waste management, and record keeping. No issues that required reanalysis or data corrections related to environmental sampling results were identified. In 2023, RMAL participated in MAPEP and DMRQA, and all results for analyses that RMAL performed in support of EPSD environmental monitoring programs were within acceptable ranges.

The Environmental Toxicology Laboratory does not hold any outside accreditations, but it operates in compliance with all methods required by EPA, TDEC, NPDES, and the UT-Battelle Environmental Sciences Division's Quality Assurance Management Program. In 2023, six internal assessments focused on adherence to approved analytical methods and data analysis were performed. No issues requiring reanalysis or data corrections related to standard toxicity testing results were identified. Updates of all standard operating procedures, reference toxicity control charts, and training requirements were completed in 2021. All standard operating procedures and lab methods comply with EPA's acute (EPA 2002a) and chronic (EPA 2002b) testing requirements for freshwater species. In 2023, the Environmental Toxicology Laboratory participated in the DMRQA program for whole effluent toxicity testing of *Pimephales promelas* (the fathead minnow, a freshwater fish) and *Ceriodaphnia dubia* (the water flea, a freshwater invertebrate). All *C. dubia* and *P. promelas* results were in acceptable ranges.

5.7.6. Data Management and Reporting

Data collected by UT-Battelle in conjunction with ORR and ORNL environmental surveillance programs and CWA activities at ORNL are managed 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 the 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 Requirements, Documents, and Records Management System provides the requirements for managing all UT-Battelle records. Requirements include creating, maintaining, and using records; scheduling, protecting, and storing records; and destroying records.

Records management programs for TWPC and Building 3019 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 ORNL

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 of past operations. The contaminated portions of ORR are on the EPA National Priorities List, 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 EPA and TDEC. The *FY 2023 Cleanup Progress: Annual Report on Oak Ridge Reservation Cleanup* (UCOR 2023) provides detailed information on OREM's 2023 cleanup activities (**here**).

5.8.1. Wastewater Treatment

At ORNL, OREM operates PWTC and the Liquid Low-Level Waste Treatment Facility. In 2023, 442.9 million L of wastewater was treated and released at PWTC. In addition, the liquid LLW system at ORNL received 427,199 L of waste. The waste treatment activities of these facilities support both OREM and 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. Newly Generated Waste Management

ORNL is the largest, most diverse 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 by-products of performing research and operational activities and must be managed to ensure that the environment is protected from associated hazards. As the prime contractor for the management of ORNL, UT-Battelle is responsible for managing most of the wastes generated from R&D activities and wastes generated from operation of the R&D facilities. If possible, waste streams are treated by on-site liquid or gaseous waste treatment facilities operated by OREM. 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 2023, ORNL performed 101 waste and recycle shipments to off-site hazardous, radiological, or mixed-waste treatment or disposal vendors.

5.8.3. Transuranic Waste Processing Center

TRU waste processing activities performed for DOE in 2023 by UCOR addressed both contact-handled and remotely handled solids and debris. These activities involved processing, treating, and repackaging waste. LLW and mixed LLW are transported to the Nevada National Security Site or to another approved off-site facility for disposal.

In 2023, 135.0 m^3 of contact-handled TRU waste was shipped from TWPC in 18 shipments (643 containers). During 2023, 5.84 m^3 of contact-handled waste was processed; no remotely handled waste was processed, and no mixed LLW (TRU waste that was recharacterized as LLW) was shipped off-site.

5.9. References

10 CFR 830. "Nuclear Safety Management." *US Code of Federal Regulations*, Washington, DC. Retrieved May 5, 2021, from https://www.govinfo.gov/content/pkg/CFR-2011-title10-vol4/pdf/CFR-2011-title10-vol4-part830.pdf.

40 CFR 60, Appendix A-1. "Method 2—Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)." *US Code of Federal Regulations*, Washington, DC.

40 CFR 82. "Protection of Stratospheric Ozone." *US Code of Federal Regulations*, Washington, DC. Retrieved June 3, 2020, from https://www.ecfr.gov/cgi-bin/text-idx?rgn=div6;node=40%3A18.0.1.1.2.6.

40 CFR 112. "Oil Pollution Protection." *US Code of Federal Regulations,* Washington, DC. Retrieved June 4, 2020, from https://www.epa.gov/sites/production/files/2014-04/documents/b_40cfr112.pdf.

40 CFR 280. "Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks (UST)." *US Code of Federal Regulations,* Washington, DC. Retrieved June 9, 2020, from https://www.ecfr.gov/cgi-bin/text-idx?SID=165cbbe4db4970349d085d9840b78873&mc=true&node=pt40.29.280&rgn=div5.

40 CFR 1508.4. "Categorical Exclusion." *US Code of Federal Regulations*, Washington, DC. Retrieved May 2, 2020, from https://www.ecfr.gov/cgi-bin/text-idx?SID=079d239aa6c408b31009767e801d0d90&mc=true&node=pt40.37.1508&rgn=div5#se40.37.1508_14.

AIM 2020. *American Innovation and Manufacturing Act*. Title 42 US Code §7675.

ANSI 1969. Guide *to Sampling Airborne Radioactive Materials in Nuclear Facilities*. ANSI N13.1-1969R. American National Standards Institute, Washington, DC.

ANSI 1999. *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities.* ANSI/HPS N13.1-1999. American National Standards Institute, Health Physics Society, New York, New York.

Bonine 2013. Bonine, T. M. *UT-Battelle Sampling and Analysis Plan for Surveillance Monitoring of Exit Pathway Groundwater at Oak Ridge National Laboratory*. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Bonine, Ketelle, and Trotter 2007. Bonine, T. M., R. H. Ketelle, and S. M. Trotter. *Operational Groundwater Monitoring Plan for the Spallation Neutron Source Site*. SNS 102040000-ES0001-R01, ORNL/TM-2004/118, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

CAA 1970. *Clean Air Act.* Title 42 US Code §7401 et seq.

CERCLA 1980. *Comprehensive Environmental Response, Compensation, and Liability*. Title 42 US Code Chapter 103.

Cleary et al. 2021. Cleary, B.M., M. E. Romano, C. Y. Chen, W. Heiger-Bernays, and K. A. Crawford, "Comparison of Recreational Fish Consumption Advisories across the USA." Current Environmental Health Reports 8(2), 71–88.

CWA 1972. *Clean Water Act.* Title 33 US Code §1251 et seq.

DOD/DOE 2018. *Department of Defense (DoD)/Department of Energy (DOE) Consolidated Quality Systems Manual (QSM) for Environmental Laboratories*. DoD/DOE QSM 5.5.1, US Department of Defense, and US Department of Energy, Washington, DC. Retrieved April 30, 2021, from https://denix.osd.mil/edqw/documents/documents/qsm-version-5-1-1-final/.

DOE 1992. *Federal Facility Agreement for the Oak Ridge Reservation*. FFA-PM/18-011, DOE/OR-014, January 1, 1992, or latest revision, US Environmental Protection Agency Region IV, US Department of Energy, and Tennessee Department of Environment and Conservation, Oak Ridge, Tennessee. Retrieved August 18, 2022, from https://www.energy.gov/sites/prod/files/em/2001_Agreements/ORR_FFA_1-1-92.pdf .

DOE 2000. *Record of Decision for Interim Actions for the Melton Valley Watershed at the Oak Ridge National Laboratory, Oak Ridge, Tennessee*. DOE/OR/01-1826&D3, US Department of Energy, Washington, DC.

DOE 2002. *Record of Decision for Interim Actions in Bethel Valley Watershed, Oak Ridge, Tennessee*. DOE/OR/01-1862&D4, US Department of Energy, Washington, DC.

DOE 2008. *Environmental Protection Program.* DOE Order 450.1A. Approved June 4, 2008. US Department of Energy, Washington, DC.

DOE 2011a. *Final Draft ^{233}U Alternatives Analysis, Phase I Report: Screening of Alternative Disposition Approaches.* US Department of Energy, Washington, DC.

DOE 2011b. *Quality Assurance.* DOE Order 414.1D. Approved April 25, 2011. US Department of Energy, Washington, DC.

DOE 2012. *Phased Construction Completion Report for the Bethel Valley Burial Grounds at the Oak Ridge National Laboratory, Oak Ridge, Tennessee*. DOE/OR/01-2533&D2. UCOR, Oak Ridge, Tennessee.

DOE 2020. *Radiation Protection of the Public and the Environment.* DOE Order 458.1, Change 4. Approved September 15, 2020. US Department of Energy, Washington, DC.

DOE 2021a. *2021 Climate Adaptation and Resilience Plan: Report to the White House National Climate Task Force and Federal Chief Sustainability Officer*. US Department of Energy, Washington, DC. August 2021. https://www.energy.gov/sites/default/files/2021-09/DOEClimateAdaptationandResiliencePlanSept21.pdf.

DOE 2021b. *Derived Concentration Technical Standard*. DOE-STD-1196-2021. US Department of Energy, Washington, DC. July 2021. https://www.standards.doe.gov/standards-documents/1100/1196-astd-2021.

DOE 2023a. *Departmental Sustainability.* DOE Order 436.1A. Approved April 25, 2023. US Department of Energy, Washington, DC.

DOE 2023b. *Fiscal Year 2024 Site Sustainability Plan Instructions*. US Department of Energy, Washington, DC. https://sustainabilitydashboard.doe.gov/PDF/Resources/FY%202024%20SSP%20Instructions%20Final-1-2.pdf

DOE 2023c. *Melton Valley/Bethel Valley Exit Pathway Phase 1 Remedial Investigation Completion Report for the U.S. Department of Energy Oak Ridge Site Oak Ridge, Tennessee.* DOE/OR/01-2953&D1, US Department of Energy, Washington, DC.

EAct 2020. *The Energy Act of 2020*. Public Law 116-260, Division Z.

EISA 2007. *Energy Independence and Security Act of 2007*. Public Law 110-140.

EO 1994. Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*. Issued February 11, 1994. Retrieved May 5, 2023, from https://www.federalregister.gov/documents/1994/02/16/94-3685/federal-actions-to-address-environmental-justice-in-minority-populations-and-low-income-populations.

EO 2021a. Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad*. Issued January 27, 2021. Retrieved April 5, 2022, from https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad.

EO 2021b. Executive Order 14057, *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability*. Issued December 8, 2021. Retrieved May 5, 2023, from https://www.whitehouse.gov/briefing-room/presidential-actions/2021/12/08/executive-order-on-catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability/.

EO 2022. Executive Order 14072, *Strengthening the Nation's Forests, Communities, and Local Economies.* Issued April 22, 2022. https://www.whitehouse.gov/briefing-room/presidential-actions/2022/04/22/executive-order-on-strengthening-the-nations-forests-communities-and-local-economies/.

EPA 2000. *Stressor Identification Guidance Document.* EPA-822-B-00-025, US Environmental Protection Agency, Office of Water, Washington, DC.

EPA 2002a. *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms*. EPA-821-R-02-012, US Environmental Protection Agency, Washington, DC. Retrieved April 17, 2021, from https://www.wbdg.org/FFC/EPA/EPACRIT/epa821_r_02_012.pdf.

EPA 2002b. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms*. EPA-821-R-02-013, US Environmental Protection Agency, Washington, DC. Retrieved April 17, 2021, from https://www.epa.gov/sites/production/files/2015-08/documents/short-term-chronic-freshwater-wet-manual_2002.pdf.

EPA 2009a. *Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act*. EPA 841-B-09-001, US Environmental Protection Agency, Washington, DC. https://www.epa.gov/sites/default/files/2015-09/documents/eisa-438.pdf.

EPA 2009b. *Performance Specification 16 for Predictive Emissions Monitoring Systems and Amendments to Testing and Monitoring Provisions*. US Environmental Protection Agency, Washington, DC. https://www.federalregister.gov/documents/2009/03/25/E9-6275/performance-specification-16-for-predictive-emissions-monitoring-systems-and-amendments-to-testing.

EPA 2014. *Laboratory Data Review for the Non-Chemist*. US Environmental Protection Agency, Region 9, San Francisco, California. https://clu-in.org/conf/tio/rcraexpert_100516/slides/Data-Review-Manual-110114.pdf.

EPA 2017. *Technical Fact Sheet—Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA)*. EPA 505-F-17-001, US Environmental Protection Agency. https://www.epa.gov/sites/production/files/2017-12/documents/ ffrrofactsheet_contaminants_pfos_pfoa_11-20-17_508_0.pdf.

EPA 2022a. *Phasedown of Hydrofluorocarbons: Establishing the Allowance Allocation and Trading Program under the AIM Act.* US Environmental Protection Agency, Washington, DC. Retrieved April 6, 2022, from https://www.federalregister.gov/documents/2021/10/05/2021-21030/phasedown-of-hydrofluorocarbons-establishing-the-allowance-allocation-and-trading-program-under-the.

EPA 2022b. "Lifetime Drinking Water Health Advisories for Four Perfluoroalkyl Substances." US Environmental Protection Agency, Federal Register, Vol. 87, No. 118. Approved June 21, 2022. https://www.govinfo.gov/app/details/FR-2022-06-21/summary (accessed March 19, 2023).

EPA 2022c. "Fact Sheet: Draft 2022 Aquatic Life Ambient Water Quality Criteria for Perfluorooctanoic acid (PFOA) and Perfluorooctane Sulfonic Acid (PFOS)." EPA 842-D-22-005, US Environmental Protection Agency, Office of Water. Retrieved March 25, 2024, from https://www.epa.gov/system/files/documents/2022-04/pfoa-pfos-draft-factsheet-2022.pdf.

EPA 2023. "Environmental Justice." US Environmental Protection Agency, Washington, DC. Retrieved March 19, 2023, from https://www.epa.gov/environmentaljustice#:~:text=Environmental%20justice%20is%20the%20fair,laws%2C%20regulations%2C%20and%20policies.

EPA 2024a. "Scope 1 and Scope 2 Inventory Guidance." US Environmental Protection Agency, Center for Corporate Climate Leadership, Washington, DC. Retrieved June 4, 2024, from https://www.epa.gov/climateleadership/scope-1-and-scope-2-inventory-guidance.

EPA 2024b. *Criteria Air Pollutants*. US Environmental Protection Agency. February 2024. https://www.epa.gov/criteria-air-pollutants.

EPAct 2005. *Energy Policy Act of 2005*. Public Law 109-58.

EPCRA 1986. *Emergency Planning and Community Right-to-Know Act*. Title 42 US Code Chapter 116.

ISO 2004. *Environmental Management Systems—Requirements with Guidance for Use*. ISO 14001:2004, International Organization for Standardization. http://www.iso.org.

ISO 2015. *Environmental Management Systems—Requirements with Guidance for Use*. ISO 14001:2015, International Organization for Standardization. http://www.iso.org.

ISO 2017. *General Requirements for the Competence of Testing and Calibration Laboratories*. ISO/IEC 17025, International Organization for Standardization. Retrieved April 17, 2021, from https://www.iso.org/publication/PUB100424.html.

Matson et al. 2022. Matson, P. G., L. M. Stevenson, R. A. Efroymson, R. T. Jett, M. W. Jones, M. J. Peterson, and T. J. Mathews, "Variation in Natural Attenuation Rates of Polychlorinated Biphenyls (PCBs) in Fish from Streams and Reservoirs in East Tennessee Observed over a 35-Year Period." *Journal of Hazardous Materials* 438, 129427.

Miller et al. 2015. Miller, C. L., D. B. Watson, B. P. Lester, J. Y. Howe, D. H. Phillips, F. He, L. Liang, and E. M. Pierce. "Formation of Soluble Mercury Oxide Coatings: Transformation of Elemental Mercury in Soils." *Environmental Science and Technology* 49, 12105–12111.

NEPA 1969. *National Environmental Policy*. Title 42 US Code Chapter 55.

NHPA 1966. *National Historic Preservation Act*. Public Law 89-665; Title 54 US Code §300101 et seq.

NRC 2000. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*. NUREG-1575, Rev. 1/EPA 402-R-97-016, Rev. 1/DOE/EH-0624, Rev. 1, US Nuclear Regulatory Commission, Environmental Protection Agency, Department of Defense, and Department of Energy, Washington, DC.

NRC 2009. *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual (MARSAME)*. NUREG-1575, Supplement 1/EPA 402-R-09-001/DOE/HS-0004. US Nuclear Regulatory Commission, Environmental Protection Agency, Department of Defense, and Department of Energy, Washington, DC.

ORNL 2024. Goins. M., A. A. Miller, M. Madgett, S. Sluder, L. Touton, and S. Stephenson. *Oak Ridge National Laboratory FY 2024 Site Sustainability Plan with FY 2023 Performance Data*. ORNL/SPR-2023/3213, Oak Ridge National Laboratory, Oak Ridge, Tennessee. https://info.ornl.gov/sites/publications/Files/Pub206094.pdf.

Pelletier 1995. Pelletier, R. F., "Application of DOE 5400.5 Requirements for Release and Control of Property Containing Residual Radioactive Material," correspondence to distribution. US Department of Energy, Office of Environmental Policy and Assistance, Washington, DC.

RCRA 1976. "Resource Conservation and Recovery Act." *Code of Federal Regulations* Title 40 parts 239–282.

SARA 1986. *The Superfund Amendments and Reauthorization Act.* Public Law 99-499. https://www.congress.gov/bill/99th-congress/house-bill/2005.

Souza et al. 2001. Souza, P. A., G. D. DuVall, and M. J. Hart. *Cultural Resource Management Plan, DOE Oak Ridge Reservation, Anderson and Roane Counties, Tennessee.* DOE/ORO/2085, US Department of Energy, Washington, DC.

TDEC 2010a. *Proposed Total Maximum Daily Loads (TMDLs) for Polychlorinated Biphenyls (PCBs) and Chlordane in Melton Hill Reservoir: Lower Clinch River Watershed (HUC 06010207), Anderson, Knox, Loudon, and Roane Counties, Tennessee*. Tennessee Water Pollution Control Board, Division of Water Pollution Control, Nashville, TN.

TDEC 2010b. *Proposed Total Maximum Daily Loads (TMDLs) for Polychlorinated Biphenyls (PCBs) and Chlordane in Watts Bar Reservoir: Watts Bar Lake Watershed (HUC 06010201), Lower Clinch River Watershed (HUC 06010207), and Emory River Watershed (HUC 06010208), Loudon, Meigs, Morgan, Rhea, and Roane Counties, Tennessee*. Tennessee Water Pollution Control Board, Division of Water Pollution Control, Nashville, TN.

TDEC 2010c. *Proposed Total Maximum Daily Loads (TMDLs) for Polychlorinated Biphenyls (PCBs) in Fort Loudoun Reservoir: Fort Loudoun Lake Watershed (HUC 06010201), Blount, Knox, and Loudon Counties, Tennessee*. Tennessee Water Pollution Control Board, Division of Water Pollution Control, Nashville, TN.

TDEC 2019. "General Water Quality Criteria." *Rules of the Tennessee Department of Environment and Conservation.* Chapter 04000-40-03. Tennessee Department of Environment and Conservation, Bureau of Environment, Division of Water Supply. https://www.epa.gov/sites/default/files/2014-12/documents/tn-chapter1200-4-3.pdf.

TDEC 2020. "Public Water Systems." *Rules of Tennessee Department of Environment and Conservation Division of Water Resources*. Chapter 0400-45-01. Tennessee Department of Environment and Conservation, Bureau of Environment, Division of Water Supply. https://publications.tnsosfiles.com/rules/0400/0400-45/0400-45-01.20190217.pdf.

TDEC 2021a. "Underground Storage Tank Program." *Rules of Tennessee Department of Environment and Conservation*. Chapter 0400-18-01. Tennessee Department of Environment and Conservation, Division of Underground Storage Tanks.

TDEC 2021b. *Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys*. DWR-WP-P-01-QSSOP-Macroinvert-122821, Tennessee Department of Environment and Conservation Division of Water Resources, Nashville, Tennessee. https://www.tn.gov/content/dam/tn/environment/water/policy-and-guidance/DWR-PAS-P-01-Quality_System_SOP_for_Macroinvertebrate_Stream_Surveys-122821.pdf.

TSCA 1976. *Toxic Substances Control Act.* Title 15 US Code §2601 et seq. https://www.epa.gov/laws-regulations/summary-toxic-substances-control-act).

UCOR 2023. *FY 2023 Cleanup Progress: Annual Report on Oak Ridge Reservation Cleanup.* OREM-23-7632, US Department of Energy Oak Ridge Office of Environmental Management, Oak Ridge, Tennessee. Retrieved March 13, 2024, from https://www.energy.gov/sites/default/files/2023-11/Cleanup%20Progress%202023.pdf.

Eating beef and drinking milk obtained from cattle that eat hay are potential radiation exposure pathways to humans. Hay from an area on the eastern edge of ORR is made available to an off-site farming operation and is sampled annually to characterize any possible doses from these pathways.

6

Oak Ridge Reservation Environmental Monitoring Program

ORR environmental surveillance is conducted to comply with DOE requirements to protect the public and the environment against undue risks associated with DOE activities. These requirements are established in DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2020), and related guidance is provided in *Environmental Radiological Effluent Monitoring and Environmental Surveillance* (DOE 2015). The objective of the ORR environmental surveillance program is to characterize environmental conditions in areas outside the ORR facility boundaries, both on and off ORR.

6.1. Meteorological Monitoring

Eight 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. Additionally, ORNL and Y-12 operate three wind profilers on ORR to better characterize upper-level winds (winds higher than 60 m above ground level).

6.1.1. Data Collection and Analysis

The eight meteorological towers on ORR are described in Table 6.1 and depicted in Figure 6.1. In this document, ORR towers are designated by “MT” followed by a numeral. Other commonly used names for these towers are provided in Table 6.1. Meteorological data are collected at different heights above the ground (1, 2, 3, 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 10 or 15 m 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. Temperature, relative humidity, and precipitation are measured at most sites at 2 m, but wind speed and wind direction typically are not. Atmospheric stability (a measure of the 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 60 m towers. The solar radiation delta-T method is a stability calculation that involves the temperature difference between 15 and 30 m heights, 15 m wind speeds, and the solar radiation value. Stability is also calculated for most sites using the sigma phi method, which relies heavily on the measurement of the standard deviation of vertical wind speed using 3D sonic wind monitors. Barometric pressure is measured at one or more of the towers at each ORR site (MT2, MT4, MT6, MT9, MT12, and MT13). Precipitation is measured at MT6 and MT9 at the Y-12 Complex; at MT13 at ETTP; and at MT2, MT3, MT4, and MT12 at ORNL. Solar radiation is measured at MT6 and MT9 at the Y-12 Complex 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). Additionally, Holian Environmental audits the Y-12-owned towers (MT6, MT9, and MT11) every 3 months.

Table 6.1. ORR meteorological towers

Tower	Alternate tower names	Location (latitude, longitude)	Altitude above MSL (m)	Measurement heights (m)
		ETTP		
MT13	J, YEOC	35.93043N, -84.39346W	237	20
		ORNL		
MT2	D,[a] 1047	35.92559N, -84.32379W	261	1, 2, 15, 35, 60
MT3	B, 6555	35.93273N, -84.30254W	256	15, 30
MT4	A, 7571	35.92185N, -84.30470W	266	1, 3, 15, 30
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
MSL = mean sea level
ORNL = Oak Ridge National Laboratory
PSS = plant shift superintendent
Y-12 Complex = Y-12 National Security Complex
YEOC = Y-12 Complex Emergency Operations Center

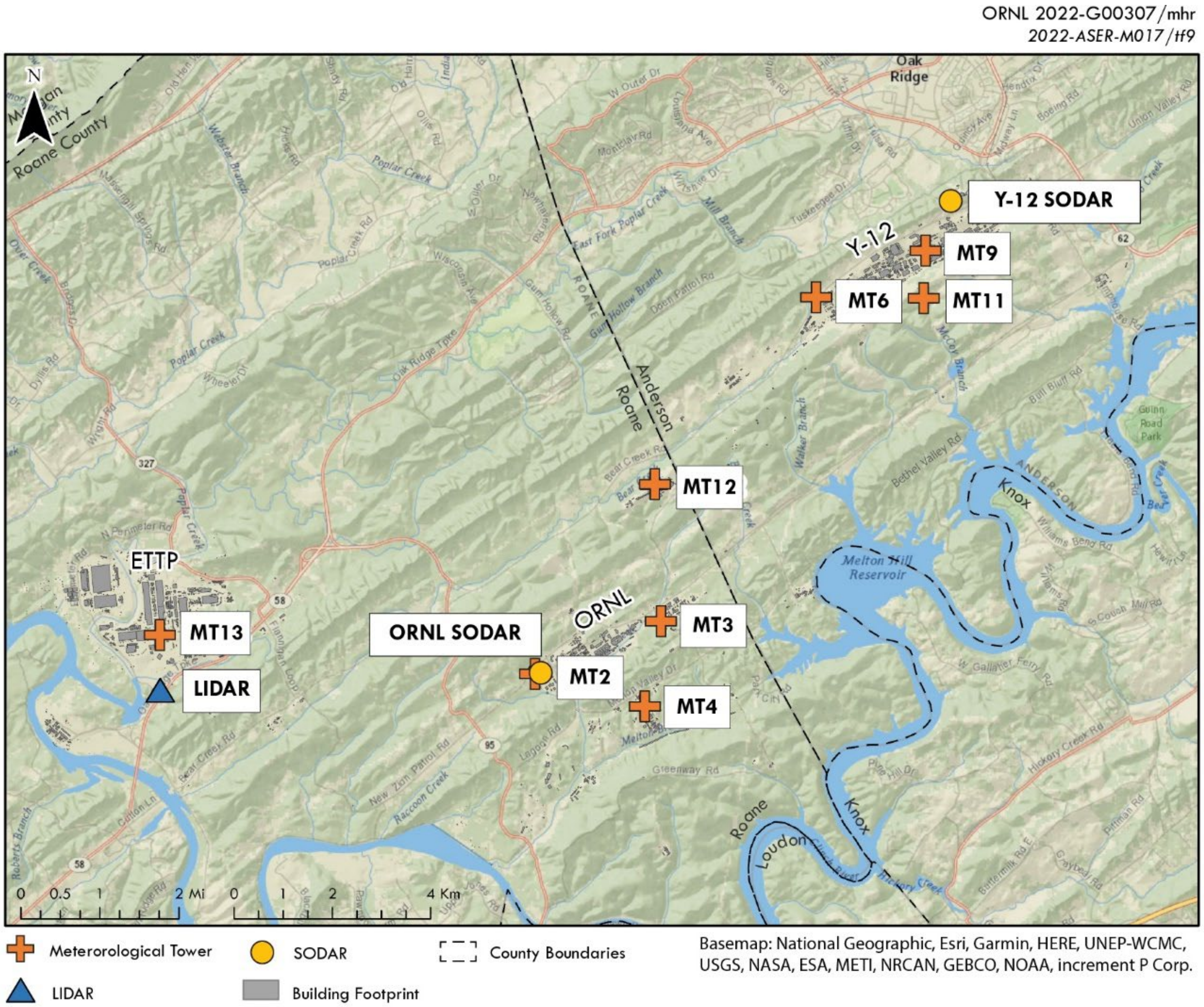


Figure 6.1. The ORR meteorological monitoring network, including light and sonic detection and ranging (LIDAR and SODAR) devices

Sonic detection and ranging (SODAR) devices have been installed at the east end of the Y-12 Complex (Pine Ridge) and adjacent to 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 (40–800 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 is the thickness of the air layer adjacent to the ground over which an emitted or entrained inert nonbuoyant tracer could be mixed by turbulence within 1 h.

Meteorological data are collected in real time from the meteorological towers at 1 min, 15 min, and 1 h 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 using the archived hourly data. Data quality is checked continuously against predetermined data constraints, and out-of-range parameters are marked as invalid and excluded from compliance modeling. Appropriate substitution data are identified when possible. Quality assurance records of missing and erroneous data are routinely kept for the eight ORR towers.

6.1.2. Results

Prevailing winds generally flow 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 the 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 is sometimes observed at ridgetop level, particularly when flow is not parallel to the ridges (see Appendix B).

The atmosphere over ORR is often characterized 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 from the facilities. However, high roughness values (caused by terrain and obstructions such as trees and buildings) may significantly mitigate these factors by increasing 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 MT2 have previously been used in stream-flow modeling and in certain research efforts. In 2023, maintenance and equipment upgrades were being performed on MT2, and precipitation data from MT3 were used instead. 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 2023 (1,179.6 mm or 46.44 in.) was about 17 percent below the long-term 1991–2020 average of 1,417.8 mm (55.80 in.). The average annual wind data recovery rates (a measure of acceptable data) during 2023 were greater than 98 percent for MT3, MT4, and MT12. Tower MT2 was down a portion of the year because of maintenance but still recorded a recovery rate greater than 40 percent in 2023. Missing data at tower MT2 were corrected through profiling and substitution along with consideration of ambient meteorological measurements and synoptic weather by on-site meteorologists. Annual wind data recovery during 2023 exceeded 98 percent for MT12 and MT13. Y-12 tower MT6 was down most of the year for maintenance, and substitute data were used.

6.2. 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 6.2). 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 enable the determination of contaminant levels at monitoring locations in the event of an emergency.

Figure 6.2. ORR ambient air station

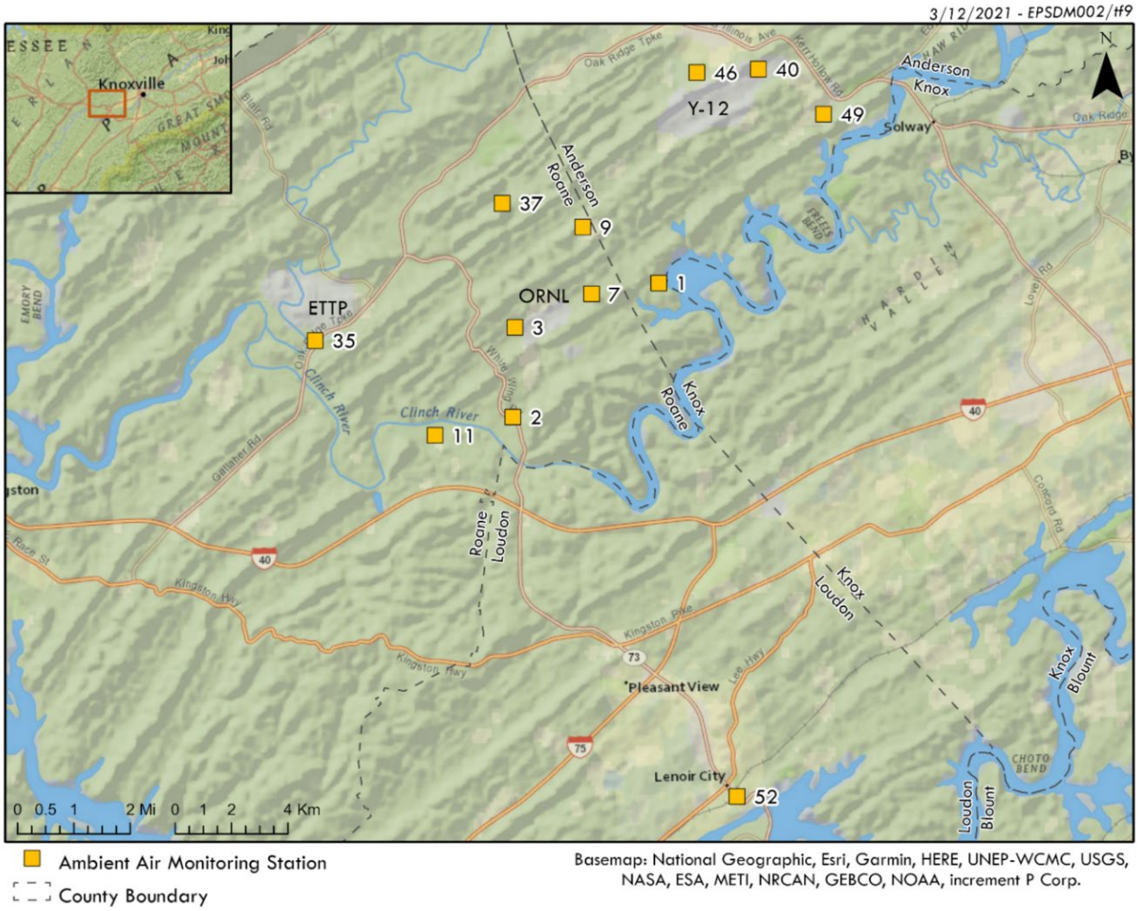
6.2.1. Data Collection and Analysis

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 enables the impacts of ORR operations to be assessed on an integrated basis.

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 and was modified in 2016 in response to changes in DOE activities and operations since the 1990s. The stations monitored in 2023 are shown in Figure 6.3. Reference samples are collected at Station 52 (Fort Loudoun Dam). Sampling was conducted at each ORR station during 2023 to quantify levels of alpha-, beta-, and gamma-emitting radionuclides.

Atmospheric dispersion modeling was used to select appropriate sampling locations 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 at each ambient air monitoring station consists of two separate instruments. Particulates are captured by a high-volume air sampler equipped with a glass-fiber filter. The filters are collected weekly, composited quarterly, and then submitted to an analytical laboratory to quantify gross alpha and gross beta activity and to determine the concentrations of specific isotopes of interest on ORR. The second instrument 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 ^{3}H analysis.



Notes:

1. *Reference samples are collected at Station 52 (Fort Loudoun Dam).*
2. *Station 7 is an ORNL site-specific monitoring location and is not part of the ORR perimeter network.*

Figure 6.3. Locations of ORR perimeter air monitoring stations

6.2.2. 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 6.2) is compared with derived concentration standards (DCSs) for air established by DOE as guidelines for controlling exposure to members of the public (DOE 2021a). All radionuclide concentrations measured at the ORR ambient air stations during 2023 were less than 1 percent of applicable DCSs.

Table 6.2. Radionuclide concentrations at ORR perimeter air monitoring stations sampled annually, 2023

Station	Average concentration (pCi/mL)[a] (Number detects/*n*)											
	^{228}Ac	^{7}Be	^{214}Bi	^{210}Pb	^{40}K	^{228}Ra	^{99}Tc	^{208}Tl	^{3}H	$^{233/234}$U	$^{235/236}$U	^{238}U
01		3.6E-08 (4/4)	8.2E-11 (1/4)	7.8E-09 (2/4)	9.4E-10 (2/4)				5.5E-06 (2/4)	4.0E-11 (4/4)	2.4E-12 (2/4)	3.9E-11 (4/4)
02		3.8E-08 (4/4)	3.9E-11 (1/4)	1.3E-08 (2/4)	1.3E-09 (3/4)				6.5E-06 (3/4)	4.1E-11 (4/4)	2.2E-12 (1/4)	4.4E-11 (4/4)
03		3.3E-08 (4/4)		1.3E-08 (3/4)	9.2E-10 (2/4)				8.4E-06 (4/4)	4.3E-11 (4/4)	2.2E-12 (1/4)	4.1E-11 (4/4)
09		3.9E-08 (4/4)		2.0E-08 (4/4)	2.9E-10 (1/4)				4.3E-05 (4/4)	4.3E-11 (4/4)	1.6E-12 (0/4)	4.6E-11 (4/4)
11		2.8E-08 (4/4)		2.8E-08 (4/4)	1.3E-09 (4/4)			3.3E-11 (1/4)	6.0E-06 (3/4)	3.9E-11 (4/4)	2.8E-12 (2/4)	4.3E-11 (4/4)
35	1.7E-10 (1/4)	3.7E-08 (4/4)		8.0E-09 (2/4)	7.3E-10 (2/4)	1.7E-10 (1/4)	1.9E-09 (2/4)		1.1E-05 (3/4)	4.2E-11 (4/4)	2.3E-12 (2/4)	4.3E-11 (4/4)
37		3.1E-08 (4/4)		8.5E-09 (1/4)	4.1E-10 (1/4)			6.1E-11 (1/4)	5.0E-06 (1/4)	4.1E-11 (4/4)	1.5E-12 (0/4)	4.5E-11 (4/4)
40	1.2E-10 (1/4)	3.8E-08 (4/4)		2.0E-08 (4/4)	7.1E-10 (2/4)	1.2E-10 (1/4)			4.6E-06 (2/4)	4.9E-11 (4/4)	2.9E-12 (1/4)	4.6E-11 (4/4)
46		3.1E-08 (4/4)		1.3E-08 (2/4)	9.6E-10 (3/4)				2.8E-06 (1/4)	4.3E-11 (4/4)	2.1E-12 (1/4)	4.3E-11 (4/4)
49		3.2E-08 (4/4)		1.5E-08 (3/4)	7.1E-10 (3/4)				2.6E-06 (1/4)	4.3E-11 (4/4)	2.2E-12 (1/4)	4.6E-11 (4/4)
52[b]		4.1E-08 (4/4)		2.2E-08 (4/4)	1.2E-09 (3/4)		1.6E-09 (1/4)		1.4E-06 (1/4)	4.0E-11 (4/4)	2.1E-12 (1/4)	4.5E-11 (4/4)

[a] *1 pCi = 3.7E-02 Bq.*

[b] *Station 52 is the reference location.*

6.3. External Gamma Radiation Monitoring

Members of the public could hypothetically be exposed directly to gamma radiation from radionuclides released into the environment, from previously released radionuclides deposited on soil and vegetation or in sediments, from radiation-generating facilities (especially high-energy accelerators), and from the storage of radioactive materials (DOE 2021b). Continuous direct radiation levels are monitored at locations around ORR to complement the sample data collected as part of the ORR ambient air monitoring program (see Section 6.2).

6.3.1. Data Collection and Analysis

External gamma exposure rates are continuously recorded every minute by dual-range Geiger-Müller tube detectors colocated with ORR ambient air stations 2, 3, 9, 11, 40, 46, 49, and 52 (see Section 6.2). The data are downloaded weekly and are averaged for the entire year. Figure 6.4 shows locations that were monitored during 2023; Table 6.3 summarizes the data for each station.

6.3.2. Results

The mean exposure rate for the reservation network in 2023 was 9.7 μR/h, and the mean rate at the reference location (Fort Loudoun Dam) was 9.2 μR/h. Background direct radiation exposure rates have been collected at the Fort Loudoun Dam (Station 52) reference location for many years. From 2013 through 2023, the exposure rates at the reference location ranged from 6.6 to 11.4 μR/h and averaged 8.9 μR/h. The maximum exposure rate at Air Station 9 (see Table 6.3) was due to the temporary storage of containerized radioactive waste near the monitoring equipment from July 10 to August 4 and does not represent typical exposure rates at this location. Station 9 is located within the ORNL site boundary and is not accessible to the public. When the data from July 10 to August 4 are excluded, the mean exposure rate for the reservation network in 2023 was 9.3 µR/h.

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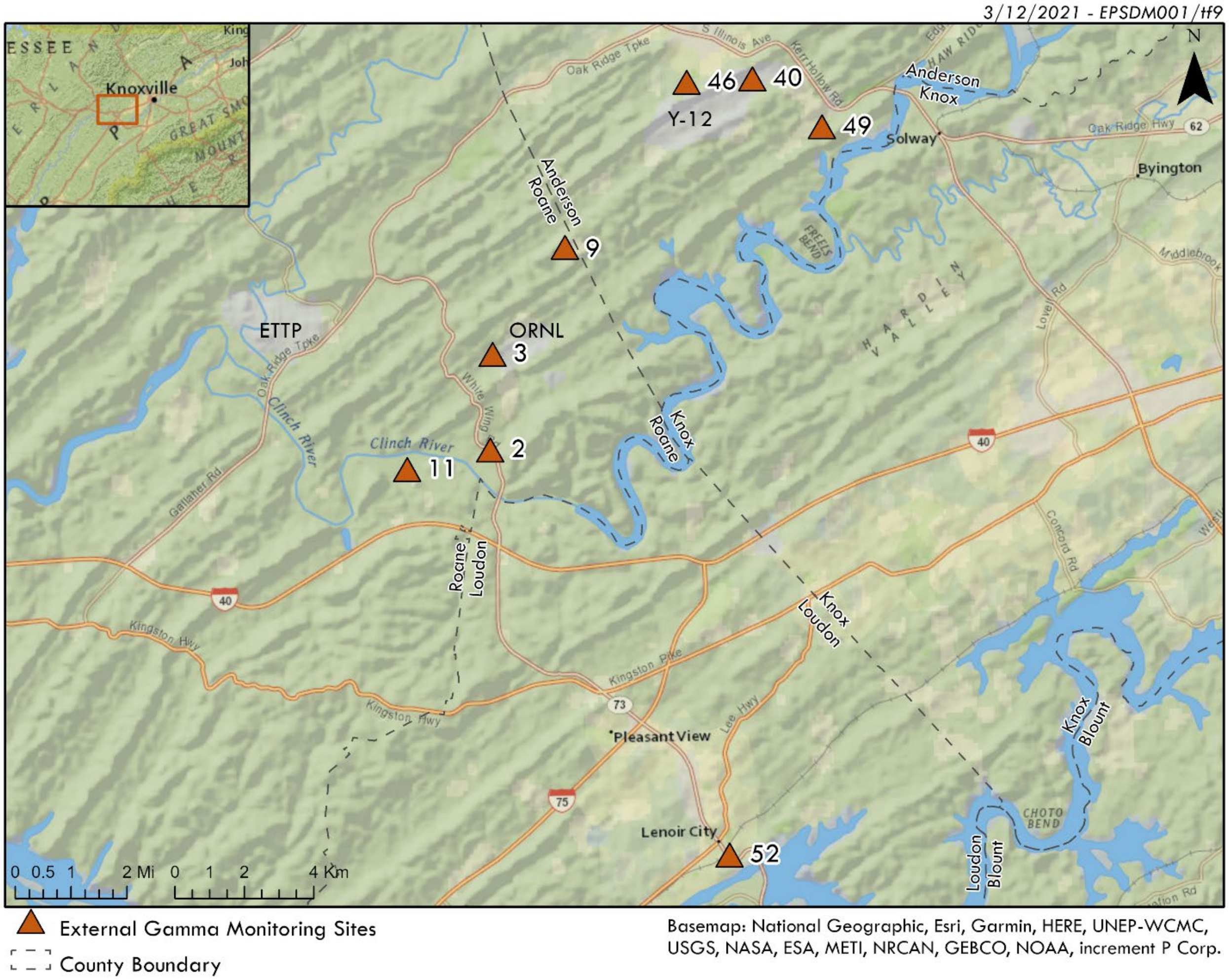

Note:

Reference samples are collected at Station 52 (Fort Loudoun Dam).

Figure 6.4. External gamma radiation monitoring locations on ORR

Table 6.3. External gamma exposure rate averages for ORR, 2023

Air station number	Number of data points (daily)	Measurement (μR/h)[a]		
		Min	Max	Mean
02	364	7.8	9.6	8.4
03	365	8.5	10.1	9.0
09	364	8.2	49.8[b]	11.3
11	365	9.2	11.3	9.9
40	365	8.6	10.9	9.5
46	363	9.6	11.4	10.3
49	365	8.7	10.9	9.4
52	360	8.2	10.5	9.2

[a] *To convert microroentgens per hour (μR/h) to milliroentgens per year, multiply by 8.760.*

[b] *The maximum exposure rate at Air Station 9 was due to the temporary storage of containerized radioactive waste near the monitoring equipment from July 10 to August 4 and does not represent typical exposure rates for this location. Station 9 is located within the ORNL site boundary and is not accessible to the public. When the data from July 10 to August 4 are excluded, the annual maximum daily exposure rate for Station 9 was 11.7 μR/h, and the annual mean exposure rate for Station 9 was 8.7 μR/h.*

6.4. 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.

6.4.1. Data Collection and Analysis

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 (Figure 6.6). Table 6.4 lists the locations and associated sampling frequencies and parameters.

In 2022, a more sensitive analytical method for determining mercury concentrations in surface water samples was adopted. The new method can detect concentrations near 0.2 ng/L, whereas the detection limit for the previously used method is about 67 ng/L. As expected, the ability to detect mercury at much lower levels resulted in detections in 10 of the 12 surface water samples collected for mercury analyses in 2023, while in the past, with the less sensitive method, mercury was rarely detected. At the sampling locations, the Clinch River is classified by the State of Tennessee for multiple uses, including recreation and domestic supply (TDEC 2019a). These two designated uses have numeric Tennessee water quality criteria (WQCs) related to protection of human health. The WQCs are used as references where applicable (TDEC 2019b). The Tennessee WQCs do not include criteria for radionuclides. Four percent of the DOE DCS is used as the criterion for radionuclide comparison (DOE 2021a).

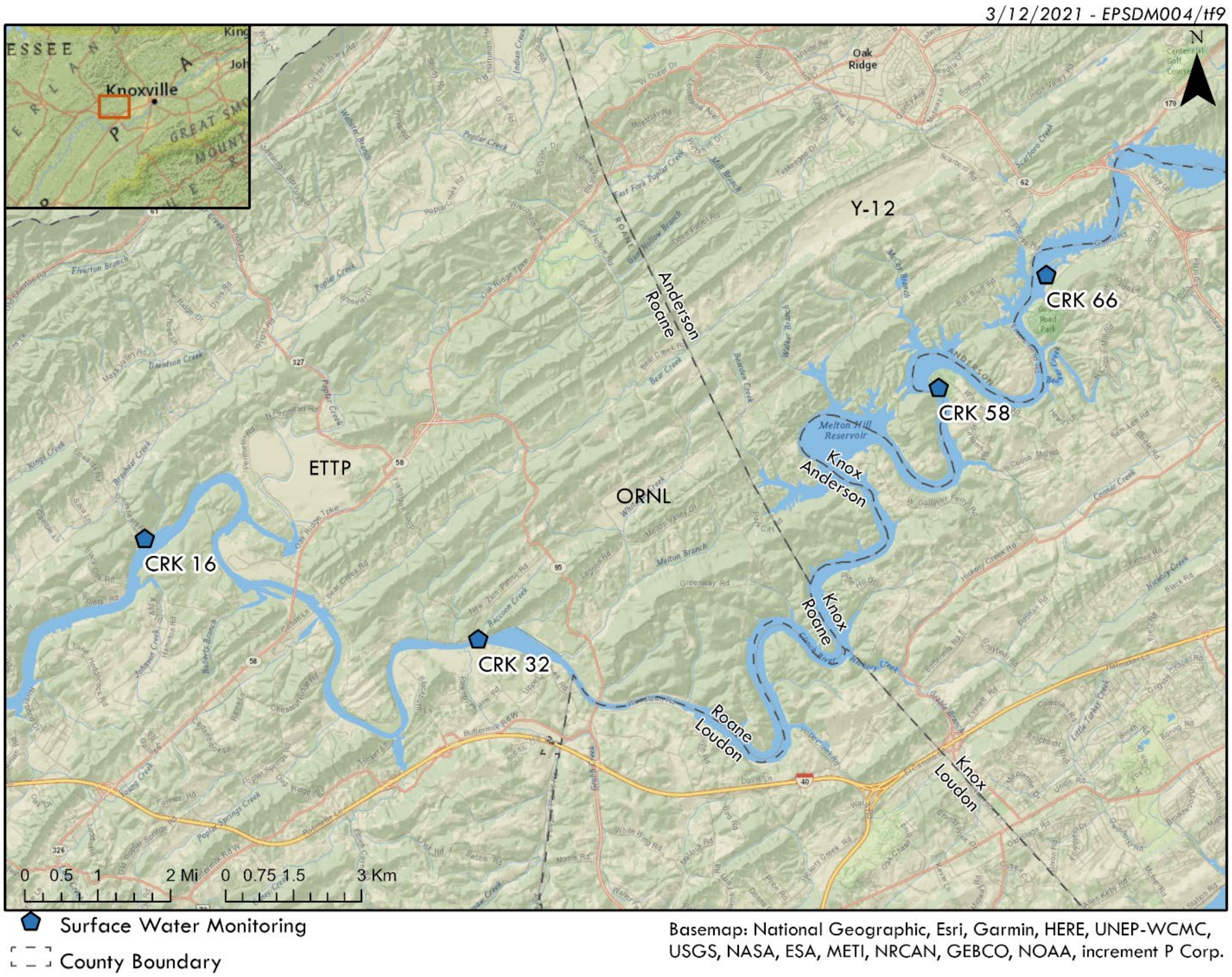

Figure 6.5. ORR surface water surveillance sampling locations

Figure 6.6. Surface water sample collection on the Clinch River

6.4.2. Results

In 2023, as has been the case since 2009, no statistical differences were found in the concentrations of routinely monitored radionuclides in surface water samples collected from the Clinch River upstream and downstream of DOE inputs. No radionuclides were detected above 4 percent of the respective DCSs.

Mercury was detected in 10 of the 12 samples collected in 2023, including samples from the location upstream of DOE inputs (Clinch River kilometer [CRK] 66). Results from two samples collected from CRK 32 were below the method detection level. As previously discussed, an increase in mercury detections was anticipated due to the adoption of the more sensitive analytical method in 2022. This method can detect mercury at much lower levels than the method previously used. The concentrations of mercury detected in 2023 surface water samples were well below the 67 ng/L detection level of the test method used prior to 2022.

Table 6.4. ORR surface water sampling locations, frequencies, and parameters, 2023

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 in the 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 2023 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). Work performed during 2023 under the ORR Groundwater Program included preparation of a report on the installation of and data obtained during the first year of sampling from three multizone exit pathway groundwater monitoring wells in west Bethel Valley adjacent to the Clinch River (DOE 2024a). Work continued on site-scale groundwater flow models for ETTP.

6.5.1. Off-Site Groundwater Assessment

During fiscal year (FY) 2023, 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 Oak Ridge Office of Environmental Management program, including sampling at six multiport monitoring wells in western Melton Valley (wells 4537, 4538, 4539, 4540, 4541, and 4542). The results of this monitoring are summarized in the 2024 *Remediation Effectiveness Report* (DOE 2024b).

DOE completed an off-site groundwater assessment project and issued a final report 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. To follow up on work from the off-site groundwater assessment, DOE conducts 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 a framework to support creation of smaller, site-scale groundwater flow models for use in planning and monitoring the effectiveness of future cleanup decisions and actions. During FY 2023, DOE developed a groundwater flow and solute transport model for the ETTP site to support Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA 1980) groundwater decision-making and further refined groundwater flow models for the Molten Salt Reactor Experiment site to support the development of an updated feasibility study of remedial alternatives for that reactor facility.

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 2023 because no dairies were found in potential ORR deposition areas. Surveys are conducted annually to determine whether any dairies are operating in areas of interest.

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" principle to ensure that doses to consumers are managed at levels well below regulatory dose thresholds. This 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. The 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 pradionuclide 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

Eating beef and drinking milk obtained from cattle that eat hay are potential radiation exposure pathways to humans. Hay from an area on the eastern edge of ORR is made available to an off-site farming operation and is sampled annually to characterize any possible doses from this pathway.

6.6.1.1. Data Collection and Analysis

Hay was collected and analyzed from the location on the eastern edge of ORR when it was cut for off-site use in October 2023. Samples were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes.

6.6.1.2. Results

In addition to the regularly detected, naturally occurring gamma emitters ^{7}Be and ^{40}K, ^{210}Pb, also a naturally occurring radioisotope, was detected in the hay sample in 2023. Radionuclides detected in the hay are shown in Table 6.5.

Table 6.5. Concentrations of radionuclides detected in hay,[a] October 2023 (pCi/kg)[b]

Radionuclide	Result
Gross alpha	c
Gross beta	1,930
^{7}Be	2,340
^{40}K	7,440
^{210}Pb	710
^{234}U	c
^{235}U	c
^{238}U	8.87

[a] *Detected radionuclides are those at or above minimum detectable activity.*

[b] *1 pCi = 3.7 × 10^{-2} Bq.*

[c] *Value was less than or equal to minimum detectable activity.*

6.6.2. Vegetables

Contaminants may reach vegetation by deposition of airborne materials, uptake from soil, and deposition of materials contained in irrigation water. As available, food crops are sampled annually from garden locations that have the potential to be affected by airborne releases from ORR to evaluate possible radiation doses to consumers. Vegetables are also sampled from a reference location for comparison. If available, crops that represent broad-leaf systems (e.g., lettuce, turnip greens), root-plant-vegetable systems (e.g., tomatoes), and root-system vegetables (e.g., turnips, potatoes) are obtained from each location and analyzed for radionuclides. Vegetable availability varies greatly from year to year.

6.6.2.1. Results

Analytical results for vegetable samples are provided in Table 6.6 no gamma-emitting radionuclides were detected above the minimum detectable activity except for the naturally occurring radionuclides ^{40}K, ^{214}Bi, and ^{214}Pb. Uranium isotopes were not detected above minimum detectable activities in any of the samples. Thorium-230 was detected in the cabbage sample from the area north of Y-12 with a low concentration just above the minimum detectable activity. This was the only radionuclide detected from the additional analyses performed in 2023.

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. Since 2016, no dairies in potential ORR deposition areas have been located, and no milk samples have been collected. Surveys to identify dairies in potential deposition areas are conducted each year, and milk sampling will resume when dairy operations in appropriate areas are located.

6.6.4. Fish

Members of the public could be exposed to contaminants originating from DOE ORR activities by consuming 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 6.7):

- Clinch River upstream from all DOE ORR inputs (CRK 70)
- Clinch River downstream from ORNL (CRK 32)
- Clinch River downstream from all DOE ORR inputs (CRK 16)

6.6.4.1. Data Collection and Analysis

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 2023, a composite sample of each of those species at each location was analyzed for selected metals, polychlorinated biphenyls (PCBs), ^{3}H, 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. Once every 5 years, additional radiological analyses are performed to confirm the dose calculations (see Chapter 7). When additional analyses were performed on fish samples in 2019 as part of this 5-year rotation, neptunium, plutonium, thorium, and uranium isotopes were detected. Based on these detections, the additional radionuclide analyses have been performed annually and include analyses for americium, neptunium, plutonium, and thorium. The results are presented in Table 6.7.

TDEC issues advisories on consumption of certain fish species caught in specified Tennessee waters. The advisories apply to fish that could contain potentially hazardous contaminants. TDEC has issued a “do not consume” advisory for catfish in the entire Melton Hill Reservoir, not just in areas that could be affected by ORR activities, because of PCB contamination. Similarly, TDEC has issued a precautionary advisory for catfish in the Clinch River arm of Watts Bar Reservoir because of PCB contamination (TDEC 2023). TDEC also issues precautionary advisories for consumption of fish when mercury levels exceed 0.3 ppm (Denton 2007). As of 2023, the three locations on the Clinch River where ORR fish are collected do not have mercury “do not consume” advisories.

Table 6.6. Concentrations of radionuclides detected in tomatoes and cabbages, 2023 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
				Cabbages			
North of Y-12[b]	c	2,750	c	2,750	c	c	c
Reference location	c	3,310	c	3,150	c	c	c
				Tomatoes			
North of Y-12	c	2,530	c	2,850	c	c	c
East of ORNL	c	2,010	c	2,370	c	c	c
West of ETTP	c	1,480	c	1,990	c	c	c
South of ORNL	c	2,150	c	2,980	c	c	c
Reference location[d]	c	1,650	c	2,460	c	c	c

[a] *Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7 × 10^{-2} Bq.*

[b] *Thorium-230, a radionuclide included in the additional analyses which have been requested since 2019, was detected in the cabbage sample from the area north of Y-12 with a concentration of 32.9 pCi/kg, just above the minimum detectable activity of 32 pCi/kg.*

[c] *Value was less than or equal to minimum detectable activity.*

[d] *Radionuclides ^{214}Bi and ^{214}Pb were detected in the tomato sample from the reference location with concentrations of 31.6 and 36.8 pCi/kg, respectively; ^{214}Bi and ^{214}Pb are naturally occurring, have short half-lives, and are routinely detected by gamma scan.*

Acronyms:

ETTP = East Tennessee Technology Park

ORNL = Oak Ridge National Laboratory

Y-12 = Y-12 National Security Complex

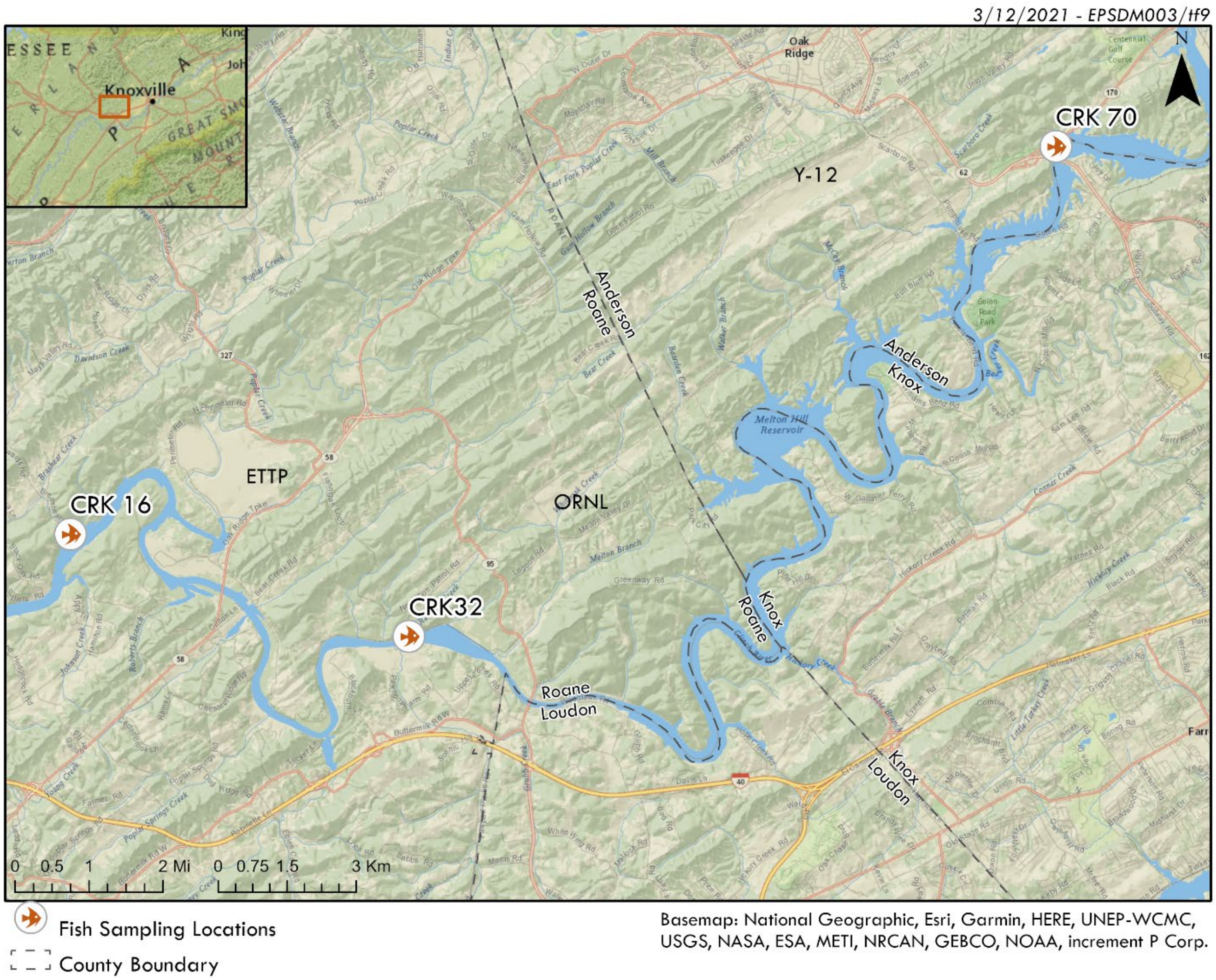

Figure 6.7. Fish-sampling locations for the ORR Surveillance Program

Table 6.7. Tissue concentrations in catfish and sunfish for detected PCBs and radionuclides, 2023[a]

	CRK 16 Downstream		CRK 32		CRK 70 Upstream	
	Catfish	**Sunfish**	**Catfish**	**Sunfish**	**Catfish**	**Sunfish**
Metals (mg/kg)						
Hg	B0.213[b]	c	c	c	c	c
PCBs (µg/kg)						
Aroclor 1248	*b*	c	19.5	c	J14.4[d]	c
Aroclor 1254	c	c	55.8	c	46.1	c
Aroclor 1260	J8.78[d]	c	46.6	c	44.6	c
Radionuclides (pCi/g)						
Beta activity	2.41	2.03	2.26	2.48	2.19	3.01
^{137}Cs	c	c	c	0.0103		c
^{40}K	3	3.48	3.46	3.38	3.55	2.97
^{230}Th	c	c	0.00637	c	c	0.033
^{232}Th	c	c	0.00356	c	c	c

[a] *Only parameters that were detected for at least one species are listed in the table.*
[b] *"B" indicates that the analyte was detected in the associated method blank.*
[c] *Value was less than or equal to minimum detectable activity.*
[d] *"J" indicates that the result is an estimated value.*

Acronyms:
CRK = Clinch River kilometer
PCB = polychlorinated biphenyl

6.6.4.2. Results

PCBs, specifically Aroclors 1260 and 1254, were detected in catfish at CRK 16 and CRK 32 in 2023. There were also low, estimated detections of Aroclor 1248 at CRK 70 and of Aroclor 1260 in catfish collected at CRK 16. Mercury was detected in catfish at CRK 16 within the historic range of values at this location; the lab reported that mercury was detected in the associated method blank, indicating this result may be biased high. Mercury was not detected above the minimum detectable level at any other location in 2023. These results are consistent with the TDEC advisories. Detected PCBs, mercury, and radionuclide concentrations are shown in Table 6.7.

6.6.5. White-Tailed Deer

In 2023, three quota deer hunts were conducted on ORR: November 4 and 5, November 11 and 12, and December 9 and 10. Each hunt was limited to 450 shotgun/muzzleloader permittees and 600 archery permittees. UT-Battelle staff; Tennessee Wildlife Resources Agency personnel; and student members of the Wildlife Society, University of Tennessee chapter, performed most of the necessary operations at the checking station.

6.6.5.1. Data Collection and Analysis

In 2023 approximately 23,000 acres were available to deer hunters on the Oak Ridge Wildlife Management Area, which includes some properties not owned by DOE, including Haw

Ridge Park (City of Oak Ridge) and the University of Tennessee Arboretum.

6.6.5.2. Results

The total ORR deer harvest in 2023 was 204, of which 120 (~58.8 percent) were bucks and 84 (~41.2 percent) were does. The heaviest buck weighed 189 lb, the heaviest doe weighed 111 lb, and the greatest number of antler points was 13. Two deer were retained for exceeding the administrative release limit of 1.5 times background for beta activity in bone (~20 pCi/g $^{89/90}Sr$) or for exceeding 5 pCi/g ^{137}Cs in edible tissue.

The decrease in the number of harvested deer between 2022 (280 deer) and 2023 (204 deer) was expected since the 2022 hunt followed 2 years of cancelled ORR hunts due to the COVID-19 pandemic. The ORR deer population likely increased over the 2 years when hunts were cancelled, improving hunters' chances of harvesting deer. The 2023 total harvest of 204 was more consistent with prepandemic numbers. In 2019 the total harvest was 221 deer (~56.6 percent bucks and ~43.4 percent does), the heaviest buck was 181 lb, the heaviest doe was 112 lb, and greatest number of antler points was 13.

Since 1985, 13,878 deer have been harvested from the Oak Ridge Wildlife Management Area, of which 220 (approximately 2 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 approximately 87 lb. (All weights are field-dressed weights.) The oldest deer harvested was a doe estimated to have been 12 years old (1989); the average age of all harvested deer is approximately 2 years. See the ORR hunt information website **here** for more information.

6.6.6. Waterfowl

The consumption of waterfowl is a potential pathway for exposing members of the public to radionuclides released from ORR operations. Canada goose hunting was allowed on the Three Bends Area of ORR (excluding the shoreline of Gallaher Bend) during the statewide season in 2023, one-half hour before sunrise until noon on September 4, 9, 10, 16, and 17, and on October 14, 15, 21, and 22. Hunting was allowed for wood duck and teal on September 9 and 10.

6.6.6.1. Data Collection and Analysis

Canada geese are rounded up each summer for noninvasive gross radiological surveys to characterize concentrations of gamma-emitting radionuclides accumulated by waterfowl that feed and live on ORR.

6.6.6.2. Results

Twenty-seven geese (all adults) were captured during the June 15, 2023, roundup on ORR. All 27 captured geese were subjected to live whole-body gamma scans. Gamma scan results showed that all were all well below the administrative release limit of 5 pCi/g ^{137}Cs.

6.6.7. Wild Turkey

Two wild turkey quota hunts were conducted April 15–16 and April 22–23. None of the 46 total turkeys harvested was retained for potential radiological contamination.

Since 1997, 970 turkeys have been harvested on spring turkey hunts. Twelve additional turkeys have been harvested since 2012 by archery hunters during fall deer hunts. The largest turkey ever harvested on ORR weighed 25.7 lb (harvested in 2009). Of all turkeys harvested, only three (less than 0.34 percent) have been retained because of potential radiological contamination: one in 1997, one in 2001, and one in 2005. Additional information is available on the ORR hunt website **here**.

6.7. Habitat Quality Improvement

Maintaining ecosystems, protecting natural areas, and ensuring functioning of support infrastructure, such as power and communications rights-of-way, roadways, and waterways, through active management is important not only in natural areas, but in developed areas as well. Multiple presidential executive orders (EOs) and memorandums of understanding, federal and state laws, orders, contracts, and agreements outline actions that must be taken to address conservation needs on lands owned by federal agencies. These conservation needs include control of invasive, non-native plants and animals; restoration of pollinator habitats; forest restoration and conservation; and creation and management of mitigation areas. EO 13751 (2016) specifically refers to safeguarding the nation from the impacts of invasive species. Additionally, EO 140008 (2021) addresses the need to tackle the climate crisis at home and abroad; goals include conservation of US lands, waters, oceans, and supporting biodiversity. EO 14072 (2022) requires the involvement of federal agencies in strengthening the nation's forests, communities, and local economies through conservation and preservation of forests and wildlife habitats, including mitigation strategies. Consequently, DOE created the *Conservation Action Plan* (DOE 2021c) to be updated annually; this plan includes climate adaptation and resilience research, fish and wildlife habitat conservation and restoration, and invasive plant and animal management, among other projects. DOE Order 436.1A (DOE 2023) further addresses conservation and sustainability actions.

6.7.1. Invasive Plant Management

Invasive, non-native plant species are among the greatest ecological threats to the United States and around the world. Invasive plants can threaten forests, wetlands, cultural resources, and other resources by increasing the risk of fire and storm damage and by encroaching onto roads, railroads, power structures, waterways, and agricultural sites. To address these threats, the Federal Noxious Weed Act (1974) was amended and incorporated into the Federal Plant Protection Act (2000). This act mandates federal agencies to develop and coordinate management programs to control invasive plants on lands under their respective jurisdictions and to adequately fund integrated pest management plans. Presidential Memorandum (2014), "Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators," includes control and removal of invasive plants and restoration and establishment of natural habitats.
EO 13751, *Safeguarding the Nation from the Impacts of Invasive Species* (2016), includes specific requirements for safeguarding against the impacts of invasive plants. The ORNL Natural Resources Management Program has maintained an invasive plant management plan for ORR since 2004. Details of federal and state laws and regulations driving this plan can be found in technical manuscripts ORNL/TM-2004/98 (Parr et al. 2004), ORNL/TM-2004/98/R1 (Quarles et al. 2011), and ORNL/TM-2004/98/R2 (McCracken and Giffen 2017).

ORNL/TM-2001/113, *Assessment of Nonnative Invasive Plants in the DOE Oak Ridge National Environmental Research Park* (Drake et al. 2002), details the results of extensive survey efforts. These and subsequent surveys have been performed to identify invasive plant problems on ORR. Data from the surveys are used to develop control plans identifying which invasive species to target and in which locations.

More than 1,100 species of plants are found on ORR, and of these, approximately 170 plant species are non-native. Fifty-seven aggressive non-native (invasive) plant species have been identified on ORR, but control efforts have been primarily focused on the subset of 12 species shown in Table 6.8. These target species have been found across ORR in disturbed areas, on power line and gas line rights-of-way, throughout riparian buffer zones, and along state highways, railroad lines, and remote-access fire roads. They have invaded natural areas to varying degrees, causing vast ecological harm in plant and animal communities. In concert with control efforts on the 12 highly invasive species, other invasive plant species are also targeted for control using *Early Detection and Rapid Response* (DOI 2020).

Table 6.8. Twelve most problematic invasive plants on ORR

Common name	Scientific name
Japanese grass, Nepal grass	*Microstegium vimineum*
Japanese honeysuckle	*Lonicera japonica*
Chinese privet	*Ligustrum sinense*
Kudzu	*Pueraria montana*
Multiflora rose	*Rosa multiflora*
Tree of heaven	*Ailanthus altissima*
Autumn olive	*Elaeagnus umbellate*
Oriental bittersweet	*Celastrus orbiculatus*
Princess tree	*Paulownia tomentosa*
Winter creeper	*Euonymus hederaceus*
Bradford/Callery pear	*Pyrus calleryana*
Mimosa	*Albizia julibrissin*

The 32,800-acre DOE ORR consists mostly of undeveloped land, including forests, wetlands, open waterways, riparian buffer zones, and several hundred acres of grassland communities and fallow fields. Three major developed facilities lie within ORR boundaries—ORNL, the Y-12 Complex, and ETTP. Surrounding these developed facilities and interspersed throughout ORR are safety and security areas, utility corridors, access roads, research and education areas, cultural and historic preservation sites, waste burial grounds, monitoring sites, fire roads, emergency evacuation corridors, new facility construction and laydown areas, and public use areas. This multiplicity of land uses presents challenges for effectively preventing and managing invasive species.

Numerous DOE contractors have responsibilities for managing portions of ORR land, as do other federal and state agencies such as the Tennessee Valley Authority and the Tennessee Wildlife Resources Agency. A portion of the ORR Natural Resources Management Team's annual funding is designated for creation and implementation of an invasive plant management plan, which focuses mainly on control efforts in natural areas and reference areas. However, efforts also include specific invasive plant incursions into locations within and surrounding the campuses of developed facilities on ORR. The *Invasive Plant Management Plan for the Oak Ridge Reservation* (Parr et al. 2004) and its two subsequent revisions (Quarles et al. 2011; McCracken and Giffen 2017) explain options for addressing the problem of invasive plants on ORR and discuss selection of appropriate control measures. Areas selected for invasive plant control tend to cover several acres or are spread out across portions of ORR. Use of select herbicides is the most cost-effective treatment method in most cases, and the invasive plants present determine which herbicides will be most effective without causing harm to surrounding native plant and animal habitats.

Invasive plant control on ORR has been conducted annually since 2003, when the invasive plant management program began. Table 6.9 indicates the extent of annual invasive plant treatments.

Table 6.9. Annual invasive plant control on ORR, 2003–2023

Year	Area treated
2003	98 acres
2004	136 acres
2005	125 acres
2006	254 acres
2007	236 acres
2008	427 acres
2009	526 acres
2010	884 acres
2011	806 acres
2012	615 acres
2013	329 acres
2014	950 acres
2015	629 acres
2016	952 acres
2017	542 acres + 47 road miles
2018	507 acres + 53 road miles
2019	450 acres + 57 road miles
2020	400 acres + 65 road miles
2021	400 acres + 51 road miles
2022	266 acres + 77 road miles
2023	260 acres + 84 road miles

Invasive plant management activities were completed in 2023 in the following locations at each of the three facilities and in natural areas on ORR:

- ORNL
  - Portions of First Creek and White Oak Creek riparian buffer zones
  - First Creek grassland management area
  - Demonstration woodland area at Spallation Drive and Bethel Valley Road
  - Bethel Valley Road and Old Bethel Valley Road
  - Haw Ridge former steam line kudzu patch
  - Fire protection roads
  - East Bethel Valley native grasslands
  - Three Bends Conservation Area
  - Tower Shielding Facility roadsides and forest edges
- Y-12
  - Kudzu control on Pine Ridge and Chestnut Ridge overlooking the Y-12 campus
  - Midway Turnpike
  - Filled Coal Ash Pile area kudzu
  - Watson Road fields
  - Old County Road, McNew Hollow Road, and Gum Branch Road
- ETTP
  - Powerhouse Trail greenway
  - P1 Pond Greenway
  - Wheat Church Vista
  - Black Oak Ridge Conservation Easement roads
  - North Boundary Greenway
  - McKinney Ridge and Blair Quarry

6.7.2. Wetlands

Wetland delineations are conducted to facilitate compliance with TDEC and US Army Corps of Engineers wetland protection requirements. In 2023, four wetlands were delineated on the ORNL campus. Two of these delineations helped projects avoid wetland impacts, and two were conducted to include in Aquatic Resource Alternation Permits. In addition, three wetlands were delineated at Clark Center Park, which is on ORR land owned by the DOE Office of Science.

6.8. Fire Protection Management and Planning

Wildland fire management is an important part of DOE's overall management of ORR. A comprehensive wildfire management program has been established and implemented for the entire ORR. The *Oak Ridge Reservation Wildland Fire Management Plan* (WFMP) (DOE 2021d) assigns responsibilities for wildland fire management and is reviewed every 3 years and revised as needed. The *Oak Ridge Reservation Wildland Fire Implementation Plan* (DOE 2021e) contains details on program implementation. The WFMP was prepared to satisfy the requirements of DOE Order 420.1C, Change 3, *Facility Safety* (DOE 2019); DOE Standard 1066, *Fire Protection* (DOE 2016); and relevant portions of Chapters 19 through 23 in National Fire Protection Association 1140, *Standard for Wildland Fire Protection* (NFPA 2022).

The WFMP outlines the overall goals and strategies necessary to manage, plan, and respond to fire in the wildland areas of ORR and to reduce the risk of wildland fire to personnel and facilities on ORR and to the public. The WFMP is reviewed at least annually.

The WFMP applies to all DOE employees, contractors, and subcontractors working on ORR and to all DOE ORR tenant activities. The DOE ORR federal manager is responsible for ORR wildland fire management activities.

The primary goal of the WFMP is to lower the overall risk of wildland fire on ORR by conducting fire prevention activities and actions to reduce the spread of a fire should one start. Another goal of the WFMP is to contain wildfires that do start to the ORR unit of origin by conducting suppression activities.

The WFMP is implemented by multiple organizations, including non-DOE entities such as the City of Oak Ridge and the State of Tennessee Division of Forestry. Memorandums of understanding that ensure collaboration between organizations are maintained for each organization that provides firefighting support on ORR.

DOE actions associated with wildland fire management include the following:

- Controlling ignition sources in the wildland areas, particularly on days when fire danger is forecasted
- Managing wildfire fuels in and near developed areas
- Developing and implementing controlled burning plans authorized by the DOE ORR federal manager
- Preparing and updating wildland fire preplans that include maps of fuel types, topographic features, roads, cultural resources, sensitive natural resources, contamination areas, and potential hazards
- Developing stakeholder involvement plans in support of the wildland fire program
- Reviewing current data to determine the potential for wildland fire, including indications of wildland fire risk
- Preparing a wildland fire risk report, including a wildland fire hazard severity analysis based on the *Standard for Wildland Fire Protection* (NFPA 2022)
- Maintaining a wildland fire road grid to support fire detection, containment, and suppression
- Conducting tabletop wildland fire exercises at least once every 3 years and full-scale exercises at least once every 5 years
- Incorporating wildland fire mitigation and response activities and procedures into the ORR land use planning process

The DOE roads and grounds contractor is responsible for establishing and maintaining the wildland fire roads, many of which delineate wildland management units (Figure 6.8), and for maintaining barricades that control access to ORR secondary roads. The management contractors at each of the three major ORR sites are responsible for providing personnel and equipment for initial response to wildland fire events and for establishing incident command. The City of Oak Ridge has entered into a mutual aid agreement with DOE to provide assistance for wildland fire activities. The State of Tennessee Department of Agriculture Division of Forestry has entered into a memorandum of understanding to provide trained personnel and heavy equipment, including fire plows, when requested to assist with wildland fires on ORR.

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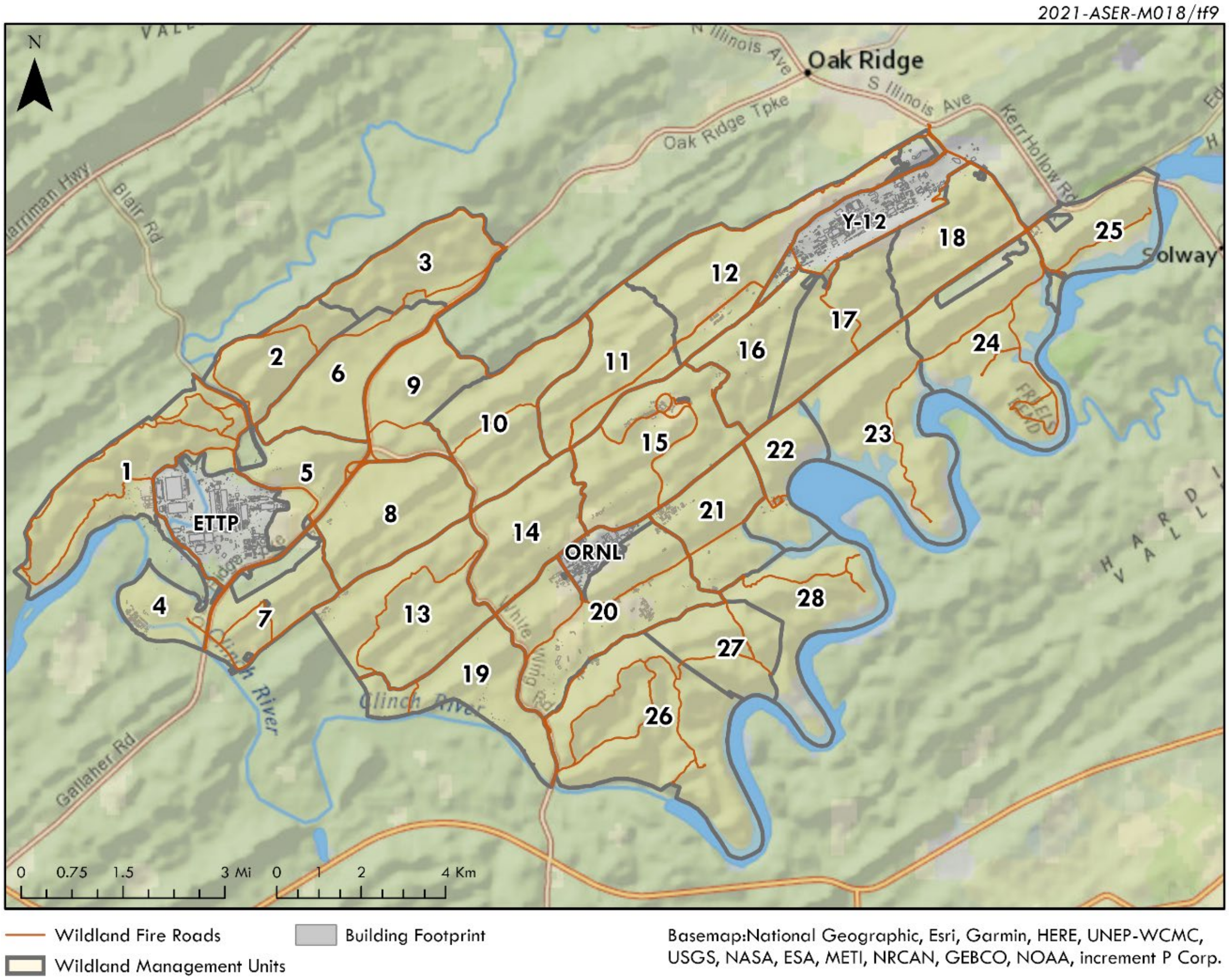


Figure 6.8. Wildland management units on ORR

Because ORR is a large (32,258.54 acres), mostly forested property with access restrictions, it is a challenge for site emergency personnel to maintain familiarity with all remote areas and back roads and to recognize and assess concerns associated with those areas quickly. Wildland management unit pre-fire plans are designed to aid responders who may or may not be familiar with an area.

The pre-fire plans are concise documents for each of the 28 ORR wildlife management units (Figure 6.8) that summarize access issues, assets, and hazard concerns. Each plan includes the wildlife management unit's name and identification number, its general location within ORR, and its boundaries and size. Important information and hazard descriptions are listed early in the document, followed by guidance on tactics, access, vegetation and fuels, water sources, topographic considerations, and hazard controls. Plan maps depict access points, utilities, hazards, research areas, fuel types, water sources, urban interface areas, and sensitive resources. Pre-fire plans are reviewed on a 3-year cycle and are updated as significant changes occur.

Copies of the plans are kept in responder vehicles for immediate reference during remote events and are available to site fire departments and emergency operations centers, shift superintendent offices, and appropriate management staff. The plans are easily updated, stored, and shared electronically. They are meant to enable quick decisions but not to dictate tactics.

The ORR forester is the point of contact for plan distribution.

The 2016 Great Smoky Mountains wildfires, also known as the Gatlinburg wildfires, demonstrated that large fires, although more frequent in western states, can occur on or near ORR. Issues related to wildland/urban interface areas are a growing concern. These areas may be characterized by relatively high housing density and increasing recreational use by the public. DOE has prioritized interface areas and has conducted controlled wildfire fuel reduction burns to limit the spread of fire to and from the community. The presence of dense pine forests increases community vulnerability to potential high-intensity wildfires. Actions to protect these areas include thinning or replacing dense pine growth, mechanical treatments to thin younger pine proactively, and mulching heavy logging slash and insect-damaged timber to interrupt fuel beds.

6.9. Quality Assurance

UT-Battelle performs the activities associated with administration, sampling, data management, and reporting for ORR environmental surveillance programs. Project scope is established by a task team whose members represent DOE, UT-Battelle, Consolidated Nuclear Security LLC, and UCOR. 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.)

6.10. References

Bowen et al. 2000. Bowen, B. M., J. A. Baars, and G. L. Stone, "Nocturnal Wind Shear and Its Potential Impact on Pollutant Transport." *Journal of Applied Meteorology* 39(3), 437–45.

CERCLA 1980. Comprehensive Environmental Response, Compensation, and Liability Act. Title 42 US Code Chapter 103.

Denton 2007. Denton, G. M., *Mercury Levels in Tennessee Fish.* Tennessee Department of Environment and Conservation, Nashville, Tennessee. https://www.tn.gov/content/dam/tn/environment/water/documents/fishmercurylevels.pdf.

DOE 2013. *Groundwater Strategy for the U.S. Department of Energy Oak Ridge Reservation, Oak Ridge, Tennessee*. Volume 1. Main Text. DOE/OR/01-2628/V1&D1, US Department of Energy Office of Environmental Management, Washington, DC. (PDF version available through online catalog at http://doeic.science.energy.gov/).

DOE 2015. *Environmental Radiological Effluent Monitoring and Environmental Surveillance*. DOE-HDBK-1216-2015, US Department of Energy, Washington, DC. Retrieved May 18, 2021, from https://www.standards.doe.gov/standards-documents/1200/1216-bhdbk-2015.

DOE 2016. *Fire Protection*. DOE-STD-1066-2016, US Department of Energy, Washington, DC. https://www.standards.doe.gov/standards-documents/1000/1066-astd-2016.

DOE 2017. *Offsite Groundwater Assessment Remedial Site Evaluation, Oak Ridge, Tennessee*. DOE/OR/01-2715&D2_R, US Department of Energy Office of Environmental Management, Washington, DC.

DOE 2019. *Facility Safety*. DOE Order 420.1C, US Department of Energy, Washington, DC. Retrieved June 15, 2021, from https://www.directives.doe.gov/directives-documents/400-series/0420.1-BOrder-C-chg3-ltdchg.

DOE 2020. *Radiation Protection of the Public and the Environment*. DOE Order 458.1, US Department of Energy, Washington, DC.

DOE 2021a. *Derived Concentration Technical Standard*. DOE-STD-1196-2021, US Department of Energy, Washington, DC. Retrieved March 28, 2022, from https://www.standards.doe.gov/standards-documents/1100/1196-astd-2021/@@images/file.

DOE 2021b. *Environmental Monitoring Plan for the Oak Ridge Reservation, Calendar Year 2021*. DOE/ORO-228/R12, US Department of Energy Office of Science, Washington, DC. Retrieved April 11, 2021, from https://doeic.science.energy.gov/ASER/ORR_EMP_CY2021_Final.pdf.

DOE 2021c. *U.S. Department of Energy Conservation Action Plan: Report to the White House Council on Environmental Quality*. US Department of Energy, Washington, DC.

DOE 2021d. *Oak Ridge Reservation Wildland Fire Management Plan.* US Department of Energy Office of Science, Washington, DC.

DOE 2021e. *Oak Ridge Reservation Wildland Fire Implementation Plan.* US Department of Energy Office of Science, Washington, DC.

DOE 2023. *Departmental Sustainability*. DOE Order 436.1A, US Department of Energy, Washington, DC.

DOE 2024a. *Melton Valley/Bethel Valley Exit Pathway Phase 1 Remedial Investigation Completion Report for the U.S. Department of Energy Oak Ridge Site Oak Ridge, Tennessee*. DOE/OR/01-2953&D2, US Department of Energy, Oak Ridge Office of Environmental Management, Oak Ridge, Tennessee.

DOE 2024b. *2024 Remediation Effectiveness Report for the U.S. Department of Energy Oak Ridge Site, Oak Ridge, Tennessee: Data and Evaluations*. DOE/OR/01-2960&D1, Prepared by the Water Resources Restoration Program, UCOR for the US Department of Energy Office of Environmental Management, Oak Ridge, Tennessee.

DOI 2020. *Early Detection and Rapid Response.* National Invasive Species Council, US Department of the Interior, Washington, DC. Retrieved April 20, 2021, from https://www.doi.gov/invasivespecies/early-detection-and-rapid-response.

Drake et al. 2002. Drake, S. J., J. F. Weltzin, and P. D. Parr, *Assessment of Nonnative Invasive Plants in the DOE Oak Ridge National Environmental Research Park.* ORNL/TM-2001/113, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

EO 2016. Executive Order 13751, *Safeguarding the Nation from the Impacts of Invasive Species*. Issued December 5, 2016. https://www.invasivespeciesinfo.gov/executive-order-13751.

Federal Memorandum of Understanding to Establish a Federal Interagency Committee for the Management of Noxious and Exotic Weeds (1994).

Federal Noxious Weed Act of 1974. Public Law 93-629 (7 U.S.C. 2801 et seq.; 88 Stat. 2148).

Federal Plant Protection Act of 2000. Public Law 106–224, Title IV (7 U.S.C. 7701 et seq). https://www.govinfo.gov/content/pkg/STATUTE-114/pdf/STATUTE-114-Pg358.pdf#page=1.

McCracken and Giffen 2017. McCracken, M. K., and N. R. Giffen, *Invasive Plant Management Plan for the Oak Ridge Reservation*. ORNL/TM-2004/98/R2, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

NFPA 2022. *Standard for Wildland Fire Protection*. NFPA 1140, National Fire Protection Association, Quincy, Massachusetts. https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1140.

Parr et al. 2004. Parr, P. D., M. G. Ryon, H. D. Quarles, N. R. Giffen, M. S. Salk, and J. W. Webb, *Invasive Plant Management Plan for the Oak Ridge Reservation*. ORNL/TM-2004/98, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

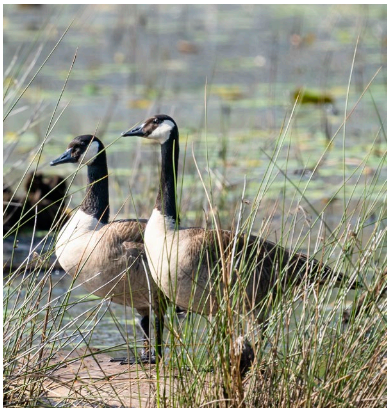
Presidential Memorandum, "Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators" (2014). https://obamawhitehouse.archives.gov/the-press-office/2014/06/20/presidential-memorandum-creating-federal-strategy-promote-health-honey-b.

Quarles et al. 2011. Quarles, H. D., M. S. Salk, P. D. Parr, M. G. Ryon, and N. R. Giffen, *Invasive Plant Management Plan for the Oak Ridge Reservation.* ORNL/TM-2004/98/R1, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

TDEC 2019a. "Use Classifications for Surface Waters." *Rules of the Tennessee Department of Environment and Conservation.* Chapter 0400-40-04. Tennessee Department of Environment and Conservation, Bureau of Environment, Division of Water Supply. https://www.epa.gov/sites/default/files/2014-12/documents/tn-chapter1200-4-4.pdf.

TDEC 2019b. "General Water Quality Criteria." *Rules of the Tennessee Department of Environment and Conservation.* Chapter 0400-40-03. Tennessee Department of Environment and Conservation, Bureau of Environment, Division of Water Supply. https://www.epa.gov/sites/default/files/2014-12/documents/tn-chapter1200-4-3.pdf.

TDEC 2023. *Posted Streams, Rivers, and Reservoirs in Tennessee*. Tennessee Department of Environment and Conservation, Division of Water Resources, Nashville, Tennessee. https://www.tn.gov/content/dam/tn/environment/water/watershed-planning/wr_wq_fish-advisories.pdf.



Radionuclides discharged to surface waters on ORR can potentially reach members of the public who use the Clinch and Tennessee Rivers for fishing, swimming, boating, or drinking water. Water and fish samples are collected at several locations on the Clinch River and are analyzed to ensure that members of the public are not exposed to harmful levels of radioactivity.

Photo by Carlos Jones

7

Dose

Activities on ORR can result in the release of small quantities of radionuclides and hazardous chemicals into the environment that could expose members of the public. Monitoring of materials released from ORR 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 2023, a hypothetical maximally exposed individual (MEI) would have received an effective dose (ED) of about 0.6 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 (40 CFR Part 61, Subpart H).

A worst-case analysis of exposures to waterborne radionuclides for all pathways combined gives a maximum possible individual ED of about 0.8 mrem. This dose is based on a person eating 41 kg/year (90 lb/year) of fish, drinking 940 L/year (248 gal/year) of drinking water, using the shoreline for 60 h/year, swimming 30 h/year, boating 63 h/year, and irrigating food or feed crops.

In addition, if a person consumed one maximum-weight harvested deer, one maximum-weight harvested turkey, and two maximum-weight harvested geese, all containing the maximum ^{137}Cs concentration, that person could have received an ED of about 1 mrem. This calculation provides an estimated upper-bound ED from consuming wildlife harvested from ORR.

Therefore, the annual dose for 2023 to an MEI from the combined exposure pathways is estimated to have been about 3 mrem. No significant doses from discharges of radioactive constituents from ORR other than those reported are known. DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2020), limits the ED that a member of the public may receive from all radionuclide exposure pathways during 1 year to no more than 100 mrem. The 2023 maximum ED from ORR is about 3 percent of the DOE Order 458.1 limit.

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 a significant adverse impact on aquatic or terrestrial biota.

7.1. Radiation Dose

Small quantities of radionuclides were released to the environment from operations at ORR facilities in 2023. Those releases are described, characterized, and quantified in previous chapters of this report. This chapter presents estimates of potential radiation doses to the public from the releases. Dose estimates were obtained using measured 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 overestimate the calculated doses. Therefore, dose calculations 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, whereas internal exposures usually result in nonuniform irradiation of the body and organs because most radionuclides deposit preferentially in specific organs or tissues. Several specialized terms and units used to characterize exposures to ionizing radiation are defined in Appendix E.

ED is a risk-based dose equivalent 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). Regardless of radiation type or method of delivery, 1 rem of ED has the same total radiological (and 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

The following sections summarize the methods and pathways used to determine potential doses to members of the public and to aquatic and terrestrial biota from radionuclides originating from ORR. Dose estimates were calculated using radionuclide concentrations measured in samples collected on or near ORR, estimated release data, and computer models.

7.1.2.1. Airborne Radionuclides

The radiological consequences of radionuclides released to the atmosphere from ORR operations during 2023 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 the center of ORR. The calculations were performed for each major facility and for the entire ORR. The dose calculations were performed using the Clean Air Act Assessment Package—1988 (CAP-88 PC) Version 4 (EPA 2015), a software program developed under EPA sponsorship to demonstrate compliance with 40 *Code of Federal Regulations* (CFR) Part 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 (e.g., vegetables, meat, and milk) and subsequent intakes by humans.

In this assessment, adult dose coefficients were used to estimate doses in CAP-88 PC. The 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 26 emission points on ORR were modeled during 2023: 3 (2 combined) points at Y-12, 22 points at ORNL, and 1 point at ETTP. Table 7.1 lists the emission point parameter values and receptor locations used in the dose calculations.

Meteorological data used in the calculations for 2023 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 2023, rainfall, as averaged over the six rain gauges located on ORR, was about 118 cm (46 in.). The average air temperature was 15.4°C (59.7°F) at the 10 to 15 m levels. The average mixing layer height (i.e., the depth of the atmosphere adjacent to the surface within which air is mixed) was 659.6 m (2,164 ft) for ETTP, 649.6 m (2,131 ft) for ORNL, and 659.6 m (2,164 ft) for Y-12. For occupants of residences, the dose calculations assumed 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 was assumed to have been produced within 80 km (50 miles) of ORR. The same assumptions were used for occupants of businesses, but the resulting doses were 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 7.1. Emission point parameters and receptor locations used in the dose calculations, 2023

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	
			ORNL				
X-laboratory hoods							
X-1000	15	0.5	0	5,710	ENE	9,990	NE
X-2000	15	0.5	0	5,410	E	9,640	NE
X-3000	15	0.5	0	5,090	E	9,250	NE
X-4000	15	0.5	0	4,870	E	9,100	NNE
X-7000	15	0.5	0	4,280	ENE	9,560	NNE
X-2026	22.9	1.05	7.02	5,430	E	9,510	NE
X-2099	3.66	0.18	16.42	5,420	E	9,520	NE
X-3001	6.86	0.44	7.50	5,250	E	9,320	NE
X-3020	61	1.22	13.55	5,290	E	9,360	NE
X-3026-East	0.81	0.97	0[b]	5,150	E	9,320	NE
X-3026-West	0.81	0.97	0[b]	5,150	E	9,320	NE
X-3039	76.2	2.44	5.36	5,150	E	9,300	NE
X-3571	3.35	0.29	0[b]	5,160	E	9,440	NNE
X-3608 filter press	8.99	0.36	9.27	5,010	ENE	9,470	NNE
X-4501	22.86	0.69	13.40	4,930	E	9,150	NNE

Table 7.1. Emission point parameters and receptor locations used in the dose calculations, 2023 (continued)

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	
ORNL (continued)							
X-7503	30.5	0.91	13.47	4,320	ENE	9,390	NNE
X-7830 group	4.6	0.25	10.51	5,610	ENE	10,910	NNE
X-7856-CIP	18.29	0.48	12.27	5,610	ENE	10,980	NNE
X-7877	13.9	0.41	13.56	5,640	ENE	10,970	NNE
X-7880	27.7	1.52	15.20	5,670	ENE	10,990	NNE
X-7911	76.2	1.52	15.00	4,310	ENE	9,620	NNE
X-7935 building stack	15.24	0.51	24.27	4,330	ENE	9,540	NNE
X-7935 glove box	9.14	0.25	0[b]	4,330	ENE	9,540	NNE
X-7966	6.10	0.29	6.40	4,270	ENE	9,460	NNE
X-8915	104.0	1.22	6.76	4,420	ESE	6,280	NE
X-decom areas	15	0.5	0	4,840	E	9,060	NNE
ETTP							
K-1407-AL CWTS	2.74	0.15	0b	270	SSW	13,450	ENE
Y-12 Complex							
Y-monitored	20	0.5	0	1,090	NNE	1,090	NNE
Y-unmonitored processes	20	0.5	0	1,090	NNE	1,090	NNE
Y-unmonitored lab hoods	20	0.5	0	1,090	NNE	1,090	NNE

[a] *Exit gas temperatures are ambient air temperatures.*

[b] *The direction of exhaust is horizontal. Therefore, an exit velocity of 0 m/s is used.*

Acronyms:

CIP = Capacity Increase Project

CWTS = Chromium Water Treatment System

decom = decommissioned

ETTP = East Tennessee Technology Park

ORNL = Oak Ridge National Laboratory

ORR = Oak Ridge Reservation

Y-12 Complex = Y-12 National Security Complex

Table 7.2. Meteorological towers and heights used to model atmospheric dispersion from source emissions, 2023

Tower	Height (m)	Source
		Y-12 Complex
MT6 (West Y-12)	30	All Y-12 sources
		ETTP
MT13 (Tower J)	20	K-1407-AL CWTS
		ORNL
MT4 (Tower A)	15	X-7830 group, X-7935 glove box, X-7966, and X-7000 lab hoods
	30	X-7503, X-7856-CIP, X-7877, X-7880, X-7911, and X-7935 building stack
MT2 (Tower D)	15	X-2099, X-3001, X-3026-East, X-3026-West, X-3571, X-3608 FP, X-decom hoods, X-1000, X-2000, X-3000, and X-4000 lab hoods
	35	X-2026 and X-4501
	60	X-3020 and X-3039
MT12 (Tower F)	10	X-8915

Acronyms:
CIP = Capacity Increase Project
CWTS = Chromium Water Treatment System
decom = decommissioned
ETTP = East Tennessee Technology Park
FP = filter press
ORNL = Oak Ridge National Laboratory
Y-12 Complex = Y-12 National Security Complex

Results

EDs from radionuclides released to the atmosphere from ORR were calculated for ORR as a whole and for each site on ORR for MEIs and for the collective population (1,272,478 persons) residing within 80 km (50 miles) of ORR based on 2020 Census data (Census 2020). CAP-88 PC Version 4 was used in 2023 to calculate individual and collective doses.

The location of the ORR MEI (i.e., the location where a hypothetical individual would receive the maximum ED from radionuclides emitted to the atmosphere from ORR) was about 1,090 m (0.7 miles) north-northeast of the main Y-12 release point, about 9,620 m (6.0 miles) north-northeast of the 7911 stack at ORNL, and about 13,450 m (8.4 miles) east-northeast of the K-1407-AL Chromium Water Treatment System (CWTS) at ETTP (Figure 7.1). This individual could have received an ED of about 0.6 mrem, which is well below the National Emission Standards for Hazardous Air Pollutants for Radionuclides standard of 10 mrem and is about 0.2 percent of the roughly 300 mrem that the average individual receives from natural sources of radiation (40 CFR Part 61, Subpart H). The maximum individual EDs calculated for each site and for ORR are listed in Table 7.3.

Table 7.4 lists the collective EDs. The calculated collective ED was about 17.6 person-rem, which is about 0.005 percent of the 383,053 person-rem that this population received from natural sources of radiation (based on an individual dose of about 300 mrem/year).

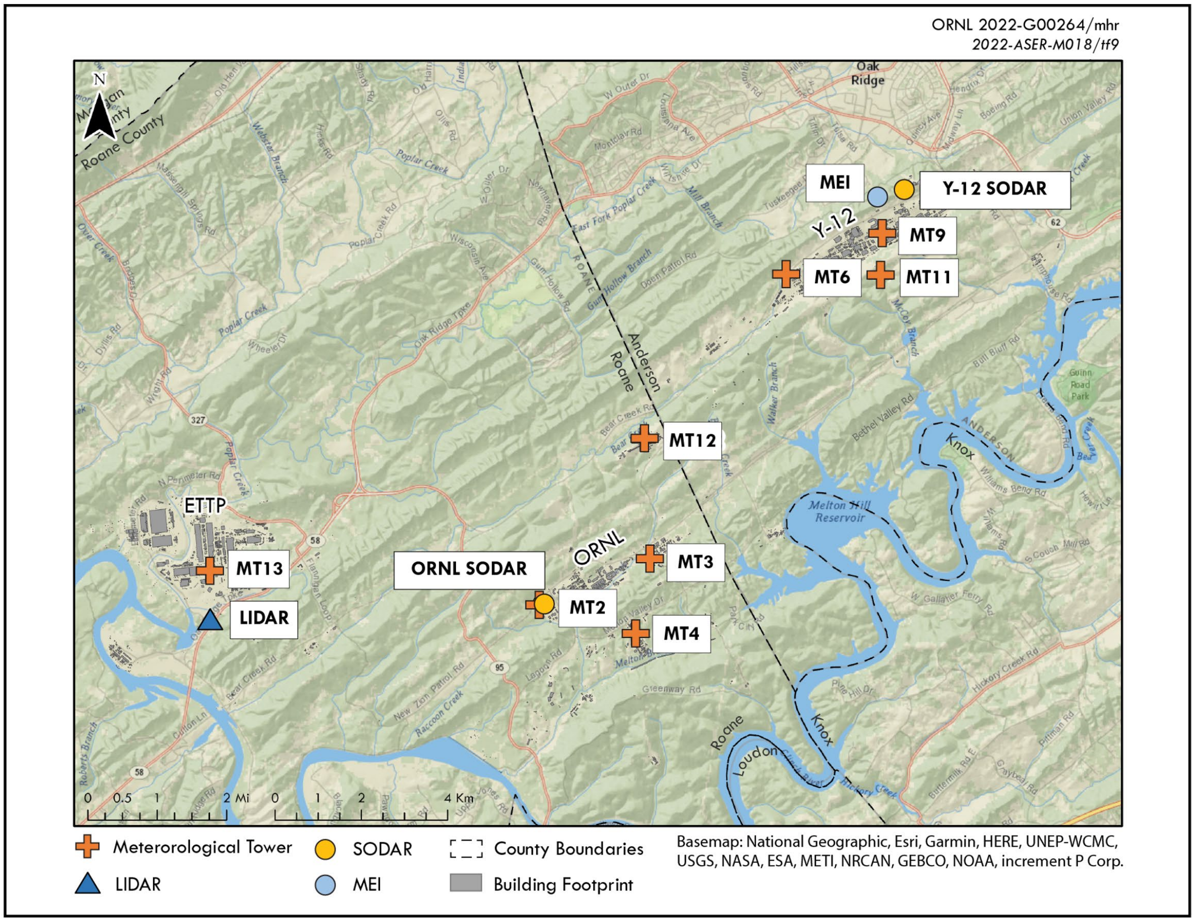


Figure 7.1. Location of the maximally exposed individual for ORR, 2023

Table 7.3. Calculated radiation doses to maximally exposed individuals from airborne releases from ORR, 2023

Site	Maximum effective dose, mrem and mSv			
	From each site		From ORR	
	mrem	mSv	mrem	mSv
ORNL[a]	0.2	0.002	0.08	0.0008
ETTP[b]	0.0005	5×10^{-6}	2×10^{-6}	2×10^{-8}
Y-12 Complex[c]	0.5	0.005	0.5	0.005
Entire ORR[d]	e	e	0.6	0.006

[a] *The ORNL MEI was located 5,150 m E of X-3039 and 4,310 m ENE of X-7911.*

[b] *The ETTP MEI was located 270 m SSW of the K-1407-AL Chromium Water Treatment System.*

[c] *The Y-12 MEI was located 1,090 m NNE of the main Y-12 Complex release point.*

[d] *The MEI for the entire ORR was 1,090 m NNE of the Y-12 Complex release point, 9,300 m NE of X-3039, and 13,450 m ENE of the K-1407-AL Chromium Water Treatment System.*

[e] *Not applicable.*

Acronyms:

ETTP = East Tennessee Technology Park

MEI = maximally exposed individual

ORNL = Oak Ridge National Laboratory

ORR = Oak Ridge Reservation

Y-12 Complex = Y-12 National Security Complex

Table 7.4. Calculated collective effective doses from airborne releases, 2023

Plant	Collective effective dose[a]	
	Person-rem	Person-Sv
ORNL	10.2	0.102
ETTP	0.0002	2×10^{-6}
Y-12 Complex	7.4	0.074
Entire ORR	17.6	0.176

[a] *Collective effective dose to the 1,276,842 persons residing within 80 km (50 miles) of ORR (based on 2020 Census data).*

Acronyms:

ETTP = East Tennessee Technology Park

ORNL = Oak Ridge National Laboratory

ORR = Oak Ridge Reservation

Y-12 Complex = Y-12 National Security Complex

The MEI for Y-12 was located at a residence about 1,090 m (0.7 miles) north-northeast of the main Y-12 release point. This individual could have received an ED of about 0.5 mrem from Y-12 airborne emissions. Uranium radioisotopes (i.e., ^{233}U, ^{234}U, ^{235}U, ^{236}U, and ^{238}U) accounted for about 98 percent, and other radionuclides accounted for about 2 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 7.4 person-rem, which is about 42 percent of the collective ED for ORR.

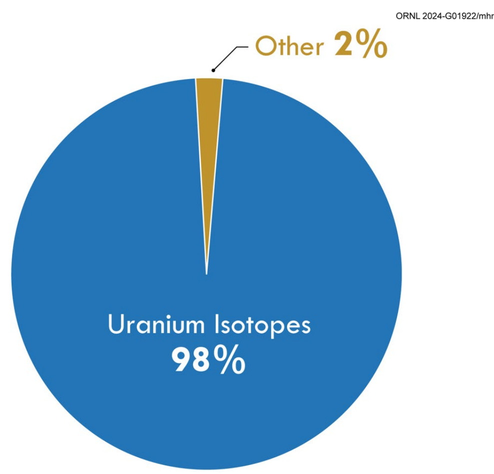


Figure 7.2. Nuclides contributing to effective dose at the Y-12 Complex, 2023

The MEI for ORNL was located at a residence about 5,150 m (3.2 miles) east of the 3039 stack and 4,310 m (2.7 miles) east-northeast of the 7911 stack. This individual could have received an ED of about 0.2 mrem from ORNL airborne emissions. Cesium-138 contributed about 39 percent, ^{212}Pb contributed about 27 percent, ^{11}C contributed about 10 percent, ^{41}Ar contributed about 9 percent, and ^{131}I contributed about 3 percent to the ORNL ED (Figure 7.3). The total contribution from ^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{239}U, and ^{240}U accounted for about 0.9 percent of the dose. Of those isotopes, ^{238}U made the largest contribution. 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 10.2 person-rem, or about 58 percent of the collective ED for ORR.

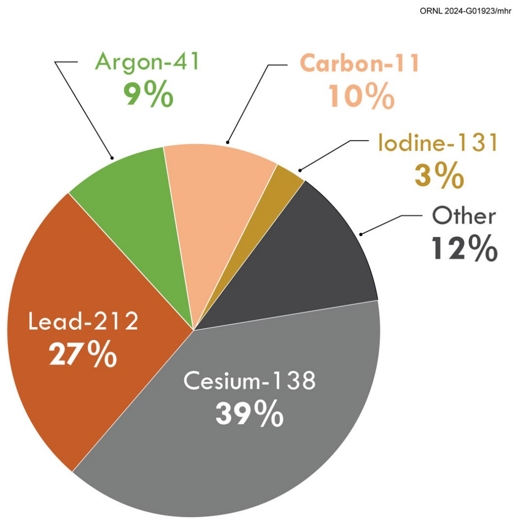


Figure 7.3. Nuclides contributing to effective dose at ORNL, 2023

The MEI for ETTP was located at a business about 270 m (0.17 miles) south-southwest of the K-1407-AL CWTS. The ED received by this individual from airborne emissions was calculated to have been about 0.0005 mrem. About 92 percent of the dose was from uranium radioisotopes (^{233}U, ^{234}U, ^{235}U, ^{236}U, and ^{238}U), about 3 percent of the dose was from progeny of uranium isotopes, and about 5 percent of the dose was from ^{99}Tc (Figure 7.4). The 2023 contribution of ETTP emissions to the collective ED to the population residing within 80 km (50 miles) of ORR was calculated have been about 0.0002 person-rem, or about 0.001 percent of the collective ED for ORR.

To evaluate the validity of the estimated doses calculated using CAP-88 PC Version 4 and emissions data (Table 7.5), the doses were compared to the EDs calculated using radionuclide air concentrations (excluding naturally occurring ^{7}Be and ^{40}K) measured in samples collected at the ORR ambient air locations (Figure 6.3). In 2022, analysis of ambient air samples transitioned to a different laboratory, resulting in possible variations in analytical procedures and reporting methodologies. Analyses included gross alpha, gross beta, gamma emitters, isotopic uranium, ^{3}H, and ^{99}Tc at selected locations.

In 2023, in addition to ^{3}H and uranium isotopes, ^{228}Ac, ^{214}Bi, ^{210}Pb, ^{228}Ra, ^{208}Tl, and ^{99}Tc were detected at ORR ambient air stations. Lead-210, a naturally occurring radioisotope, was detected at all ORR ambient air sampling locations listed in Table 7.5 and at the background location, Station 52. On average, the dose contribution from ^{210}Pb at ambient air sampling locations was nearly 4.2 mrem. Measured air concentrations of ^{210}Pb were excluded from calculated EDs because ^{210}Pb is naturally occurring and was emitted from only two sources on ORR at concentration levels significantly below those measured in ambient air samples.

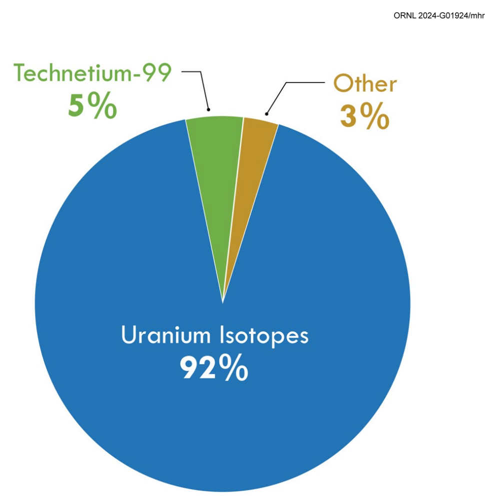


Figure 7.4. Nuclides contributing to effective dose at ETTP, 2023

Based on measured air concentrations, hypothetical individuals assumed to reside at the ambient air stations could have received EDs between 0.02 and 0.2 mrem/year, while EDs calculated using CAP-88 PC Version 4 and emissions data were between 0.1 and 0.6 mrem/year. As shown in Table 7.5, EDs calculated using CAP-88 PC Version 4 and emissions data tended to be greater than or similar to EDs calculated using measured air concentrations.

Table 7.5. Hypothetical effective doses from living near ORR and ETTP ambient air monitoring stations, 2023

Station	Calculated effective doses			
	Using air monitor data		Using CAP-88[a] and emission data	
	mrem/year	mSv/year	mrem/year	mSv/year
		ORR		
1	0.03	0.0003	0.3	0.003
2	0.03	0.0003	0.2	0.002
3	0.04	0.0004	0.6	0.006
11	0.03	0.0003	0.3	0.003
35[b]	0.2	0.002	0.1	0.001
37	0.03	0.0003	0.3	0.003
40	0.1	0.001	0.6	0.006
46	0.02	0.0002	0.3	0.003
49	0.02	0.0002	0.2	0.002
52[b,c]	0.06	0.0006	0.03	0.0003
		ETTP		
K11	1×10^{-5}	1×10^{-7}	0.05	0.0005
K12	*d*	*d*	0.05	0.0005

[a] CAP-88 PC Version 4 software, developed under US Environmental Protection Agency sponsorship to demonstrate compliance with 40 CFR Part 61, Subpart H.

[b] In 2023, analysis to detect ^{99}Tc was requested for Stations 35 and 52.

[c] Background ambient air monitoring station.

[d] No radionuclides were detected during 2023 at this location.

Acronyms:

CAP-88 PC = Clean Air Act Assessment Package—1988

ETTP = East Tennessee Technology Park

ORR = Oak Ridge Reservation

Station 52, located remotely from ORR, gives an indication of potential EDs from background sources. Samples from Stations 35 and 52 were analyzed for ^{99}Tc in 2023. Technetium-99 was detected in one sample at the background location and in two samples at Station 35. Based on measured air concentrations (excluding the naturally occurring isotopes ^{7}Be and ^{40}K), the ED at Station 52 was estimated to be 0.06 mrem/year. Based on air concentrations calculated using CAP-88 PC Version 4, the ED was estimated to be 0.03 mrem/year.

The measured air concentrations of ^{7}Be at ORR stations were similar to those at the background air monitoring station.

EDs calculated using measured air concentrations of radionuclides at ambient air stations located near the MEIs for each site are significantly less than EDs calculated using source emissions data. Station 1 is located near the off-site MEI for ORNL. The ED calculated with measured air concentrations was 0.03 mrem/year, and the ED estimated using source emissions data was 0.3 mrem/year. Station 46 is located near the off-site MEI for the Y-12 Complex and ORR. The ED calculated with measured air concentrations was 0.02 mrem/year, and the ED estimated using source emissions data was 0.3 mrem/year. Station K11 is located near the on-site MEI for ETTP. The ED calculated with measured air concentrations was 1×10^{-5} mrem/year, and the

ED calculated using source emissions data was 0.05 mrem/year.

7.1.2.2. Waterborne Radionuclides

Radionuclides discharged to surface waters from ORR enter the Tennessee River system via the Clinch River. Discharges from Y-12 enter the Clinch River via Bear Creek and East Fork Poplar Creek (EFPC), which both enter Poplar Creek before it enters the Clinch River. Discharges from Rogers Quarry enter McCoy Branch, which flows into Melton Hill Lake. Discharges from ORNL enter the Clinch River via White Oak Creek (WOC) and enter Melton Hill Lake via 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 get drinking water from the Clinch and Tennessee Rivers and use these rivers for fishing, swimming, boating, and other shoreline activities. For assessment purposes, surface waters potentially affected by ORR are divided into the following seven segments:

- Melton Hill Lake above all possible ORR inputs
- Melton Hill Lake
- Upper Clinch River (from the Melton Hill Dam to the confluence with Poplar Creek)
- Lower Clinch River (from the confluence with Poplar Creek to the 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 water and fish determined by laboratory analyses of water and fish samples. (See Sections 6.4 and 6.6.4.) The second method calculates possible radionuclide concentrations in water and fish from measured radionuclide discharges with known or estimated streamflows. Both methods use reported concentrations of radionuclides to estimate radiation doses if the reported value is statistically significant 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), and the doses are calculated using per capita committed ED coefficients for water ingestion (DOE 2021). Utilizing the two methods to estimate potential doses accounts for field measurements and discharge measurements.

Drinking water consumption

Estimated maximum EDs to a person drinking water were calculated using both measured radionuclide concentrations in off-site surface water and measured radionuclide discharges to the off-site surface water, excluding naturally occurring radionuclides such as ^{40}K and ^{7}Be. During fiscal year 2023, 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.

Water drawn into treatment plants from the Clinch and Tennessee River systems could be affected by discharges from ORR. Because they are based on radionuclide concentrations in water before it enters a processing plant, the dose estimates given in this section likely are high. (No in-plant radionuclide concentration data are available for the treatment plants.)

Based on a nationwide health and nutrition survey (EPA 2023) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane Counties, which reflects 2020 decennial US Census data (Census 2020; Fryar et al. 2016), the drinking water consumption rate for the MEI is assumed to be 940 L/year (248 gal/year), and the drinking water consumption rate for the average person is 280 L/year (74 gal/year). The average drinking water consumption rate was used to estimate the collective EDs. The EDs for the seven surface water segments were as follows:

- **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), an MEI drinking water at this location could have received an ED of about 0.02 mrem. The collective ED to the 46,765 persons who drink water from the City of Oak Ridge water plant would have been 0.3 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 0.02 mrem; the collective dose to the 70,666 persons who drink water from this plant could have been 0.5 person-rem.
- **Upper Clinch River.** There are no known drinking water intakes in this river segment.
- **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 0.006 mrem. The collective dose to the 31,199 persons who drink water from these plants could have been about 0.06 person-rem.
- **Lower system.** Several water treatment plants are located on tributaries of Watts Bar Lake and Chickamauga Lake. An MEI drinking water from those plants could have received an ED of about 0.006 mrem. The collective dose to the 308,389 persons who drink water from the lower system could have been about 0.4 person-rem.
- **Poplar Creek/lower EFPC.** No drinking water intakes are located on Poplar Creek or on lower EFPC.

Fish consumption

Fishing is common on the Clinch and Tennessee River systems. Based on a nationwide health and nutrition survey (EPA 2023) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane Counties, which reflects 2020 decennial US Census data (Census 2020; Fryar et al. 2016), avid fish consumers were assumed to have eaten 41 kg (90 lb) of fish during 2023. The average person used for collective dose calculations was assumed to have consumed 11 kg (24 lb) of fish in 2023. The average fish consumption value is based on a nationwide food consumption survey (EPA 2023) and is weighted based on the 2020 decennial US Census populations of Anderson, Knox, Loudon, and Roane Counties (Census 2020; Fryar et al. 2016). The maximum ED at each location was estimated using one of the two previously mentioned methods: by using measured radionuclide concentrations in fish or by calculating possible radionuclide concentrations in fish from measured radionuclide discharges and known or estimated streamflows. The number of individuals who could have eaten fish is based on lake creel surveys and commercial fishing reporting conducted annually by the Tennessee Wildlife

Resources Agency (TWRA) (TWRA 2019; TWRA 2021; TWRA 2023). Routine fish tissue analyses include gross alpha, gross beta, gamma spectroscopy for gamma emitters, and ^{3}H. Detected or statistically significant radionuclides in 2023 included ^{7}Be, ^{137}Cs, ^{40}K, ^{238}Pu, $^{239/240}Pu$, ^{228}Th, ^{230}Th, and ^{232}Th.

In 2023, the maximum EDs from fish consumption at upper Melton Hill Lake and upper Clinch River were determined using measured radionuclide concentrations in sunfish samples collected at CRK 70 and CRK 32. The maximum ED for fish consumption at lower Clinch River was determined using measured radionuclide concentrations in catfish samples collected at CRK 16. However, the maximum fish consumption EDs at the remaining locations were estimated using the measured radionuclide concentrations in water to estimate radionuclide concentrations in fish.

- **Upper Melton Hill Lake above all possible ORR inputs.** For reference purposes, a hypothetical avid fish consumer who ate fish caught at CRK 70, which is above all possible ORR inputs, could have received an ED of about 0.7 mrem. The collective ED to the 13 persons who could have eaten fish harvested at that location could have been about 0.003 person-rem.
- **Melton Hill Lake.** An avid fish consumer who ate fish from Melton Hill Lake could have received an ED of about 0.06 mrem. The collective ED to the 119 persons who could have eaten fish harvested at that location could have been about 0.002 person-rem.
- **Upper Clinch River.** An avid fish consumer who ate fish from the upper Clinch River could have received an ED of about 0.3 mrem. The collective ED to the 42 persons who could have eaten fish harvested at that location could have been about 0.003 person-rem.
- **Lower Clinch River.** An avid fish consumer who ate fish from the lower Clinch River could have received an ED of about 0.1 mrem. The collective ED to the 99 persons who could have eaten fish harvested at that location could have been about 0.003 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 0.01 mrem. The collective ED to the 283 persons who could have eaten fish harvested at that location could have been about 0.0007 person-rem.
- **Lower system.** An avid fish consumer who ate fish from the lower system could have received an ED of about 0.009 mrem. The collective ED to the about 8,053 persons who could have eaten fish harvested at that location could have been about 0.02 person-rem.
- **Poplar Creek/lower EFPC.** An avid fish consumer who ate fish from Poplar Creek/lower EFPC could have received an ED of about 0.3 mrem, but it is considered unlikely that a person would consume fish from those locations. Assuming 200 persons could have eaten fish from lower EFPC and from Poplar Creek, the collective ED could have been about 0.02 person-rem.

Other uses

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 is 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). Another survey was conducted regarding visitor and property owner activities for Chickamauga and Watts Bar Reservoirs (Poudyal et al. 2017).

The data from these surveys 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.

- **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 0.001 mrem. The collective ED to the 14,483 other users could have been 0.002 person-rem.
- **Melton Hill Lake.** An individual other user of Melton Hill Lake could have received an ED of about 2×10^{-6} mrem. The collective ED to the 40,044 other users could have been about 5×10^{-6} person-rem.
- **Upper Clinch River.** An individual other user of the upper Clinch River could have received an ED of about 1×10^{-6} mrem. The collective ED to the 13,114 other users could have been about 2×10^{-6} person-rem.
- **Lower Clinch River.** An individual other user of the lower Clinch River could have received an ED of about 1×10^{-6} mrem. The collective ED to the 30,599 other users could have been about 3×10^{-6} person-rem.
- **Upper Watts Bar Lake.** An individual other user of upper Watts Bar Lake could have received an ED of about 3×10^{-7} mrem. The collective ED to the 87,424 other users could have been about 2×10^{-6} person-rem.
- **Lower system (Watts Bar and Chickamauga Lakes).** An individual other user of the lower system could have received an ED of about 3×10^{-7} mrem. The collective ED to the 3,173,423 other users could have been about 5×10^{-5} 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 5×10^{-4} mrem. The collective ED to the 200 other users of Poplar Creek and lower EFPC could have been about 4×10^{-6} person-rem.

Irrigation

Although no known locations 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 instream 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 1×10^{-7} to 0.03 mrem in 2023. The average instream dose at CRK 16 was estimated to have been about 0.007 mrem. Based on all water discharges at CRK 16, the sum of doses was estimated to have been 2×10^{-6} mrem. The individual was assumed to have consumed 16 kg (35 lb) of leafy vegetables, 91 kg (201 lb) of produce, 259 L (68 gal) of milk, and 63 kg (139 lb) of meat (beef) during the year. The doses were calculated using per capita committed ED coefficients for water and milk ingestion (DOE 2021).

Summary

Table 7.6 summarizes potential EDs from identified waterborne radionuclides around ORR. The estimated maximum individual ED was about 0.8 mrem to a person who obtained his or her drinking water and annual complement of fish from the water systems in Table 7.6 and who participated in other water uses throughout those systems. The total collective ED from waterborne radionuclides to the population engaging in these activities was estimated to have been about 1.3 person-rem. These doses are small relative to the overall doses from natural sources of radiation; the estimated maximum individual ED from identified waterborne radionuclides is about 0.3 percent of the average individual background dose of roughly 300 mrem/year, and the total collective ED from waterborne radionuclides is about 0.0003 percent of the 383,053 person-rem that the population within 80 km (50 miles) received from natural sources of radiation.

Table 7.6. Summary of annual maximum individual (mrem) and collective (person-rem) effective doses from waterborne radionuclides, 2023[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	0.02	0.7[d]	0.001	0.8
Collective	0.3	0.003[d]	0.002	0.3
Melton Hill Lake (CRK 58, Knox County water plant)				
Individual	0.02	0.06	2×10^{-6}	0.08
Collective	0.5	0.002	5×10^{-6}	0.5
Upper Clinch River (CRK 23, 32)				
Individual	N/A[e]	0.3[d]	1×10^{-6}	0.3
Collective	N/A[e]	0.003[d]	2×10^{-6}	0.003
Lower Clinch River (CRK 16)				
Individual	N/A[e]	0.1[d]	1×10^{-6}	0.1
Collective	N/A[e]	0.003	3×10^{-6}	0.003
Upper Watts Bar Lake (Kingston municipal water plant)				
Individual	0.006	0.01	3×10^{-7}	0.02
Collective	0.06	0.0007	2×10^{-6}	0.06
Lower system (lower Watts Bar Lake and Chickamauga Lake)				
Individual	0.006	0.009	3×10^{-7}	0.01
Collective	0.4	0.02	5×10^{-5}	0.4
Lower East Fork Poplar Creek and Poplar Creek				
Individual	N/A[e]	0.3	5×10^{-4}	0.3
Collective	N/A[e]	0.02	4×10^{-6}	0.02

[a] 1 mrem = 0.01 mSv.

[b] Doses based on measured radionuclide concentrations in water or estimated from measured discharges and known or estimated streamflows.

[c] Total doses and apparent sums of individual pathway doses may differ because of rounding.

[d] Doses based on measured radionuclide concentrations in fish samples.

[e] Not at or near drinking water supply locations.

Acronym: *CRK = Clinch River kilometer*

7.1.2.3. Radionuclides in Food

The CAP-88 PC computer codes are used to calculate radiation doses from ingestion of meat, milk, and vegetables that could contain radionuclides released from ORR.

Milk, vegetables, hay, wildlife, and fish are sampled and analyzed annually, as available, to characterize doses from radionuclides that could be consumed in food products that originated at local farms and gardens and in game harvested by hunting and fishing on or near ORR.

Milk

Since 2016, no dairies in potential ORR deposition areas have been located, and no milk samples have been collected. Surveys to identify dairies in potential deposition areas are conducted each year. A small dairy operation located in the vicinity of ORR was identified in 2020, but milk samples could not be obtained. No additional suitable locations were identified in 2023. Milk sampling will resume when dairy operations in appropriate areas are located.

Vegetables

The food crop sampling program is described in Chapter 6. Tomatoes were obtained from four local gardens, and leafy greens were obtained from one local garden. Additionally, both tomatoes and leafy greens were obtained from the same distant background location in Claiborne County. Samples of root vegetables were not available in 2023. In addition to analyses for gross alpha, gross beta, gamma emitters, and isotopic uranium, an expanded list of radionuclides is included in the analytical suite every 5 years. In 2023, in addition to ^{7}Be, ^{40}K, and isotopes of uranium, statistically significant concentrations of ^{241}Am, ^{214}Bi, ^{214}Pb, $^{239/240}$Pu, ^{90}Sr, and ^{230}Th were detected in vegetable samples. Dose estimates are based on hypothetical consumption rates of vegetables that contain statistically significant or detected concentrations of radionuclides that could have come from ORR. Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined 2020 decennial US Census population of Anderson, Knox, Loudon, and Roane Counties (Census 2020; Fryar et al. 2016), a hypothetical home gardener was assumed to have eaten a maximum of about 16 kg (35 lb) of homegrown leafy greens and 73 kg (161 lb) of homegrown tomatoes. The hypothetical local gardener could have received an ED of between 0 and 0.4 mrem, depending on the garden location and the vegetable consumed. Of this total, between 0 and 0.4 mrem could have come from eating leafy greens, and between 0 and 0.2 mrem from eating tomatoes. A person eating vegetables from the distant background garden could have received a committed ED of 0.4 mrem from eating leafy greens and 0.04 mrem from eating tomatoes.

Potassium-40 is a naturally occurring, fertilizer-introduced radionuclide that was identified in the samples and accounted for most of the beta activity found in them. Potassium-40 concentrations in tomatoes were similar at all garden locations, including the background location. Likewise, ^{40}K concentrations in leafy greens at the one garden location were comparable to the those at the background location. The presence of ^{40}K in the samples added, on average, about 3 mrem to the hypothetical home gardener's ED. In 2023, gardeners who provided vegetable samples were asked about water sources and fertilizers used. Fertilizers were used at two of the four garden locations and at the background location. Water sources for the gardens typically include city water. Most of the activity found in vegetables is thought to be due to the ^{40}K and to unidentified naturally occurring beta-emitting radionuclides, not emissions from ORR.

Hay

Another environmental pathway that is typically evaluated is eating beef and drinking milk obtained from hypothetical cattle that eat hay harvested from one location on ORR. Hay samples collected on ORR are normally analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. In 2023, statistically significant concentrations of ^{7}Be, ^{40}K, ^{210}Pb, and ^{238}U were detected in hay samples. Both ^{7}Be and ^{40}K are naturally occurring and are not included in reported EDs from drinking milk and eating beef; however, their presence contributed about 9 mrem to the total dose. Lead-210, also a naturally occurring radioisotope, contributed nearly 6.5 mrem to this pathway. Excluding the dose contributions from ^{210}Pb, ^{7}Be, and ^{40}K, the ED from drinking milk and eating beef was 0.007 mrem.

White-tailed deer

In 2023, TWRA conducted three 2-day deer hunts on ORR. (See Section 6.6.5.) During the hunts, 204 deer were harvested and taken to the TWRA checking station, where a bone sample and a muscle tissue sample were collected from each deer. The samples were field counted for radioactivity to ensure that the deer met the wildlife release criteria of net counts less than 1.5 times background (~20 pCi/g $^{89/90}$Sr) of beta activity in bone and the administrative limit of 5 pCi/g of ^{137}Cs in edible tissue (ORNL 2011; ORNL 2020).[1] Two deer exceeded the wildlife release criteria and were retained in 2023.

[1] The 2020 version of CSD-AM-RML-RA01 supersedes the 2011 version.

The average ^{137}Cs concentration in muscle tissue of the 202 released deer was 0.4 pCi/g; the maximum ^{137}Cs concentration in the released deer was 0.5 pCi/g. The ^{137}Cs activity in each sample was less than minimum detectable levels. The average weight of released deer was approximately 43 kg (95 lb); the maximum weight was 86 kg (189 lb). The EDs attributed to field-measured ^{137}Cs concentrations and actual field weights of the released deer ranged from about 0.1 to 1 mrem, with an average of about 0.5 mrem.

Potential doses from the consumption of deer that might have moved off ORR and been harvested elsewhere were also evaluated. In this scenario, if an individual consumed one average-weight deer (43 kg [95 lb], assuming that 55 percent of the field weight was edible meat) with the 2023 average field-measured concentration of ^{137}Cs (0.4 pCi/g), that individual could have received an ED of about 0.5 mrem. If an individual consumed a deer of maximum weight and ^{137}Cs content, that individual could have received an ED of about 1 mrem.

In 2023, muscle tissue samples from six released deer and two retained deer were collected and analyzed for radionuclides. Analyses included ^{137}Cs, ^{90}Sr, and ^{40}K. Comparison of the released-deer field results with analytical ^{137}Cs concentrations showed that the field concentrations were greater than the analytical results and that all concentrations were less than the administrative limit of 5 pCi/g (ORNL 2011; ORNL 2020).[1] Analytical results for ^{90}Sr concentrations in the muscle tissue of the six released deer ranged from 0 to 0.03 pCi/g. Using the analytical results for ^{137}Cs and ^{90}Sr (excluding ^{40}K, a naturally occurring radionuclide) and actual deer weights, the estimated doses ranged from about 0.002 to 0.2 mrem for the six released deer and between 0.1 and 0.3 mrem for the two retained deer.

The maximum ED to an individual consuming venison from two or three deer was also evaluated. In 2023, 23 hunters each harvested two or three deer from ORR. Based on ^{137}Cs concentrations determined by field counting and actual field weights, the ED to a hunter who consumed two or more deer was estimated to have been between about 1 and 2 mrem.

The collective ED from eating venison from all the deer harvested on ORR in 2023 was estimated to have been about 0.1 person-rem based on the 2023 average field-derived ^{137}Cs concentration of 0.4 pCi/g and an average weight of 43 kg (95 lb). The collective dose is based on the number of harvested deer. Additional individuals may also have consumed the harvested venison, but the collective dose would be essentially the same.

Canada geese

Twenty-seven geese were captured during the 2023 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. The maximum ^{137}Cs concentration in the released geese was 0.3 pCi/g. All ^{137}Cs concentrations were below minimum detectable activity levels. The average weight of the geese screened during the roundup was about 4.3 kg (9.5 lb), and the maximum weight was about 5.4 kg (12 lb).

The EDs attributed to field-measured ^{137}Cs concentrations of the geese ranged from 0.02 to 0.03 mrem. However, for bounding purposes, if a person consumed a released goose with an average weight of 4.3 kg (9.5 lb) and an average ^{137}Cs concentration of 0.2 pCi/g, the estimated ED would have been approximately 0.02 mrem. About half the weight of a Canada goose was assumed to be edible. The estimated ED was about 0.04 mrem for an individual who consumed a goose with the maximum ^{137}Cs concentration of 0.3 pCi/g and maximum weight of 5.4 kg (12 lb).

It is possible that a person could have eaten more than one goose that spent time on ORR. The average seasonal goose bag per active hunter from Tennessee in the Mississippi Flyway was 2.2 (±60 percent) geese per hunting season between 2021 and 2023 (US Fish and Wildlife Service 2023). A person who consumed two geese of maximum weight with the highest measured concentration of ^{137}Cs would have received an ED of about 0.08 mrem.

Between 2000 and 2009, 22 samples of goose tissue were analyzed. Potential doses were evaluated 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 potential dose, omitting the contribution of naturally occurring ^{40}K, ranged from 0.01 to 0.5 mrem. The average potential dose was 0.2 mrem (EP&WSD 2010).

Eastern wild turkey

Wild turkey hunts scheduled on ORR for 2020 through 2022 were canceled because of the COVID-19 pandemic but resumed in 2023. Two wild turkey hunts took place on the reservation in 2023: April 15 and 16 and April 22 and 23. Participating hunters are permitted to harvest one turkey per season from the reservation. If a turkey is retained, the hunter is permitted to harvest another turkey. Forty-six turkeys were harvested during the turkey hunts, and one turkey was harvested during the deer hunt, which took place on December 9 and 10, for a total of 47 turkeys. No harvested turkeys were retained. The average weight of the released turkeys was about 8.7 kg (19 lb). The maximum weight was about 11 kg (24 lb). Turkeys 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 in the released turkeys was 0.08 pCi/g, with a maximum concentration of 0.1 pCi/g. Almost all ^{137}Cs concentrations were below minimum detectable activity levels.

The EDs attributed to ^{137}Cs concentrations field measured in the turkeys ranged from 2×10^{-5} to 0.03 mrem. However, for bounding purposes, if a person consumed a released turkey with an average weight of 8.7 kg (19 lb) and an average ^{137}Cs concentration of 0.08 pCi/g, the estimated ED would have been approximately 0.02 mrem. About half the weight of a turkey was assumed to be edible. The estimated ED to an individual who consumed a hypothetical turkey with the maximum ^{137}Cs concentration of 0.1 pCi/g and maximum weight of 11 kg (24 lb) was about 0.04 mrem.

The collective ED from eating all the harvested turkeys from ORR with a 2023 average field-derived ^{137}Cs concentration of 0.08 pCi/g and an average weight of 8.7 kg (19 lb) is estimated to be about 0.0008 person-rem. The collective dose is based on the number of harvested turkeys. It is possible that additional individuals may have consumed the harvested turkeys; however, the collective dose would be essentially the same.

No tissue samples from turkeys were analyzed in 2023. 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, omitting the contribution of naturally occurring ^{40}K, ranged from 0.06 to 0.2 mrem (EP&WSD 2010).

7.1.2.4. 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). Because of radiological activities on ORR, external radiation exposure rates were measured at six of the ORR ambient air monitoring stations and at Station 52, the reference ambient air station (Figure 6.2). External gamma exposure rates were continuously recorded by dual-range Geiger-Müller tube detectors colocated with ORR ambient air stations. In 2023, exposure rates averaged about 9.4 μR/h and ranged from 7.8 to 11.4 μR/h. These exposure rates correspond to an annual average dose of about 58 mrem with a range of 48 to 70 mrem. At the background ambient air station, the exposure rate averaged about 9 μR/h and ranged from 8.2 to 10.5 μR/h. The resulting average annual dose was about 57 mrem with a range of 50 to 64 mrem. The annual doses based on measured exposure rates at or near ORR boundaries were typically within the range of the doses measured at the background location;

slightly higher exposure rates were observed at ambient air monitoring Stations 11 and 46.

7.1.3. Current-Year Summary

A summary of the maximum EDs to individuals by exposure pathway is given in Table 7.7. In the unlikely event that a person was exposed to all the sources and pathways for the duration of 2023, that person could have received a total ED of about 3 mrem. Of that total, 0.6 mrem would have come from airborne emissions, approximately 0.8 mrem from waterborne emissions (0.02 mrem from drinking water, 0.7 mrem from consuming fish, 0.001 mrem from other water uses along the Clinch River, and 0.03 mrem from irrigation at CRK 16), and about 1 mrem from consuming wildlife. Direct radiation measurements at six ORR ambient air monitoring stations were at or near background levels in 2023. There were no known significant doses from discharges of radioactive constituents from ORR other than those reported.

7.1.4. Five-Year Trends

EDs associated with selected exposure pathways for 2019 through 2023 are given in Table 7.8. In 2023, the air pathway dose increased largely due to an increase in emissions from Y-12. The fish consumption dose increased in 2019 due to a catfish sample collected at CRK 16, in which $^{239/240}$Pu was a primary dose contributor; however, the catfish sample collected at CRK 70, which is above ORR discharge locations, also contained $^{239/240}$Pu. Catfish and sunfish samples from both CRK 16 and CRK 70 were reanalyzed, and although the results were generally lower, the difference was not statistically significant, and the original results were used in dose calculations. The increases in the fish consumption dose and drinking water dose in 2021 were due to the contribution of ^{241}Am detected in the second-quarter water sample taken at CRK 58. Recent direct radiation measurements indicated doses near background levels. Doses from consumption of wildlife have been similar for the past 5 years, although the dose from consumption of geese increased slightly in 2021, and the dose from consumption of deer decreased slightly in 2023.

7.1.5. Doses to Aquatic and Terrestrial Biota

The following sections summarize the results of assessments conducted to determine the potential effect of radionuclides originating from ORR on aquatic and terrestrial biota.

7.1.5.1. Aquatic Biota

DOE Order 458.1 (DOE 2020) 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 (Version 1.8), a companion tool for implementing DOE technical standard DOE-STD-1153-2019, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2019). 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. A 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, protecting the more sensitive organisms is generally assumed to adequately protect other, less sensitive organisms. Depending on the radionuclide, either aquatic organisms (e.g., crustaceans) or riparian organisms (e.g., raccoons) may be more sensitive and are typically the limiting organisms for the general screening phase of the graded approach for aquatic system evaluations.

Table 7.7. Summary of maximum estimated effective doses from ORR activities to an adult by exposure pathway, 2023

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	0.6	0.006	0.6	17.6	0.176		1,276,842[b]
Liquid effluents							
Drinking water	0.02	0.0002	0.02	1.2	0.012		457,019
Eating fish	0.7	0.007	0.7	0.04	0.0004		8,809[d]
Other activities	0.001	1×10^{-5}	0.001	0.003	3×10^{-5}		3,359,287[d]
Irrigation	0.03	0.0003	0.03				
Other pathways							
Eating deer	1[e]	0.01[e]	1	0.1[e]	0.001[e]		202[e]
Eating geese	0.08[f]	0.0008[f]	0.08	*g*	*g*		
Eating turkeys	0.04[h]	0.0004[h]	0.04	8×10^{-4} [h]	8×10^{-6} [h]		47[h]
Direct radiation	N/A[i]	N/A					
All pathways							
Total	3[j]	0.03	3	19	0.19	383,053	

[a] Estimated background collective dose is based on the roughly 300 mrem/year individual dose and the population within 80 km (50 miles) of ORR.

[b] Population is based on 2020 Census data.

[c] Population estimates are based on community and noncommunity drinking water supply data from the Tennessee Department of Environment and Conservation Division of Water.

[d] Population estimates for fish are based on creel and commercial fishing data. Fractions of fish harvested from Melton Hill, Watts Bar, and Chickamauga Reservoirs are based on creel survey data. Melton Hill, Watts Bar, and Chickamauga recreational use information was obtained from the Tennessee Valley Authority (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 visitors that may live outside the 80 km radius.

[e] Estimates for eating deer are based on consuming one hypothetical deer of the heaviest weight measured among the captured deer and with the highest ^{137}Cs concentration measured in the released deer on ORR; collective dose is based on the number of harvested deer.

[f] Estimates for eating geese are based on consuming two hypothetical geese, each with the heaviest weight measured among the captured geese and with the highest measured concentration of ^{137}Cs in the 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 a hypothetical turkey with the heaviest weight measured in the harvested turkey and with the highest ^{137}Cs concentration measured in the released turkey on ORR; collective dose is based on the number of harvested turkeys.

[i] Current exposure rate measurements at ambient air monitoring stations are at or near background levels.

[j] Dose estimates have been rounded.

Acronyms:

DOE = US Department of Energy

ORR = Oak Ridge Reservation

Table 7.8. Trends in effective dose from ORR activities, 2019–2023 (mrem)[a]

Pathway	2019	2020	2021	2022	2023
Airborne effluents—all pathways	0.4	0.4	0.5	0.2	0.6
Fish consumption (Clinch River)	4	2	3	0.4	0.7
Drinking water (Kingston)	0.01	0.02	3	0.03	0.006
Deer	2	*b*	*b*	2	1
Geese	0.1	0.07	0.2	0.1	0.08
Turkeys	0.04	*b*	*b*	*b*	0.04

[a] *1 mrem = 0.01 mSv*

[b] *Wild turkey hunts scheduled on ORR for 2020 through 2022 and deer hunts for 2020 and 2021 were canceled because of the COVID-19 pandemic.*

Acronym: *ORR = Oak Ridge Reservation*

At ORNL, doses to aquatic organisms are based on surface water concentrations at the following instream sampling locations:

- Melton Branch (X13) and Melton Branch Weir
- WOC headwaters (WOC 6.8), WOC (X14), and White Oak Dam (WOD) (X15)
- ORNL Sewage Treatment Plant Wastewater Discharge Point (X01)
- WOC 7500 Bridge
- First Creek
- Fifth Creek
- Northwest Tributary
- Raccoon Weir
- Waste Area Grouping 6 Monitoring Station 3 (tributary to WOC at WOD)
- CRK 32 and CRK 66

Based on the results of the general screening phase, in which the maximum concentrations of radionuclides in water were compared with default BCGs or second-level screenings at X01, X15, and WOC 7500 Bridge, the absorbed dose rates to aquatic organisms at all ORNL locations were below the DOE aquatic dose limit of 1 rad/day.

At Y-12, doses to aquatic organisms were estimated from surface water concentrations 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
- Discharge Point S24
- Discharge Point S17 (unnamed tributary to the Clinch River)
- Discharge Point S19 (Rogers Quarry)
- Outfall 200 on EFPC

Absorbed dose rates to aquatic organisms at the Y-12 locations were below the DOE aquatic dose limit of 1 rad/day based on general screenings or second-level screenings at Surface Water Hydrological Information Support System Station 9422-1, S24, and Outfall 200.

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)
- CRK 16 and CRK 23

Absorbed dose rates to aquatic organisms were below the DOE aquatic dose limit of 1 rad/day at the ETTP sampling locations based on general screening results.

7.1.5.2. Terrestrial Biota

A terrestrial organism assessment was conducted to evaluate impacts on biota in accordance with requirements in DOE Order 458.1 (DOE 2020). An absorbed dose rate of 0.1 rad/day is recommended as the limit for terrestrial animal exposure to radioactive material in soils. RESRAD-Biota code (Version 1.8), a companion tool for implementing *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2019), was used for the terrestrial organism assessment to demonstrate compliance with this limit. As is the case with aquatic and riparian biota, certain terrestrial organisms are more sensitive to ionizing radiation than others, and protecting the more sensitive organisms is generally assumed to adequately protect other, less sensitive organisms.

Soil sampling for terrestrial dose assessment was initiated in 2007 and was repeated in 2014 and 2021. Additionally, 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. ORR site-specific bioaccumulation factors were calculated using 2007 and 2014 maximum soil concentrations and radionuclide concentrations in tissue for biota inhabiting the WOC floodplain.

In 2007, 2014, and 2021, 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. This biota sampling strategy was developed using guidance provided in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2019) and existing radiological information on the concentrations and distribution of radiological contaminants on ORR. In 2021, soil samples were collected from the same general locations as samples collected in 2007 and 2014. Soil sampling locations were as follows:

- **WOC floodplain.** Analytes detected in soil samples at this location in 2021 included ^{241}Am, ^{137}Cs, ^{60}Co, $^{243/244}$Cm, ^{238}Pu, $^{239/240}$Pu, ^{40}K, $^{89/90}$Sr, $^{233/234}$U, ^{235}U, and ^{238}U.
- **Mitchell Branch floodplain.** Analytes detected in soil samples at this location in 2021 included ^{241}Am, $^{239/240}$Pu, ^{99}Tc, $^{233/234}$U, and ^{238}U.
- **Bear Creek Valley floodplain.** Analytes detected in soil samples at this location in 2021 included ^{241}Am, $^{243/244}$Cm, $^{233/234}$U, ^{235}U, and ^{238}U.
- **EFPC floodplain.** Analytes detected in soil samples at this location in 2021 included $^{233/234}$U, ^{235}U, and ^{238}U.
- **Background locations.** Soils were also sampled in 2021 near Gum Hollow Branch, which represents Conasauga Group geologic formations, and near Bearden Creek, which represents Chickamauga Group geologic formations. Analytes detected in soil samples at the background locations in 2021 included ^{241}Am, ^{137}Cs, $^{239/240}$Pu, ^{40}K, $^{89/90}$Sr, $^{233/234}$U, ^{235}U, and ^{238}U.

In 2021, all soil samples except for those collected on the WOC floodplain upstream of WOD passed the initial-level screening (a comparison of maximum radionuclide soil concentrations to default BCGs). Cesium-137 was the primary dose contributor to terrestrial biota on the WOC floodplain and was also the primary dose contributor in 2007 and 2014. Strontium-90 also contributed significantly to wildlife dose on the

WOC floodplain in 2021 but to a lesser extent than ^{137}Cs. Because of measured concentrations in soil on the WOC floodplain and the results of second-level screening (comparison of average radionuclide soil concentrations to default BCGs), further evaluation was completed using ORR site-specific bioaccumulation factors and average radionuclide soil concentrations. The results of the additional screening evaluation indicated that absorbed dose rates to terrestrial organisms on the WOC floodplain were less than the DOE limit of 0.1 rad/day.

Future evaluations of exposure to terrestrial organisms will be conducted within the next 5 years if an abnormal event occurs that could have adverse impacts on terrestrial organisms.

7.2. Chemical Dose

Chemicals released during ORR operations could migrate to off-site locations, resulting in potential exposure of the public. The following sections summarize the results of an informational risk assessment for chemicals found in drinking water and fish on or near ORR.

7.2.1. Drinking Water Consumption

Surface water and groundwater are both potential sources of drinking water for populations in areas adjacent to ORR. Samples of surface water and groundwater are collected from sources near ORR and are analyzed to determine the presence and concentrations of chemicals that could pose a health risk for the local population.

7.2.1.1. Surface Water

To evaluate the drinking water exposure pathway, hazard quotients (HQs) and risks were estimated downstream of ORNL and downstream of ORR discharge points to the Clinch River (Table 7.9).

An HQ is a ratio that compares the estimated exposure dose or intake to a reference dose for noncarcinogens. HQs of less than 1 indicate an unlikely potential for adverse noncarcinogenic health effects. Likewise, risks are evaluated from estimated exposure dose or intake and cancer slope 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). (See Appendix F.) Based on a nationwide health and nutrition survey (EPA 2023) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane Counties, which reflects 2020 decennial US Census data (Census 2020; Fryar et al. 2016), the drinking water consumption rate for the MEI is assumed to be 940 L/year (2.6 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.

Table 7.9. Chemical hazard quotients and estimated risks for drinking water from the Clinch River at CRK 23 and CRK 16, 2023

Analyte	Hazard quotient	
	CRK 23[a]	CRK 16[b]
Metals		
Copper	4×10^{-4}	5×10^{-4}
Mercury	6×10^{-5}	8×10^{-4}
Nickel	c	9×10^{-4}
Uranium	3×10^{-2}	4×10^{-2}

[a] *CRK 23 is no longer a water intake location.*

[b] *CRK 16 is downstream of all DOE inputs to the Clinch River and is not a water intake location.*

[c] *The parameter was undetected.*

Acronym: *CRK = Clinch River kilometer*

Calculated HQs for 2023 for CRK 16 and CRK 23 (Table 7.9) were based on detected water concentration values. At all locations, HQs were less than 1 for chemical analytes in water for which there are reference doses. Maximum contaminant levels were also not exceeded (Table 7.9). Beginning in 2022, mercury concentrations at CRK 66, CRK 32, and CRK 16 were measured using a more sensitive analysis method with a lower reporting limit than was used in previous years. HQs were 9×10^{-5} for CRK 66, 6×10^{-5} for CRK 32 and CRK 23, and

8×10^{-4} for CRK 16 in 2023. In 2023, no chemical analytes were detected for which risk levels for carcinogens were calculated. CRK 16, located downstream of all ORR discharge points, is not a source of drinking water, but data from that location were used as surrogates to evaluate potential exposure to contaminants in drinking water from the Clinch River.

7.2.1.2. Groundwater

During fiscal year 2023, 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. (See Section 6.5.) Currently, no water is consumed from these off-site groundwater wells.

7.2.2. Fish Consumption

Chemicals in water can accumulate in tissues of 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 health and nutrition survey (EPA 2023) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane Counties, which reflects 2020 decennial US Census data (Census 2020; Fryar et al. 2016), avid fish consumers were assumed to have eaten 41 kg (90 lb) of fish during 2023. This fish consumption rate of 112 g/day (41 kg/year) was used for estimating exposure to both noncarcinogenic and carcinogenic chemicals. This is the same fish consumption rate used in the estimation of the radiological dose from consumption of fish.

For consumption of sunfish, HQs of less than 1 were calculated for all detected analytes at all locations. For consumption of catfish, HQs of less than 1 were calculated for all detected analytes except for mercury (CRK 16), Aroclor 1248 and Aroclor 1254 (CRK 70 and CRK 32), and Aroclor 1260 (CRK 70, CRK 32, and CRK 16) (Table 7.10). For carcinogens, risk values greater than 10^{-6} were calculated for the intake of chromium VI in sunfish at CRK 70. For catfish, risk values greater than 10^{-6} were calculated for Aroclor 1248 (CRK 70 and CRK 32), Aroclor 1254 (CRK 70 and CRK 32), and Aroclor 1260 (CRK 70, CRK 32, and CRK 16). The Tennessee Department of Environment and Conservation (TDEC) has issued a fish advisory that states that catfish should not be consumed from the entire Melton Hill Reservoir or from the Tennessee River portion of the Watts Bar Reservoir because of polychlorinated biphenyl contamination (TDEC 2023). TDEC has also issued a precautionary fish consumption advisory for catfish in the Clinch River arm of the Watts Bar Reservoir (TDEC 2023).

Table 7.10. Chemical hazard quotients and estimated risks for fish caught and consumed from locations on ORR, 2023[a]

	Sunfish			Catfish		
	CRK 70[b]	CRK 32[c]	CRK 16[d]	CRK 70[b]	CRK 32[c]	CRK 16[d]
			Hazard quotients for metals			
Barium	8×10^{-4}					
Chromium	0.7					
Copper	0.009	0.004	0.007	0.009	0.01	0.007
Iron	0.03					
Manganese	0.004	0.004	0.002	0.002		0.009
Mercury						1
Selenium	0.1	0.1	0.1			
Zinc	0.04	0.03	0.04	0.04	0.03	0.04
			Hazard quotients for Aroclors			
Aroclor 1248				1	1	
Aroclor 1254				3	4	
Aroclor 1260				3	3	0.6
			Risks for carcinogens			
Chromium	4×10^{-4}					
Aroclor 1248				1×10^{-5}	2×10^{-5}	
Aroclor 1254				5×10^{-5}	6×10^{-5}	
Aroclor 1260				4×10^{-5}	5×10^{-5}	9×10^{-6}
PCBs (mixed)[e]				1×10^{-4}	1×10^{-4}	9×10^{-6}

[a] *Blank space for a location indicates that the parameter was undetected.*

[b] *Melton Hill Reservoir, reference location 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 PCBs comprise the summation of Aroclors detected or estimated.*

Acronyms:

CRK = Clinch River kilometer

ORR = Oak Ridge Reservation

PCB = polychlorinated biphenyl

7.3. References

40 CFR Part 61, Subpart H. "Subpart H—National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities." *US Code of Federal Regulations*, Washington, DC. Retrieved February 25, 2021, from https://www.ecfr.gov/cgi-bin/text-idx?SID=eff89c419f5d1ed63e14b4d1765f4bf9&mc=true&node=pt40.10.61&rgn=div5#sp40.10.61.h.

Census 2020. 2020 Census Results. US Census Bureau, Washington, DC. https://www.census.gov/programs-surveys/decennial-census/decade/2020/2020-census-results.html.

DOE 2019. A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota. DOE-STD-1153-2019. US Department of Energy, Washington, DC.

DOE 2020. *Radiation Protection of the Public and the Environment*. DOE Order 458.1, Ltd. Chg. 4. Approved February 11, 2011 (Ltd. Chg. 4 dated September 15, 2020). US Department of Energy, Washington, DC.

DOE 2021. *Derived Concentration Technical Standard*. DOE-STD-1196-2021. US Department of Energy, Washington, DC.

EP&WSD 2010. *Radiological Monitoring and Dose Report for Selected Wildlife Populations Oak Ridge Reservation*. EPWSD-EPS-TP-01, Oak Ridge National Laboratory, Environmental Protection and Waste Services Division, Oak Ridge, Tennessee.

EPA 2011. *Exposure Factors Handbook.* EPA/600/R-090/052F, US Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington, DC.

EPA 2015. *CAP-88 & CAP-88 PC*. US Environmental Protection Agency, November 2015, Washington, DC. Retrieved February 25, 2021, from https://www.epa.gov/radiation/cap-88-cap-88-pc.

EPA 2023. *What We Eat in America—Food Commodity Intake Database 2005-10*. US Environmental Protection Agency, Office of Pesticide Programs, and University of Maryland. Retrieved April 7, 2024, from https://fcid.foodrisk.org.

Hamby 1991. Hamby, D.M., "LADTAP XL: An Improved Electronic Spreadsheet Version of LADTAP II." DE93003179, Westinghouse Savannah River Company, Aiken, South Carolina.

NCRP 2009. *Ionizing Radiation Exposure of the Population of the United States.* NCRP Report No. 160, National Council on Radiation Protection and Measurements, Bethesda, Maryland.

NRC 1977. Regulatory Guide 1.109, Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I. US Nuclear Regulatory Commission, Washington, DC.

Fryar et al. 2016. Fryar, C. D., Q. Gu, C. L. Ogden, and K. M. Flegal. *Anthropometric Reference Data for Children and Adults: United States, 2011-2014*. Vital and Health Statistics, Series 3, Number 39. National Center for Health Statistics, Hyattsville, Maryland.

ORNL 2011. *Deer Hunt Radiation Monitoring Guidelines.* CSD-AM-RML-RA01, Oak Ridge National Laboratory, Chemical Sciences Division, Oak Ridge, Tennessee.

ORNL 2020. *Wildlife Monitoring at the TWRA Monitoring Station.* CSD-AM-RML-RA01, Oak Ridge National Laboratory, Chemical Sciences Division, Oak Ridge, Tennessee.

Poudyal et al. 2017. Poudyal, N. C., H. Gotwald, B. English, K. Jensen, J. Menard, C. Caplenor, C. Maldonado, and D. Watkins, "Results from Visitor and Property Owner Surveys on Chickamauga, Norris, and Watts Bar Reservoir in Summer 2016." University of Tennessee Institute of Agriculture, March 24.

Stephens et al. 2006. Stephens, B. et al. *Recreation Use on Melton Hill Reservoir*. Human Dimensions Research Lab, University of Tennessee Agriculture Institute.

TDEC 2023. *Posted Streams, Rivers, and Reservoirs in Tennessee*. Tennessee Department of Environment and Conservation, Division of Water Resources, Nashville, Tennessee. Retrieved April 26, 2024, from https://www.tn.gov/content/dam/tn/environment/water/watershed-planning/wr_wq_fish-advisories.pdf.

TWRA 2019. *Final Report, Report No. 19-06, Tennessee Statewide Creel Survey, 2018 Results*, Fisheries Management Division, Tennessee Wildlife Resources Agency.

TWRA 2021. *Final Report, Report No. 21-06, Tennessee Statewide Creel Survey, 2020 Results*, Fisheries Management Division, Tennessee Wildlife Resources Agency.

TWRA 2023*, Tennessee's Commercial Fish and Mussel Report, Report No. 23-01,* Fisheries Management Division, Tennessee Wildlife Resources Agency.

US Fish and Wildlife Service 2023. Migratory Bird Hunting Activity and Harvest during the 2021-22 and 2022-23 Hunting Seasons. US Fish and Wildlife Service.

A

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.

anthropogenic—Of, relating to, or resulting from the influence of human beings on nature.

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.

background radiation—Radiation from cosmic sources; naturally occurring radioactive materials, including radon (except as a decay product of source or special nuclear material), and global fallout as it exists in the environment from the testing of nuclear explosive devices.

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.

carbon-pollution-free electricity—Electrical energy produced from resources that do not generate carbon emissions (such as marine energy, solar, wind, thermal, geothermal, hydroelectric, nuclear, renewably sourced hydrogen, and electrical energy generation from fossil resources) that enables active capture and storage of carbon dioxide emissions to meet EPA requirements.

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.

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 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 Justice—The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

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.

Net-zero emissions (net-zero)—The achievement of a balance between greenhouse gas emissions produced and greenhouse gas emissions taken out of the atmosphere.

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.

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.

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.

B

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 with the level of evaporation and transpiration normally experienced throughout the year. The *subtropical* designation indicates that the region experiences a wide range of seasonal temperatures. Subtropical areas are typified by significant differences in temperature between summer and winter. Also, in humid subtropical climates, at least 4 months have an average temperature above 10°C (50°F). Monthly precipitation does not differ significantly throughout the year, but the types of precipitation may vary.

Oak Ridge winters are characterized by large-scale 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, are most frequent during spring and rarely occur in winter. The Cumberland Mountains and Cumberland Plateau frequently inhibit the intensity of severe systems that traverse the region to the east, particularly those moving from west to east, because of 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 tornadoes.

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 fall precipitation is usually adequate, August through October often are the driest months of the year. Precipitation during the fall tends to be less cyclical than in other seasons, but it is occasionally enhanced by decaying tropical cyclones moving north from the Gulf of Mexico. In November, midlatitude cyclones begin to dominate the weather and typically continue to do so until May.

Decadal-scale climate changes regularly affect the East Tennessee region. Most of these changes appear related to the hemispheric temperature and precipitation effects caused by the frequencies and phases of the El Niño–Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the Atlantic Multidecadal Oscillation (AMO). The ENSO is a recurring climate pattern involving changes in the temperature of waters in the central and eastern tropical Pacific Ocean. About every 3 to 7 years, the surface waters across a large swath of the tropical Pacific Ocean warm or cool by anywhere from 1°C to 3°C compared to normal. The PDO is a long-term climate pattern that affects the temperature of the Pacific Ocean and the weather patterns around it. The PDO is a naturally occurring phenomenon that shifts between warm and cool phases, with each phase lasting around 20–30 years. The PDO can strongly impact global weather and is important in long-range weather forecasting (Dutton 2021). The AMO is an ongoing series of long-duration changes in the sea surface temperature of the North Atlantic Ocean, with cool and warm phases that may last for 20–40 years each and a difference of about −17.2°C (1.0°F) between extremes. These changes are natural and have been occurring for at least the past 1,000 years.

These medium- and long-range sea surface temperature patterns collectively influence decadal-scale and longer regional temperature and precipitation trends in eastern Tennessee. The AMO shifted from a cold sea surface temperature phase to a warm sea surface temperature phase in the mid-1990s; this phase has generally continued through the present, but temperatures have shown signs of a slight decrease within the past 5 years. The PDO entered an either cool or transitional sea surface temperature phase around 2000. Although the ENSO pattern frequently caused warmer Eastern Pacific sea surface temperatures during the 1990s, that warming subsided somewhat in the 2000s. The El Niño returned to prominence during the 2010s. A very strong El Niño occurred in 2015–2016, causing above-normal temperatures both locally and across much of the globe by 2016. Additionally, evidence exists that human-induced climate change may be affecting local temperatures via well-mixed greenhouse gases, land cover change, carbon soot, aerosols, and other first-order influences. Solar influences on the jet stream via changes to the stratospheric temperature gradient over the 11-year solar cycle also contribute to interannual climate variability (Ineson et al. 2011). Perhaps in part because of the effects of the AMO and ENSO, the Oak Ridge climate warmed about 1.2°C from the 1970s to the 1990s, and through the 2010s (the most recent decade for which data are available) it remained within 0.2°C of the value observed in the 1990s. 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 past 30 years, primarily by increasing minimum temperatures. Similar trends were noted through the 2000s and 2010s, with an average of 10 fewer days per year of minimum temperatures below 0°C. This 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 observed in the more than 1°C difference between the average temperatures for 2014 (14.8°C) and 2015 (16.0°C), 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 (i.e., 14.5°C in 2018) but rose again in

2019 under the influence of weak El Niño conditions (15.2°C). The average temperature declined in 2020 to 14.7°C with the onset of La Niña conditions, which persisted early into 2023 before positive sea surface temperature anomalies returned through the end of the year (i.e., strengthening El Niño conditions).

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 that 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 within ORR (Birdwell 2011). Along-valley and mountain-valley circulations are thermally driven and occur within a broad 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 is frequently 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. Because it necessitates some degree of vertical motion transfer, forced channeling is less pronounced during periods when cool air is trapped under warmer air just off the surface (i.e., inversion). Although it may result from interactions between large valleys and mountain ranges (such as the Great Valley and the surrounding mountains), forced channeling is especially important in narrow, small valleys such as those within ORR and the Great Valley (Kossman and Sturman 2002).

Forced channeling within the Central Great Valley is the dominant large-scale wind mechanism, influencing 50–60 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 (45°–90°) when they initiate or terminate. At small scales, ridge-and-valley terrain produces forced-channeled local flow in more than 90 percent of cases.

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. This sometimes results in a split-flow pattern, with 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). A northwest wind flow through the convex shape of the Great Valley may lead to a divergent wind flow pattern in the Knoxville area, resulting in downward air motion. Horizontal flow is also reduced by the windward Cumberland Mountains, which increase buoyancy and the apparent force caused by the earth's rotation, or the Coriolis effect (also known as Froude and Rossby ratios). Consequently, the leeward terrain of the 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 is a consequence of the horizontal transport and momentum aloft being transferred to the surface. However, Coriolis effects may turn the winds to the left by up to 40° (Birdwell 1996).

In the Central Valley, vertically coupled winds dominate about 25–35 percent of each occurrence; however, most vertically coupled 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 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).

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 the 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 pressure-driven channeling shift from up-valley to down-valley flow or in the opposite direction if large-scale pressure systems induce reversals in air pressure gradients across the axis of the Great Valley. Because 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 one another with varied directions of movement (Monti et al. 2002).

Within the Central Great Valley, and especially within ORR, winds dominated by down-valley pressure-driven channeling range in frequency from 2 to 10 percent of cases, 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 than 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 complex terrain. These winds occur because of pressure and temperature differences caused by varied surface-air energy exchanges at similar altitudes along a valley's axis, sidewalls, or slopes. Conditions are ideal for the development of thermally driven winds 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. The frequency of large-scale thermally driven winds is highest during summer and especially fall, when surface heating and low humidity help drive flow patterns (Birdwell 2011).

A wind rose is a graphical chart that characterizes the speeds and directions of winds at a location. A wind rose is presented in a circular format, and the length of each "spoke" around the circle indicates the amount of time that the wind blows from a particular direction. Colors along the spokes indicate categories of wind speed (NOAA n.d.). Annual wind roses were compiled in 2023 for each of the eight DOE-managed ORR meteorological towers (towers MT2, MT3, MT4, MT6, MT9, MT11, MT12, and MT13). The wind roses represent large-scale trends and should be used with discretion when estimating short-term variations.

B.3. Temperature and Precipitation

Temperature and precipitation normals (1991–2020) and extremes (1948–2023) and their durations for the city of Oak Ridge and ORNL are summarized in Table B.1. Decadal temperature and precipitation averages for five decades (1970s–2010s) are provided in Table B.2. Hourly freeze data (1985–2023) are given in Table B.3.

Overall, at ORNL, 2023 was 0.1°C warmer than normal compared with the 1991–2020 Oak Ridge base period, and precipitation was 16 percent below normal compared with the 1991–2020 mean.

B.3.1. Recent Climate Change with Respect to Temperature and Precipitation

Table B.2 presents a decadal analysis of temperature patterns from 1970 to 2019. In general, temperatures in the Oak Ridge area rose from the 1970s to the 1990s and have nearly stabilized since the 1990s. Based on these average decadal temperatures, temperatures rose 1.2°C between 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 past five was the 2000s at 15.2°C (59.4°F), although temperatures in the 2010s were virtually the same (15.2°C or 59.4°F). More detailed analysis reveals that these temperature changes have been neither linear nor equal with respect to the seasons.

January and February average temperatures increased by about 2.5°C from the 1970s to the 1990s and have declined by just over 1°C since the 1990s. The observed peak in the 1990s may be associated with the effects of the AMO, other natural effects, and/or anthropogenic effects. The Arctic has seen the largest increase in temperatures anywhere in the Northern Hemisphere over the past 30 years, and this increase has a corresponding effect on Oak Ridge temperatures in winter because of the influx of Arctic air masses.

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 these months. However, changes to average December temperatures have not been as dramatic as those in January and February. 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 6.0°C by the 2010s.

Compared with the 1970s, temperatures have warmed 1.0°C, 1.5°C, and 2.1°C during the climatological spring months of March, April, and May, respectively. However, most of the warming in March and April did not occur until the 2000s. The tendency toward warmer springs has slightly lengthened the growing season.

Summer months (June, July, and August) were 1.8°C, 1.3°C, and 0.9°C warmer on average, respectively, in the 2010s than in 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 1.0°C since the 2000s. Warming for June and July has virtually stopped since the 2000s.

Climatological fall months (September, October, and November) generally had the smallest average temperature increases (0.9°C, 1.3°C, and 0.1°C, respectively) since the 1970s. In fact, average temperatures in September and October have remained fairly consistent since the 1990s, and November has not shown a clear trend across the decades since the 1970s.

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 warmer than 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. Beginning with the 2020 ASER, the base period used to determine the mean annual temperature was updated from 1981–2010 to 1991–2020. The mean annual temperature increased by about 0.6°C, mainly because the cooler 1980s values were eliminated.

Decadal precipitation averages suggest some important changes in precipitation patterns in Oak Ridge from the 1970s to 2010s. Although overall decadal precipitation averages have remained between about 48 and 60 in. annually, some decadal shifts were observed in monthly and seasonal patterns of rainfall. During winter (December, January, and February), precipitation remained fairly constant after the 1970s.

However, February precipitation in the 2010s (and for winter overall after the 2000s) increased significantly. Spring precipitation (March, April, and May) declined about 20 percent after the 1970s. Summer (June, July, and August) precipitation changes are mixed. June values changed little between the 1970s and the 2010s, but July values increased by about 20 percent, and August values declined by about 20 percent. Similar patterns were observed for the fall months. During the 2010s, September precipitation values increased by about 10 percent compared with the 1970s, whereas October values decreased by about 10 percent. Little change occurred in precipitation for November. Overall, annual average precipitation in the 2010s was about 3 percent less than it was in the 1970s (59.68 vs. 58.18 in.). Also, precipitation values in the 1980s and 2000s were 10 to 20 percent less than those in the 2010s, and precipitation levels in the 1990s were similar to levels observed in the 2010s.

The increase in winter temperatures since the 1970s has affected monthly and annual snowfall amounts. 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 9.8 cm (3.9 in.) per year. This decrease seems to have occurred largely since the mid-1990s. January and February temperatures cooled slightly in the 2010s compared with the 2000s, which seems to have reversed the decrease in snowfall slightly, with annual averages of 13.2 cm (5.2 in.) during the 2010s. Concurrent with the overall decrease in snowfall, the annual number of hours of subfreezing weather generally declined after 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.

Table B.3 presents the number of hours of subfreezing temperatures in Oak Ridge for each year from 1985 to 2023. During the mid- to late 1980s, there were about 900 to 1,000 h of subfreezing temperatures during a typical year. In recent years, the value has fallen to about 600 to 700 h, although higher values have occurred relatively recently (e.g., 1,123 h in 2010). However, in some years in the 2010s, only 350 to 500 h of subfreezing weather were observed.

B.4. Moisture

ORR's humid environment results in frequent saturation of the surface layer, especially at night. Average annual relative humidity at ORNL (tower MT2) is 75.4 percent (2015–2021) at 2 m above ground level and 72.9 percent at 15 m above the ground. The average annual absolute humidity, a measure of the actual amount of water vapor (moisture) in the air regardless of the air's temperature, for MT2 is 10.3 g/m^3 at both 2 and 15 m above ground level. This value varies greatly throughout the year, ranging from a monthly minimum of about 4.7 g/m^3 during winter to a maximum of about 16.9 g/m^3 during summer.

Table B.1. Climate normals (1991–2020) and extremes (1948–2023) for ORNL

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Temperature, °C													
30-year average max	8.8	11.4	16.5	21.9	26.2	29.8	31.4	31.2	28.1	22.2	15.4	10.3	21.1
2023 average max	11.0	14.7	16.5	30.0	23.4	26.1	29.0	28.5	26.9	21.4	16.3	11.2	21.3
75-year record max	25	27	30	33	35	41	41	39	39	35	28	26	41
30-year average min	-1.5	0.2	3.9	5.8	13.4	17.8	20.1	19.5	15.9	9.1	3.0	0.3	9.0
2023 average min	0.5	3.4	2.5	6.1	13.9	15.9	20.0	19.9	16.0	9.3	3.3	0.9	9.3
75-year record min	-27	-25	-17	-7	-1	4	9	10	1	-6	-16	-22	-27
30-year average	3.5	5.8	10.2	13.2	19.7	23.7	25.6	25.2	21.8	15.5	9.1	5.2	14.9
2023 average	5.5	8.7	9.4	13.5	18.8	20.8	24.0	23.6	20.7	14.6	9.3	5.7	14.6
2023 departure from average	3.8	4.7	0.6	1.8	-1.2	-2.9	-1.6	-1.6	-1.1	-0.9	0.2	0.5	0.1
30-year average heating degree days, °C													
	451	351	252	110	31	1	0	0	9	101	270	399	1,974
30-year average cooling degree days, °C													
	0	0	7	18	80	170	235	221	120	22	1	0	874
Precipitation, mm													
30-year average	132.4	138.7	129.8	131.6	106.5	113.1	141.5	84.6	100.4	80.0	120.7	138.5	1,417.8
2023 totals	174.2	139.5	136.1	74.9	64.3	179.8	95.5	134.4	20.8	7.62	48.5	142.0	1,217
2023 departure from average	41.8	0.8	6.3	-56.7	-42.2	66.7	-46.0	49.8	-79.6	-72.38	-72.2	3.5	-200.2
75-year max monthly	337.2	384.7	311.0	356.5	271.9	283	489.6	265.8	257.6	203.8	310.5	321.2	1,939.4
75-year max 24 h	108.0	131.6	120.4	158.5	112.0	94.0	124.8	190.1	160.1	67.6	130.1	130.1	190.1
75-year min monthly	23.6	21.3	54.1	46.2	20.3	13.5	31.3	13.7	Trace	Trace	34.8	17.0	911.4
Snowfall, in.													
30-year average	4.6	5.1	2	0	0	0	0	0	0	0	2.5	2.5	14.5
2023 totals	Trace	0	0	0	0	0	0	0	0	0	0	Trace	Trace
75-year max monthly	24.4	43.7	53.4	15	Trace	0	0	0	0	Trace	16.5	53.4	105.2
75-year max 24 h	21.1	28.7	30.5	13.7	Trace	0	0	0	0	Trace	16.5	30.5	30.5

Table B.1. Climate normals (1991–2020) and extremes (1948–2023) for ORNL (continued)

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Days w/temp													
30-year max ≥ 32°C	0	0	0	0.1	1.5	7.7	14.4	12.7	4.9	0.1	0	0	41.4
2023 max ≥ 32°C	0	0	0	0	0	0	4	4	0	0	0	0	8
30-year min ≤ 0°C	19.8	15.4	8.7	1.8	0.1	0	0	0	0	0.9	10.3	16.5	73.5
2023 min ≤ 0°C	16	9	10	2	0	0	0	0	0	0	8	14	90
30-year max ≤ 0°C	2.6	0.8	0.1	0	0	0	0	0	0	0	0	0.8	4.3
2023 max ≤ 0°C	0	0	0	0	0	0	0	0	0	0	0	0	0
Days w/precipitation													
30-year avg ≥ 0.01 in.	11.8	11.6	12.4	11.1	11.5	11.4	12.3	9.8	8.1	8.3	9.2	12.2	129.7
2023 days ≥ 0.01 in.	15	14	9	9	8	13	12	12	4	3	6	10	115
30-year avg ≥ 1.00 in.	1.7	1.4	1.4	1.5	1.1	1.2	1.6	0.9	1.2	1	1.7	1.7	16.4
2023 days ≥ 1.00 in.	0	1	1	1	0	3	2	2	0	0	1	1	11

Table B.2. Decadal climate change (1970–2019) for city of Oak Ridge/ORNL, with 2023 comparisons

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Temperature, °C													
1970–1979 avg max	6.6	9.7	15.6	21.4	24.8	28.5	30.0	29.7	26.8	20.8	14.5	10.0	19.9
1980–1989 avg max	6.9	10.2	15.9	21.0	25.6	29.8	31.6	30.7	27.1	21.3	15.6	8.6	20.3
1990–1999 avg max	9.4	12.3	16.2	21.9	26.2	29.7	32.1	31.4	28.4	22.6	15.2	10.4	21.3
2000–2009 avg max	8.8	11.2	17.0	21.4	25.8	29.8	30.8	31.4	27.6	21.8	15.9	9.8	21.0
2010–2019 avg max	8.1	11.2	16.3	22.6	26.8	30.2	31.2	30.8	28.5	22.3	15.1	11.4	21.2
1980s vs. 2010s	1.2	1.0	0.3	1.6	1.2	0.4	-0.2	0.0	1.4	1.0	-0.5	2.3	0.8
2000s vs. 2010s	-0.7	0.0	-0.8	1.2	1.0	0.4	0.5	-0.6	0.9	0.5	-0.8	1.1	0.2
2023 avg max	11.0	14.7	16.5	21.1	23.9	26.2	29.1	28.4	26.9	21.1	16.3	11.7	20.6
1970–1979 avg min	-3.4	-2.4	3.0	6.7	11.6	15.7	18.3	18.1	15.5	7.5	2.6	-0.8	7.7
1980–1989 avg min	-4.1	-2.1	1.7	6.0	11.4	16.2	19.0	18.4	14.4	7.5	3.1	-2.3	7.4
1990–1999 avg min	-0.9	0.0	2.9	7.2	12.5	17.2	20.0	18.9	15.1	8.2	2.2	0.1	8.6
2000–2009 avg min	-1.4	0.0	4.4	8.6	13.6	18.0	20.0	20.0	16.1	9.5	3.9	-0.4	9.4
2010–2019 avg min	-2.0	0.6	4.2	8.8	14.1	18.2	20.3	19.5	16.4	9.4	2.7	1.2	9.5
1980s vs. 2010s	2.0	2.6	2.5	2.7	2.7	2.1	1.3	1.1	2.0	2.0	-0.4	3.6	2.1

Table B.2. Decadal climate change (1970–2019) for city of Oak Ridge/ORNL, with 2023 comparisons (continued)

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
2000s vs. 2010s	-0.6	0.6	-0.2	0.1	0.5	0.4	0.3	-0.5	0.3	-0.1	-1.2	1.6	0.1
2023 avg min	0.5	3.4	2.5	6.1	13.9	15.9	20.0	19.8	16.0	9.3	3.3	0.8	9.3
1970–1979 avg	1.6	3.7	9.3	14.1	18.1	22.1	24.1	23.9	21.1	14.2	8.6	4.6	13.8
1980–1989 avg	1.4	4.1	8.8	13.5	18.5	23.0	25.3	24.6	20.8	14.4	9.4	3.1	13.9
1990–1999 avg	4.2	6.2	9.6	14.5	19.4	23.5	26.0	25.2	21.9	15.5	8.8	5.3	15.0
2000–2009 avg	3.7	5.6	10.7	15.3	19.7	23.9	25.4	25.7	21.9	15.6	9.9	4.7	15.2
2010–2019 avg	3.0	5.3	10.3	15.7	20.3	24.0	25.4	24.6	21.9	15.4	8.7	6.4	15.1
1980s vs. 2010s	1.5	1.8	1.5	2.1	1.8	0.9	0.1	0.2	1.2	1.1	-0.7	2.8	1.2
2000s vs. 2010s	-0.7	0.2	-0.4	0.3	0.6	0.0	0.0	-1.0	0.1	-0.2	-1.2	1.2	-0.1
2023 avg	5.5	8.7	9.4	13.5	18.8	20.8	24.0	23.6	20.7	14.6	9.3	5.7	14.6
Precipitation, mm													
1970–1979 avg	143.4	94.6	169.4	118.3	149.8	120.5	130.4	109.8	107.2	99.8	129.6	145.3	1,516.4
1980–1989 avg	100.4	109.1	112.6	88.8	110.6	84.1	120.4	82.6	108.9	79.8	128.0	107.6	1,236.2
1990–1999 avg	141.4	136.5	149.0	126.3	113.4	110.0	134.8	83.6	71.9	67.3	109.8	161.0	1,429.4
2000–2009 avg	116.9	121.8	115.6	125.0	117.8	95.2	138.9	78.4	108.8	74.0	121.4	124.4	1,333.4
2010–2019 avg	130.1	146.6	117.4	131.9	93.8	132.4	156.8	92.5	114.1	91.0	128.0	151.7	1,478.2
1980s vs. 2010s	29.5	37.6	4.6	42.9	-16.8	15.2	36.3	9.9	5.3	11.2	0.0	44.3	239.3
2000s vs. 2010s	13.2	24.9	1.7	6.9	24.1	13.5	17.8	14.0	5.3	17.0	6.7	27.2	146.9
2023 totals	174.2	139.5	136.1	74.9	64.3	179.8	95.5	134.4	20.8	7.6	48.5	142.0	1,217.0
Snowfall, cm													
1970–1979 avg	11.1	12.5	4.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.5	4.4	35.1
1980–1989 avg	11.4	8.8	2.2	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	32.8
1990–1999 avg	6.9	7.8	8.1	Trace	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.1	10.9
2000–2009 avg	2.1	4.5	Trace	Trace	0.0	0.0	0.0	0.0	0.0	0.0	Trace	1.7	8.3
2010–2019 avg	5.3	6.4	0.3	Trace	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.4	13.2
1980s vs. 2010s	-5.2	-1.8	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	-2.8	-12.4
2000s vs. 2010s	3.6	2.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	6.6
2023 totals	Trace	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Trace	Trace

Table B.3. Hourly subfreezing temperature data for Oak Ridge, Tennessee, 1985–2023[a] *(Hours at or below 0°C, −5°C, −10°C, 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	1,399	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	1,190	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	1,029	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	1,123	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

Table B.3. Hourly subfreezing temperature data for Oak Ridge, Tennessee, 1985–2023 (continued)[a] *(Hours at or below 0°C, −5°C, −10°C, 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
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	146	46	1	0	46	0	0	0	80	9	0	5	0	0	0	0	0	93	11	0	90	0	0	0	466	66	1	0
2020	124	14	0	0	102	11	0	0	20	1	0	12	0	4	0	0	0	30	0	0	210	49	11	0	502	75	11	0
2021	151	1	0	0	144	33	0	0	34	0	0	31	0	0	0	0	0	121	0	0	70	0	0	0	551	34	0	0
2022	271	45	0	0	126	3	0	0	37	11	0	3	0	0	0	8	0	59	3	0	170	75	36	13	674	137	36	13
2023	67	0	0	0	31	3	0	0	53	5	0	0	0	0	0	0	0	77	10	0	130	1	0	0	358	19	0	0
Avg	241	75	17	2	151	33	6	1	61	6	0	10	0	0	0	6	0	69	4	0	184	37	5	1	723	156	28	4

[a] *Source: 1985–2014 National Oceanic and Atmospheric Administration, Atmospheric Turbulence and Diffusion Division, KOQT Station, Automated Surface Observing System; 2015–2023 ORNL, Tower "D." (For much of 2023, data from Tower "B" were used instead of data from Tower "D.")*

B.5. Severe Weather

On average, thunderstorms and associated lightning occur in the Oak Ridge area at a rate of 48 days per year, with a monthly maximum of about 11 days occurring in July. About 40 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. There were just over 40 total thunderstorm days in 2023.

Hailstorms are infrequent on ORR and typically occur in association with severe thunderstorms. Hailstorms are usually caused by high-altitude thunderstorm updrafts, which propel water droplets above the freezing level. Some hail events have been known to occur in association with nonthunder 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 0.75 in.). From 1961 through 1990, about 6 hail events (with hailstones larger than about 2 cm) were documented 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.

A tornado outbreak occurs in East Tennessee about once every 3 to 6 years on average. The Fujita Tornado Scale, usually referred to as the F-Scale, was developed in 1973 to classify tornadoes based on the resulting damage. The scale ranges from F0 (minimal damage) to F5 (incredible damage). The version used today—the Enhanced Fujita Scale— went into effect in 2007 and ranges from EF0 tornadoes with winds of 65 to 85 mph to EF5 tornadoes with winds exceeding 200.0 mph. Tornado indices from the National Weather Service in Morristown, Tennessee, show that since 1950, three tornadoes have been documented within 10 km (6 miles) of ORNL: two F0 tornadoes and one F3 (severe damage) tornado. The 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 is the only documented tornado that has occurred within ORR.

Eleven additional tornadoes have been documented since 1950 within 20 km (12 miles) of ORNL, ranging in intensity from F0/EF0 to F2/EF2. The most recent of these was an EF2 that occurred during the afternoon of August 7, 2023, and touched down just west of Pellissippi Parkway before crossing the road and traversing east for a track totaling 6.1 km (3.8 miles). Just days prior, a brief EF0 tornado spun up along Highway 70 in Oral, Tennessee, in Roane County. Both tornadoes formed within passing squall lines, which produced widespread high winds and associated damage across the local area. The remaining tornadoes 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.

The annual probability that a tornado will strike any location in a grid square can 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 this calculation is greatly affected by the assumed path area of a tornado. In total, about 24 tornadoes have been documented within 35 km (22 miles) of ORNL since 1950.

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 during times of 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, which are downwind oscillations that result from terrain-induced disruption within the horizontal flow. Like water flowing over a boulder, when air is perpendicular to a stationary boundary (e.g., the Cumberland or Smoky Mountains), it tends to stay at the same altitude or sink in a stable air mass. This causes a "ripple" or "wave" on the lee side of the terrain. This effect on mountain-wave formation may be important to the impact that the nearby Cumberland Mountains could 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 because of direct insolation (i.e., exposure to the sun's rays) on the cloud tops. Warming may also occur within the clouds as latent energy, which is released because of the condensation of moisture. Surface air underlying the clouds may remain relatively cool because 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 radiational cooling of fog or low stratus decks has also been observed to help modify stability in the surface layer (Whiteman et al. 2001). This occurs because the emittance of long-wave radiation further cools the surface layer and thus strengthens the associated inversion.

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 in turn is influenced by the large-scale weather-related pressure differences from one location to another (gradient). Ridge-and-valley terrain may significantly block such winds and their associated mechanical energy (Carlson and Stull 1986). Consequently, radiational cooling at the surface is enhanced because less wind energy is available to remove chilled air.

Stable boundary layers also exhibit intermittent turbulence, which is associated with the above factors. The process results from interactions 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 increases 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. Because 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 were compiled for all ORR tower sites for 2023. The wind roses reveal that unstable conditions and deep mixing depths are associated with less channeling of winds and that stable conditions and shallow mixing depths tend to promote channeled flow.

B.7. References

Birdwell 1996. Birdwell, K. R., "A Climatology of Winds over a Ridge and Valley Terrain within the Great Valley of Eastern Tennessee." Master's thesis, Department of Geosciences, Murray State University, Murray, Kentucky.

Birdwell 2011. Birdwell, K. R., "Wind Regimes in Complex Terrain of the Great Valley of Eastern Tennessee." Doctoral dissertation, Department of Geography, University of Tennessee, Knoxville, Tennessee.

Carlson and Stull 1986. Carlson, M. A., and R. B. Stull, "Subsidence in the Nocturnal Boundary Layer." *Journal of Climate and Applied Meteorology* **25**, 1088–99.

Dutton 2021. Dutton, J., "What is the Pacific Decadal Oscillation (PDO)?" World Climate Service. https://www.worldclimateservice.com/2021/09/01/pacific-decadal-oscillation/.

Eckman 1998. Eckman, R. M., "Observations and Numerical Simulations of Winds within a Broad Forested Valley." *Journal of Applied Meteorology* **37**, 206–19.

Ineson et al. 2011. Ineson, S., A. A. Scaife, J. R. Knight, J. C. Manners, N. J. Dunstone, L. J. Grey, and J. D. Haigh, "Solar Forcing of Winter Climate Variability in the Northern Hemisphere." *Nature Geoscience* **4,** 753–57.

Kossman and Sturman 2002. Kossman, M., and A. P. Sturman, "Pressure Driven Channeling Effects in Bent Valleys." *Journal of Applied Meteorology* **42**, 151–58.

Lewellen and Lewellen 2002. Lewellen, D. C., and W. S. Lewellen, "Entrainment and Decoupling Relations for Cloudy Boundary Layers." *Journal of the Atmospheric Sciences* **59**, 2966–86.

Monti et al. 2002. Monti, P., H. J. S. Fernando, M. Princevac, W. C. Chan, T. A. Kowalewski, and E. R. Pardyjak, "Observations of Flow and Turbulence in the Nocturnal Boundary Layer over a Slope." *Journal of the Atmospheric Sciences* **59**, 2513–34.

NOAA, n.d., "Wind Roses - Charts and Tabular Data." National Oceanic and Atmospheric Administration Climate.gov. Retrieved January 13, 2024, from https://www.climate.gov/maps-data/dataset/wind-roses-charts-and-tabular-data.

Van De Weil et al. 2002. Van De Weil, B. J. H., A. F. Moene, R. J. Ronda, H. A. R. De Bruin, and A. A. M. Holtslag, "Intermittent Turbulence and Oscillations in the Stable Boundary Layer over Land. Part II: A System Dynamics Approach." *Journal of the Atmospheric Sciences* **59**, 2567–81.

Whiteman 2000. Whiteman, C. D., *Mountain Meteorology: Fundamentals and Applications*. Oxford University Press, New York.

Whiteman et al. 2001. Whiteman, C. D., S. Zhong, W. J. Shaw, J. M. Hubbe, and X. Bian, "Cold Pools in the Columbia River Basin." *Weather and Forecasting* **16**, 432–47.

C

Appendix C Reference Standards and Data for Water

Table C.1. Reference standards for radionuclides in water

Parameter[a]	National primary drinking water standard[b]	DCS[c]
^{241}Am		740
^{214}Bi		1,000,000
^{109}Cd		42,000
^{143}Ce		210,000
^{60}Co		14,000
^{51}Cr		3,800,000
^{137}Cs		4,100
^{155}Eu		1,000,000
Alpha particles[d,e]	15	
Beta particles and photon emitters (mrem/year)[e]	4	
^{3}H Tritated Water		2,600,000
^{3}H Organic Bound Tritium		1,000,000
^{131}I		2,800
^{40}K		16,000
^{237}Np		1,400
^{234}Pa		300,000
^{238}Pu		430
$^{239/240}Pu$		400
^{226}Ra		280
^{228}Ra		73
^{226}Ra and ^{228}Ra combined[e]	5	
^{106}Ru		19,000
^{90}Sr		1,700
^{99}Tc		390,000
^{228}Th		830
^{230}Th		720
^{232}Th		620
^{234}Th		84,000
^{234}U		1,200

Table C.1. Reference standards for radionuclides in water (continued)

Parameter[a]	National primary drinking water standard[b]	DCS[c]
^{235}U		1,300
^{236}U		1,300
^{238}U		1,400
Uranium, total (ug/L)[e]	30	

[a] Only the radionuclides included in the Oak Ridge Reservation monitoring programs are listed. Unless labeled otherwise, units are pCi/L.

[b] 40 Code of Federal Regulations 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-1196-2022, December 2022.

[d] Including ^{226}Ra and excluding radon and uranium.

[e] Carcinogenic pollutant (EPA uses a 10^{-6} level to determine an increased risk of cancer)

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		3.0	3.0	6, 9
Acrylonitrile (c)				0.51, 2.5
Alachlor	2 (E1, T)			
Aldicarb[c]	3 (E1)			
Aldicarb sulfone[c]	2 (E1)			
Aldicarb sulfoxide[c]	4 (E1)			
Aldrin (c)		3.0	–	0.00049, 0.00050
Aluminum	50 to 200 (E2)			
Anthracene				8,300, 40,000
Antimony	6 (E1, T)			5.6, 640
Arsenic (c)	10 (E1, T)			10.0, 10.0
Arsenic(III)		340[d]	150[d]	
Asbestos	7 million fibers/L (MFL) (E1)			
Atrazine	3 (E1, T)			
Barium	2,000 (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 (PAHs) (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

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	
g-BHC (Lindane) (b)	0.2 (E1, T)	0.95	–	0.98, 1.8
Bis(2-chloroethyl) ether (c)				0.30, 5.3
Bis(2-chloro-isopropyl) ether				1,400, 65,000
Bis(2-ethylhexyl) phthalate (Di (2-ethylhexyl) phthalate) (c)	6 (E1, T)			12, 22
Bis (Chloromethyl) ether (c)				0.0010, 0.0029
Bromate	10 (E1)			
Bromoform (c)				43, 1,400
Butyl Benzyl Phthalate (BBP) (c)				1,500, 1,900
Cadmium	5 (E1, T)	1.8[e]	0.72[e]	
Carbaryl		2.1	2.1	
Carbofuran	40 (E1, T)			
Carbon tetrachloride (c)	5 (E1, T)			2.3, 16
Chlordane (b) (c)	2 (E1, T)	2.4	0.0043	0.0080, 0.0081
Chloride	250,000 (E2)			
Chlorine (TRC)	4,000 (E1)	19	11	
Chlorine dioxide (as Cl_2)	800 (E1)			
Chlorite	1,000 (E1)			
Chloramines (as Cl_2)	4,000 (E1)			
Chlorobenzene (Monochlorobenzene)	100 (E1, T)			130, 1,600
Chlorodibromomethane (Dibromochloromethane) (c)				4.0, 130
Chloroform (c)				57, 4,700
2-Chloronaphthalene				1,000, 1,600
2-Chlorophenol				81, 150
Chlorpyrifos		0.083	0.041	
Chromium (total)	100 (E1, T)			
Chromium(III)		570[e]	74[e]	
Chromium(VI)		16[d]	11[d]	
Chrysene (c)				0.038, 0.18
Coliforms	630/100 mL (geometric mean) (T); no more than 5% of samples per month can be positive for total coliforms (E1)	630/100 mL, *E. coli* (geometric mean); 2880/100 mL, maximum, *E. coli* (single sample) 630/100 mL, *E. coli* (geometric mean); 2880/100 mL, maximum, *E. coli* (single sample)		126/100 mL (geometric mean), *E. coli;* 487/100 mL, maximum lakes/ reservoirs/state scenic river/Exceptional Tennessee Water/ Outstanding Natural Resource Water, *E. coli;* 941/100 mL, maximum, other water bodies, *E. coli*

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	
Color	15 color units (E2)			
Copper	1,300 (E1 "Action Level") 1,000 (E2)	13[e]	9.0[e]	
Cyanide (as free cyanide)	200 (E1, T)	22[f]	5.2[f]	140, 140
2,4-D (Dichlorophenoxyacetic acid)	70 (E1, T)			
4,4'-DDD (b) (c)				0.0031, 0.0031
4,4'-DDE (b) (c)				0.0022, 0.0022
4,4'-DDT (b) (c)		1.1	0.001	0.0022, 0.0022
Dalapon	200 (E1, T)			
Demeton		–	0.1	
Diazinon		0.17	0.17	
Dibenz(a,h)anthracene (c)				0.038, 0.18
1,2-dibromo-3-chloropropane (DBCP) (c)	0.2 (E1, T)			
1,2-Dichlorobenzene (*ortho*-)	600 (E1, T)			420, 1,300
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, 7,100
Cis-1,2-Dichloroethylene	70 (E1, T)			
trans 1,2-Dichloroethylene	100 (E1, T)			140, 10,000
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)			
Dinoseb	7 (E1, T)			
Dimethyl phthalate				270,000, 1,100,000
Dimethylphenol				380, 850
Di-n-butyl phthalate				2,000, 4,500
Dinitrophenols (DNP)				69, 5,300
2,4-Dinitrotoluene (DNT) (c)				1.1, 34
Dioxin (2,3,7,8-TCDD) (b) (c)	3 E-5 (E1, T)			0.000001[g], 0.000001[g]
Diquat	20 (E1, T)			
1,2-Diphenylhydrazine (Hydrazobenzene) (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)			

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	
Endrin	2 (E1, T)	0.086	0.036	0.059, 0.06
Endrin aldehyde				0.29, 0.30
Ethylbenzene	700 (E1)			530, 2,100
Ethylene dibromide (1,2-Dibromoethane, EDB)	0.05 (E1, T)			
Fluoranthene				130, 140
Fluorene				1,100, 5,300
Fluoride	4,000 (E1) 2,000 (E2)			
Foaming agents	500 (E2)			
Glyphosate	700 (E1, T)			
Guthion		–	0.01	
Haloacetic acids (HAA5) (c)	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
Hexachlorocyclohexane-Technical (HCH) (b)(c)				0.123, 0.414
Hexachlorocyclopentadiene	50 (E1, T)			40, 1,100
Hexachloroethane (c)				14, 33
Indeno(1,2,3-cd)Pyrene (c)				0.038, 0.18
Iron	300 (E2)			
Isophorone (c)				350, 9,600
Lead	5 (T) 15 (E1 "Action Level")	65[e]	2.5[e]	
Malathion		–	0.1	
Manganese	50 (E2)			
Mercury (b)	2 (T) 2 (E1 inorganic)	1.4[d]	0.77[d]	0.05, 0.051
Methoxychlor	40 (E1, T)	–	0.001	
Methyl bromide				47, 1,500
2-Methyl-4,6-dinitrophenol (4,6-Dinitro-O-cresol, DNOC)				13, 280
Methylene chloride (Dichloromethane) (c)	5 (E1, T)			46, 5,900
Nickel	100 (T)	470[e]	52[e]	610, 4,600
Nitrate as N	10,000 (E1,T)			
Nitrite as N	1,000 (E1, T)			
Nitrobenzene				17, 690
Nitrosamines				0.0008, 1.24
N-Nitrosodibutylamine (NDBA) (c)				0.063, 2.2

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	
N-Nitrosodiethylamine (NDEA) (c)				0.008, 2.4
N-Nitrosopyrrolidine (NPYR) (c)				0.16, 340
N-Nitrosodimethylamine (NDMA) (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 Numbers (E2)[h]			
Oxamyl (Vydate)	200 (E1, T)			
Parathion		0.065	0.013	
Pentachlorobenzene (b)				1.4, 1.5
Pentachlorophenol (c)	1 (E1, T)	19[i]	15[i]	2.7, 30
pH	6.5 to 8.5 units (E2) 6.0 to 9.0 units (T)	6.0 to 9.0 units for wadeable streams; 6.5 to 9.0 units for larger rivers, lakes, reservoirs, and wetlands		6.0 to 9.0 units
Phenol				10,000, 860,000
Picloram	500 (E1,T)			
Polychlorinated biphenyls (PCBs), total (b)(c)	0.5 (E1, T)	–	0.014	0.00064, 0.00064
Pyrene				830, 4,000
Selenium	50 (E1, T)			170, 4,200
Selenium (lentic)[j]		20	1.5[k]	
Selenium (lotic)[l]		20	3.1[k]	
Silver	100 (E2)	3.2[e]	–	
Simazine	4 (E1, T)			
Styrene	100 (E1, T)			
Sulfate	250,000 (E2)			
1,2,4,5-Tetrachlorobenzene (b)				0.97, 1.1
1,1,2,2-Tetrachloroethane (c)				1.7, 40
Tetrachloroethylene (Perchloroethylene, PCE) (c)	5 (E1, T)			6.9, 33
Thallium	2 (E1, T)			0.24, 0.47
Toluene	1,000 (E1, T)			1,300, 15,000
Total dissolved solids	500,000 (E2, T)			
Toxaphene (b)(c)	3 (E1, T)	0.73	0.0002	0.0028, 0.0028
Tributyltin (TBT)		0.46	0.072	
1,2,4-Trichlorobenzene (1,2,4-TCB)	70 (E1, T)			35, 70

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	
1,1,1-Trichloroethane (Methyl Chloroform)	200 (E1, T)			
1,1,2-Trichloroethane (c)	5 (E1, T)			5.9, 160
Trichloroethylene (TCE) (c)	5 (E1, T)			25, 300
2,4,5-Trichlorophenol				1,800, 3,600
2,4,6-Trichlorophenol (c)				14, 24
2,4,5 Trichlorophenoxyprioponic acid (2,4,5-TP, Silvex)	50 (E1, T)			
Trihalomethanes (total) (THMs) (c)	80 (E1)			
Vinyl chloride (c)	2 (E1, T)			0.25, 24
Xylenes (total)	10,000 (E1, T)			
Zinc	5,000 (E2)	120[e]	120[e]	7,400, 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 it is the only stream on ORR 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 the "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] *Administrative stay of the effective date.*

[d] *Criteria are expressed as dissolved.*

[e] *Criteria are expressed as dissolved and are a function of total hardness (mg/L). Criteria displayed correspond to a total hardness of 100 mg/L.*

[f] *Criteria may be applied as free cyanide if Standard Methods 4500-CN, 4500-CN G, or OIA-1677 are used.*

[g] *Total dioxin in the sum of the concentrations of all dioxin and dibenzofuran isomers after multiplication by Toxic Equivalent Factors.*

[h] *Threshold Odor Numbers (TON) are whole numbers that indicate how many dilutions it takes to produce odor-free water.*

[i] *Criteria are expressed as a function of pH; values shown correspond to a pH of 7.8.*

[j] *Lentic – Still water aquatic ecosystems such as ponds, lakes, or reservoirs.*

[k] *The numeric water criteria are applicable for all purposes, but for water quality assessment, fish tissue values may be used to confirm or refute impacts to aquatic life in accordance with and using values from EPA's Final Criterion: Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater (June 30, 2016).*

[l] *Lotic – Flowing water aquatic ecosystems such as streams and rivers.*

Acronyms and other definitions:

EPA = US Environmental Protection Agency

TDEC = Tennessee Department of Environment and Conservation

(b) = bioaccumuative parameter (TDEC)

(c) = carcinogenic pollutant (TDEC uses a 10^{-5} risk level and EPA uses a 10^{-6} level to determine an increased risk of cancer)

D

Appendix D National Pollutant Discharge Elimination System Noncompliance Summaries for 2023

D.1. East Tennessee Technology Park

The East Tennessee Technology Park program was 100 percent compliant with the numerical permit limits during 2023. ETTP's NPDES storm water permit in effect during 2023 (TN0002950) was issued on February 4, 2022, and became effective on April 1, 2022. Compliance was determined by more than 95 laboratory analyses, field measurements, and flow estimates.

D.2. Y-12 National Security Complex

The Y-12 National Security Complex was nearly 100 percent compliant with the NPDES permit limits in 2023. Approximately 4,100 data points were obtained from sampling required by the NPDES permit. Y-12's NPDES permit (TN0002968) was issued on August 5, 2022, and became effective on October 1, 2022. The new permit is currently under appeal in part, and settlement negotiations are ongoing.

D.3. Oak Ridge National Laboratory

In 2023, compliance with the Oak Ridge National Laboratory NPDES permit was determined by approximately 1,736 laboratory analyses and field measurements. ORNL wastewater treatment facilities achieved a numeric permit compliance rate of 99.9 percent in 2023. One *Escherichia coliform* exceedance occurred in June 2023 at X01 (Sewage Treatment Plant) due to an operational issue with the disinfection system ozone diffuser. The diffuser has since been fixed. A renewed NPDES permit was issued for ORNL in May 2019 from TDEC. Several conditions in the permit were appealed, and others were addressed in permit modifications issued in December 2022 and February 2023. Another minor modification was scheduled to become effective on March 1, 2023, but some conditions were appealed and remained unresolved in 2023. An NPDES permit renewal application was submitted to TDEC in June 2023, and until a new permit is issued, the February 2023 permit, which expired December 31, 2023, has been administratively extended.

E

Appendix E Radiation

This appendix presents basic information about radiation. The information is intended to serve as a basis for understanding the potential doses associated with releases of radionuclides from the Oak Ridge Reservation, not as a comprehensive discussion of radiation and its effects on the environment and on biological systems.

Radiation comes from natural and anthropogenic (human-produced) 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, as well as 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, as illustrated in Figure E.1.

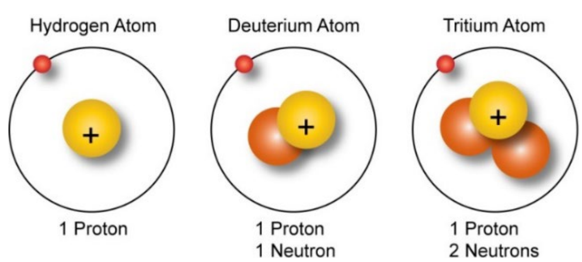


Figure E.1. The hydrogen atom and its isotopes

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, and some are radioactive. Radioactive isotopes are called radionuclides or radioisotopes. In an attempt to become stable, radionuclides emit energy in the form of rays or particles. This emission of energy 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 a form of energy that travels in waves. It comes from natural and anthropogenic sources and includes gamma rays, x-rays, ultraviolet light, and radio waves. Particulate radiation consists of particles that have mass and energy, such as alpha and beta particles. Radiation is also characterized as ionizing or nonionizing by its energy and the way it interacts with matter.

Ionizing Radiation

Normally an atom has an equal number of protons (positively charged) and electrons (negatively charged), but atoms can lose or gain electrons in a process known as ionization. Ionizing radiation removes bound electrons from an electrically neutral atom, leaving the atom with a net positive charge. Examples of ionizing radiation include alpha and beta particles, gamma rays, and x-rays (World Health Organization 2016).

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.

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 and is lower in energy than ionizing radiation (Department of Labor 2023). It includes the spectrum of ultraviolet light, visible light, infrared radiation, microwaves, radio waves, and other extremely low frequency fields. 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 2023).

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 exposure to radiation on the health of the environment and the public, the radiation must be measured. By quantifying the levels of exposure, its potential to cause damage may be estimated.

Activity

To determine the level of radiation in the environment, the rate of radioactive decay or activity is measured. The rate of decay varies widely among 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) nuclear disintegrations per second (dps). In the International System of Units, 1 dps equals 1 becquerel (Bq).

Absorbed Dose

The total amount of energy absorbed per unit mass of an exposed material as a result of exposure to radiation is expressed in a unit of measure known as a rad, short for "radiation absorbed dose." The amount of radiation, or number of rads, humans or biota are exposed to is used to estimate the effect of the absorbed energy and the potential biological damage that may occur. In the International System of Units, 100 rads equal 1 gray (Gy).

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, an abbreviation for "roentgen equivalent man." 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 rems; 1 millisievert (mSv) equals 100 mrem. The effective dose (ED) is the tissue-weighted sum of equivalent dose, which accounts for type of radiation absorbed via a radiation weighting factor in specified tissues or organs. The ED is based on tissue-weighting factors for 12 specific tissues or organs plus a weighting factor for the remaining organs and tissues. In addition, the ED is based on the recently developed lung model, gastrointestinal absorption fractions, and biokinetic models used for selected elements. Specific types of EDs are defined as follows (ICRP 2007):

- Committed ED – the weighted sum of the committed organ or tissue equivalent doses in the human body during the 50-year period following intake (70 years for children)
- Collective ED – the product of the mean ED for a population and the number of persons exposed

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 subsequently the people drinking the milk. 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

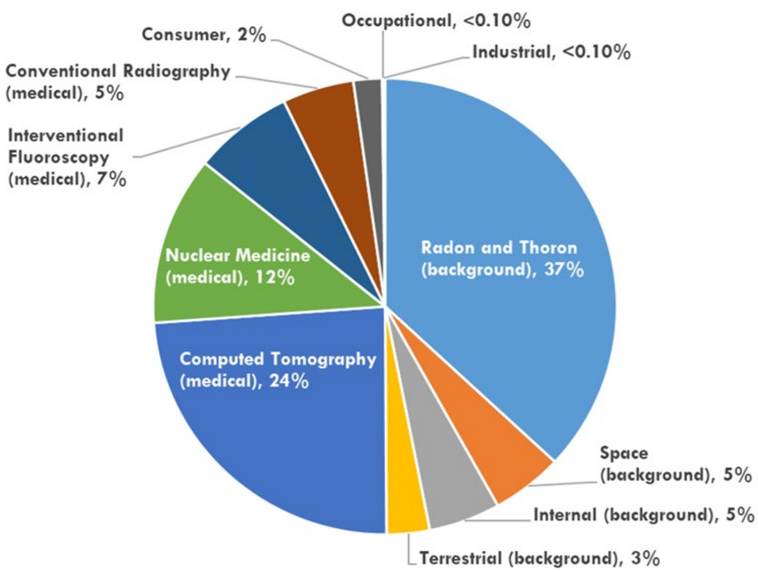
E.5. Radiation Sources and Doses

Basically, the process of radioactive decay generates radiant energy. People absorb some of the energy to which they are exposed, either from external radiation sources or internally deposited radionuclides. The amount of energy absorbed is reflected in an individual's dose. Whether radiation is natural or anthropogenic, 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 shows 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.



Source: NCRP 2009

Figure E.3. All exposure categories for collective effective dose for 2006

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 as the atmosphere becomes less dense. 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 Coasts, about 90 mrem (0.9 mSv) on the Colorado Plateau, and about 46 mrem (0.46 mSv) elsewhere in the United States (EPA 2024).

E.5.1.2. Internal Exposures

Radionuclides in the environment enter the body with the air people breathe and the foods they eat. They can also enter through an open wound. Natural radionuclides that can be inhaled and ingested include isotopes of uranium and their 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 to an individual 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 lungs 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, ^{232}Th, and the ^{238}U series. The primary source of ^{40}K in body tissues is food, primarily fruits and vegetables. Sources of radionuclides from the ^{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. Anthropogenic Radiation

In addition to background radiation, most people are exposed to anthropogenic sources of radiation such as 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).

Consumer Products

Some consumer products are sources of radiation. The radiation in these products—which includes 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 annual dose to an individual from consumer products and activities averages 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 0.03 percent). Television and display monitors, sewage sludge and ash, and self-illuminating signs contribute negligible doses (NCRP 2009).

Medical Sources

Radiation is an important tool in diagnostic medicine and treatment, which are the main sources of exposure to the public from anthropogenic 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, so not all organs are uniformly irradiated. Nuclear medicine examinations and treatments involve the internal administration of radioactive compounds, or radiopharmaceuticals, by injection, inhalation, consumption, or insertion. 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 internally administer radiopharmaceuticals, account for a significant portion of dose from anthropogenic 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.

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 these sources has been estimated at less than 1 mrem (0.01 mSv) per year (NCRP 1987).

E.6. References

Alter 1986. Alter, H. *A Glossary of Terms in Nuclear Science and Technology*. American Nuclear Society, La Grange Park, Illinois.

Department of Labor 2023. *OSHA Safety and Health Topics: Non Ionizing Radiation.* Retrieved May 14, 2023, from https://www.osha.gov/non-ionizing-radiation.

EPA 2024. *Calculate Your Radiation Dose.* US Environmental Protection Agency. Retrieved May 19, 2024, from https://www.epa.gov/radiation/calculate-your-radiation-dose.

ICRP 2007. *The 2007 Recommendations of the International Commission on Radiological Protection*. ICRP Publication 103. *Annals of the ICRP* 37 (2-4). International Commission on Radiological Protection, Ottawa, Canada.

ICRP 2008. *Nuclear Decay Data for Dosimetric Calculations.* ICRP Publication 107. *Annals of the ICRP* 38(3)*.* International Commission on Radiological Protection, Ottawa, Canada.

NCRP 1987. *Ionizing Radiation Exposure of the Population of the United States*. NCRP Report No. 93. National Council on Radiation Protection and Measurements, Bethesda, MD.

NCRP 2009. *Ionizing Radiation Exposure of the Population of the United States*. NCRP Report No. 160, National Council on Radiation Protection and Measurements, Bethesda, Maryland.

World Health Organization 2016. *Ionizing radiation, health effects and protective measures*. Retrieved May 14, 2023, from https://www.who.int/news-room/fact-sheets/detail/ionizing-radiation-health-effects-and-protective-measures.

F

Appendix F Chemicals

This appendix presents basic information about chemical risk assessment for carcinogens and noncarcinogens. The information is intended to serve as a basis for understanding the toxicity associated with possible releases from the Oak Ridge Reservation (ORR) and is not a comprehensive discussion of chemicals and their effects on human health and the environment.

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 into space. At the same time, we must be cautious to ensure uncontrolled and over-expanded use of chemicals does not endanger our own existence (Diamanti-Kandarakis et al. 2009, Duruibe et al. 2007, Li et al. 2018, Sunderland et al. 2019).

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 direct or indirect human actions. Building materials used in home construction 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 applying pesticides and fertilizers to soil. Other chemicals may have been transported long distances through the atmosphere from industrial sources and then deposited on soil or water.

F.2. Pathways of Chemicals from the Oak Ridge Reservation to the Public

Pathways are the routes or ways through which a person can encounter a chemical substance. Chemicals may be released to the air, soil, or 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 (intake of food, soil, or water), or dermal contact (touching soil or swimming in water). For example, fish that live in a river containing effluents may take in some of the chemicals present in the water. People eating 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. Toxicity

Toxicity refers to an adverse effect of a chemical on human health. Health effects from chemical exposures vary based on the chemical's toxicity. The toxic effect can be acute (a short-term, possible severe health effect) or chronic (a longer-term, persistent health effect). Although we ingest chemicals in food, water, and medications every day, toxic chemicals are typically nontoxic or harmless below certain concentrations or thresholds.

Chemical health effects due to toxicity are divided into two broad categories: adverse or systemic effects from noncarcinogens and cancer from carcinogens. The potential health hazards of noncarcinogens range from mild (e.g., skin irritation) to severe (e.g., death). Carcinogens cause or increase the incidence of malignant neoplasms or cancers. A chemical can have both carcinogenic and noncarcinogenic effects. Toxic effects can result from short-term or long-term chemical exposures.

Concentration limits or advisories are set by government agencies for some chemicals that are known or suspected to have adverse effects on human health. These concentration limits are used to calculate chemical doses that would not be harmful to individuals who are particularly sensitive to a chemical. These chemical doses are converted to slope factors to address carcinogenic risk and to reference doses to address noncarcinogenic hazards (Hayes and Kobets 2023)

F.3.1. Dose Terms for Carcinogens

A slope factor is a plausible upper-bound estimate of the probability of a response per daily dose of a chemical during a lifetime of exposure (70 years). The slope factor conservatively estimates the probability of cancer due to chemical exposure for an individual's lifetime to a particular concentration. Units are expressed as risk per dose in mg/kg-day.

A slope factor converts the estimated daily dose, averaged over a lifetime exposure, to the incremental risk of an individual developing cancer. Because it is unknown for most chemicals whether a threshold (an intake below which no adverse effect occurs) exists for carcinogens, units for carcinogens are set in terms of risk factors. The standard cancer benchmarks used by the US Environmental Protection Agency (EPA) range from 1 in 1,000,000 to 1 in 10,000 (i.e., 10^{-6} to 10^{-4}), depending on the subpopulation exposed. In other words, a certain chemical concentration in food or water could cause a risk of one additional cancer for every 1,000,000 (10^{-6} risk level) to 10,000 (10^{-4} risk level) exposed persons.

F.3.2. Dose Term for Noncarcinogens

A reference dose is an estimate of a daily chemical exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a period of exposure. Units are expressed as milligrams of chemical per kilogram of body weight per day (mg/kg-day). Reference dose values are derived from chemical intakes that resulted in no adverse effect or the lowest dose that showed an adverse effect in humans or laboratory animals.

Uncertainty factors are typically used in deriving reference doses. Uncertainty adjustments may be made to account for (1) interspecies variability in response when extrapolating from animal studies to humans; (2) response variability in humans; (3) uncertainty in estimating a no-effect level from a dose where effects were observed; (4) extrapolation from shorter duration studies to a full life-time exposure; and (5) data deficiencies (Dankovic et al., 2015). The use of uncertainty factors in deriving reference doses is thought to help protect sensitive human subpopulations.

F.3.3. Toxicity Value Sources

The slope factors and reference doses used for ORR calculations are selected from a tiered hierarchy system devised by EPA (EPA 2003). Values in the Integrated Risk Information System database, a Tier 1 toxicity value source, are considered to be validated and have undergone rigorous peer review and an EPA consensus review process. The EPA's Provisional Peer-Reviewed Toxicity Value database is a Tier 2 toxicity value source with values primarily derived for use in EPA's Superfund Program. Provisional Peer-Reviewed Toxicity Values are derived from a review of the relevant scientific literature using EPA methods, sources of data and guidance for value derivation. Tier 2 values have undergone rigorous peer review, but an EPA consensus review has not been performed. Tier 3 toxicity value sources include other sources of information and are used when Tier 1 or 2 values are not available for a contaminant. Multiple Tier 3 toxicity value sources are used on ORR including the Agency for Toxic Substances and Disease Registry Minimal Risk Levels, the EPA's Office of Pesticide Programs Human Health Benchmarks for Pesticides, EPA's Health Effects Summary Table, and other federal and state sources.

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. Chemical concentrations in liquids are typically expressed in milligrams or micrograms of chemical per liter of water (mg/L or µg/L, respectively); concentrations in solids, such as soil and fish tissue, are expressed in milligrams or micrograms of chemical per kilogram of sample material (e.g., mg/kg or µg/kg for soil or fish tissue).

The instruments used to measure chemical concentrations are sensitive; however, there are limits below which they cannot detect chemicals of interest. Concentrations 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. Concentrations that use these estimated values are indicated by the less-than symbol (<), which specifies that the value for a parameter could not be quantified at the analytical detection limit.

F.5. Risk Assessment Methodology

The methods for assessing the cancer risk and noncancer hazard resulting from exposure to a particular chemical are discussed in the following paragraphs.

Exposure Assessment

To estimate an individual's potential exposure via a specific exposure pathway, the daily dose of the chemical must be determined. For example, chemical dose (in units of mg of contaminant per kilogram of body weight per day) from drinking water and eating fish from the Clinch River is assessed in the following manner:

Clinch River surface water and fish tissue samples are analyzed to measure chemical contaminant concentrations. Estimated daily doses to the public are calculated by multiplying chemical concentrations measured in the samples by the surface water intake rate (liters/day) and fish ingestion rate (kg/day), respectively. The average daily intakes are then multiplied by the exposure duration (in years) and exposure frequency (days/year) and divided by an averaging time (365 days/year multiplied by a lifetime [70 years] for carcinogens or the exposure duration for noncarcinogens). The default exposure assumptions are conservative and, in many cases, may result in higher estimated daily doses than an individual would actually receive.

Calculation Method

Carcinogenic risk calculations use slope factors and daily doses averaged over a lifetime (70 years). To estimate the potential carcinogenic risk from ingestion of water and fish, the estimated average daily dose (mg/kg-day) is multiplied by the slope factor (risk per mg/kg-day), resulting in units of risk. As mentioned earlier, acceptable risk levels for carcinogens range from 10^{-6} (risk of developing cancer over a human lifetime is 1 in 1,000,000) to 10^{-4} (risk of developing cancer over a human lifetime is 1 in 10,000). Carcinogenic risks greater than 10^{-4} indicate a concern for adverse health effects or the need for further study.

Noncarcinogenic hazard calculations use reference doses and daily doses averaged over the exposure duration. To calculate the potential hazard from ingestion of water and fish, the estimated average daily dose (mg/kg-day) is divided by the RfD (mg/kg-day), resulting in a unitless value called a hazard quotient. Hazard quotient values less than 1 indicate an unlikely potential for adverse noncarcinogenic health effects; hazard quotient values greater than 1 indicate a concern for adverse health effects or the need for further study.

F.6. References

Dankovic et al. 2015. Dankovic, D.A, B. D. Naumann, A. Maier, M. L. Dourson, and L. S. Levy. "The Scientific Basis of Uncertainty Factors Used in Setting Occupational Exposure Limits." *Journal of Occupational and Environmental Hygiene*. 12:sup1, S55-S68.

Diamanti-Kandarakis et al. 2009. Diamanti-Kandarakis, E, J.P. Bourguignon, L.C. Giudice, R. Hauser, G.S. Prins, A.M. Soto, R.T. Zoeller, and A.C. Gore. "Endocrine-Disrupting Chemicals: An Endocrine Society Scientific Statement." Endocrine Reviews. 30(4), 293-342.

Duruibe et al. 2007. Duruibe, J.O., M.O.C. Ogwuegbu, and J.N. Egwurugwu. "Heavy metal pollution and human biotoxic effects." International Journal of the Physical Sciences. 2(5), 112-118.

EPA 2003. Human Health Toxicity Values in Superfund Risk Assessment. *OSWER Directive 9285.7-53*. December 5, 2003.

Hayes and Kobets 2023. Hayes, A.W. and T Kobets (Eds.) *Hayes' Principles and Methods of Toxicology.* CRC Press, Boca Raton, FL.

Li et al. 2018. Li, J.Y., H.H. Liu, and J.P. Chen. "Microplastics in freshwater systems: A review on occurrence, environmental effects, and methods for microplastic detection." Water Research. 137. 362-374.

Sunderland et al. 2019. Sunderland, E.M., X.C. Hu, C. Dassuncao, A.D. Tokranov, C.C. Wagner, and J.G. Allen. "A review of the pathways of human exposure to poly- and perfluoroalkyl substances (PFASs) and present understanding of health effects." Journal of Exposure Science and Environmental Epidemiology. 29(2), 131-147.

G

Appendix G Radiological Airborne Emissions at Oak Ridge National Laboratory

This appendix presents annual radioactive airborne emissions for ORNL in 2023. All data 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.

Table G.1. Radiological airborne emissions from all sources at ORNL, 2023 (Ci)[a]

Isotope	Inhalation Form[b]	Chemical Form	Stack								Total Minor Sources	ORNL Total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{225}Ac	M	particulate									3.09E-06	3.09E-06
^{226}Ac	M	particulate									1.07E-09	1.07E-09
^{227}Ac	M	particulate									6.5E-07	6.5E-07
^{228}Ac	M	particulate									1.28E-20	1.28E-20
^{105}Ag	M	particulate									6.25E-21	6.25E-21
^{106m}Ag	M	particulate									2.05E-25	2.05E-25
^{108}Ag	B	unspecified									1.4E-18	1.4E-18
^{108m}Ag	M	particulate									3.17E-14	3.17E-14
^{110}Ag	B	unspecified									5.39E-12	5.39E-12
^{110m}Ag	M	particulate									6.6E-08	6.6E-08
^{111}Ag	M	particulate									4.66E-08	4.66E-08
^{112}Ag	M	particulate									1.49E-09	1.49E-09
^{26}Al	M	particulate									2.99E-09	2.99E-09
^{241}Am	M	particulate	4.49E-06	4.24E-07		4.91E-09			7.54E-07		2.72E-07	5.95E-06
^{241}Am	F	particulate			1.39E-07		6.73E-10	3.08E-07			2.2E-09	4.5E-07
^{242}Am	M	particulate									2.03E-10	2.03E-10
^{242m}Am	M	particulate									2.04E-10	2.04E-10
^{243}Am	M	particulate									3.14E-09	3.14E-09
^{244}Am	M	particulate									1.23E-20	1.23E-20
^{245}Am	M	particulate									1.15E-19	1.15E-19
^{246m}Am	M	particulate									7.04E-24	7.04E-24
^{247}Am	B	unspecified									2.53E-57	2.53E-57
^{37}Ar	B	unspecified									1.92E-12	1.92E-12
^{39}Ar	B	unspecified									6.09E-04	6.09E-04
^{41}Ar	B	unspecified							9.59E+02	8.15E+01		1.04E+03
^{71}As	M	particulate									5.0E-49	5.0E-49
^{72}As	M	particulate									1.91E-38	1.91E-38
^{73}As	M	particulate									1.8E-16	1.8E-16
^{74}As	M	particulate									1.52E-17	1.52E-17

Table G.1. Radiological airborne emissions from all sources at ORNL, 2023 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								Total Minor Sources	ORNL Total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{195}Au	M	particulate									2.33E-21	2.33E-21
^{128}Ba	M	particulate									4.79E-84	4.79E-84
^{131}Ba	M	particulate									2.43E-23	2.43E-23
^{133}Ba	M	particulate									3.58E-13	3.58E-13
^{137m}Ba	B	unspecified									2.69E-07	2.69E-07
^{139}Ba	M	particulate							6.08E-01			6.08E-01
^{140}Ba	M	particulate							7.52E-04		7.59E-09	7.52E-04
^{7}Be	M	particulate	3.19E-07	2.62E-07		2.98E-06					2.61E-06	6.17E-06
^{7}Be	S	particulate			3.0E-06						1.26E-07	3.13E-06
^{10}Be	M	particulate									6.29E-16	6.29E-16
^{206}Bi	M	particulate									3.21E-09	3.21E-09
^{207}Bi	M	particulate									9.72E-19	9.72E-19
^{208}Bi	B	unspecified									1.49E-19	1.49E-19
^{210}Bi	M	particulate									1.27E-18	1.27E-18
^{210m}Bi	M	particulate									8.17E-20	8.17E-20
^{211}Bi	B	unspecified									4.14E-08	4.14E-08
^{212}Bi	M	particulate									1.9E-11	1.9E-11
^{213}Bi	M	particulate									2.08E-18	2.08E-18
^{214}Bi	M	particulate									8.15E-19	8.15E-19
^{245}Bk	M	particulate									1.49E-44	1.49E-44
^{247}Bk	M	particulate									1.65E-24	1.65E-24
^{248}Bk	M	particulate									1.21E-20	1.21E-20
^{249}Bk	M	particulate									1.39E-11	1.39E-11
^{250}Bk	M	particulate									5.14E-21	5.14E-21
^{251}Bk	B	unspecified									1.37E-23	1.37E-23
^{77}Br	M	particulate									1.46E-46	1.46E-46
^{82}Br	M	particulate									6.58E-10	6.58E-10
^{11}C	G	dioxide								9.97E+03		9.97E+03
^{14}C	M	particulate									3.3E-09	3.3E-09
^{41}Ca	M	particulate									7.07E-12	7.07E-12

Table G.1. Radiological airborne emissions from all sources at ORNL, 2023 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total Minor Sources	ORNL Total
^{45}Ca	M	particulate									1.41E-12	1.41E-12
^{47}Ca	M	particulate									2.13E-19	2.13E-19
^{109}Cd	M	particulate									3.57E-12	3.57E-12
^{111m}Cd	B	unspecified									7.57E-44	7.57E-44
^{113}Cd	M	particulate									4.06E-16	4.06E-16
^{113m}Cd	M	particulate									9.47E-11	9.47E-11
^{115}Cd	M	particulate									1.16E-08	1.16E-08
^{115m}Cd	M	particulate									1.41E-09	1.41E-09
^{134}Ce	M	particulate									1.28E-05	1.28E-05
^{139}Ce	M	particulate									1.36E-06	1.36E-06
^{141}Ce	M	particulate									2.38E-05	2.38E-05
^{143}Ce	M	particulate									6.73E-09	6.73E-09
^{144}Ce	M	particulate									6.41E-05	6.41E-05
^{248}Cf	M	particulate									3.29E-20	3.29E-20
^{249}Cf	M	particulate									1.76E-17	1.76E-17
^{250}Cf	M	particulate									3.23E-16	3.23E-16
^{251}Cf	M	particulate									1.97E-18	1.97E-18
^{252}Cf	M	particulate							9.05E-10		1.29E-08	1.38E-08
^{252}Cf	F	particulate									6.87E-11	6.87E-11
^{253}Cf	M	particulate									1.82E-21	1.82E-21
^{254}Cf	M	particulate									8.69E-22	8.69E-22
^{36}Cl	M	particulate									3.01E-13	3.01E-13
^{240}Cm	M	particulate									1.64E-19	1.64E-19
^{241}Cm	M	particulate									1.87E-14	1.87E-14
^{242}Cm	M	particulate									5.09E-07	5.09E-07
^{243}Cm	M	particulate	5.0E-08	1.33E-08		1.0E-08			1.35E-08		4.49E-10	8.72E-08
^{243}Cm	F	particulate			6.32E-09		1.1E-09				4.28E-10	7.85E-09
^{244}Cm	M	particulate	5.0E-08	1.33E-08		1.0E-08			1.35E-08		3.08E-06	3.16E-06
^{244}Cm	F	particulate			6.32E-09		1.1E-09				4.28E-10	7.85E-09
^{245}Cm	M	particulate									4.47E-11	4.47E-11

Table G.1. Radiological airborne emissions from all sources at ORNL, 2023 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								Total Minor Sources	ORNL Total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{246}Cm	M	particulate									1.18E-12	1.18E-12
^{247}Cm	M	particulate									1.3E-09	1.3E-09
^{248}Cm	M	particulate									3.79E-11	3.79E-11
^{249}Cm	M	particulate									5.67E-24	5.67E-24
^{250}Cm	M	particulate									1.52E-22	1.52E-22
^{56}Co	M	particulate									2.17E-15	2.17E-15
^{57}Co	M	particulate									8.71E-12	8.71E-12
^{58}Co	M	particulate									2.94E-11	2.94E-11
^{60}Co	M	particulate									6.93E-07	6.93E-07
^{60}Co	S	particulate			3.3E-07			1.0E-07				4.3E-07
^{60m}Co	M	particulate									1.05E-18	1.05E-18
^{51}Cr	M	particulate									2.1E-08	2.1E-08
^{131}Cs	F	particulate									5.0E-21	5.0E-21
^{132}Cs	F	particulate									1.25E-20	1.25E-20
^{134}Cs	F	particulate									7.2E-06	7.2E-06
^{135}Cs	F	particulate									2.09E-11	2.09E-11
^{136}Cs	F	particulate									3.85E-09	3.85E-09
^{137}Cs	F	particulate	3.56E-07	3.9E-06					6.36E-06		2.44E-04	2.55E-04
^{137}Cs	S	particulate			1.0E-04			1.81E-07			6.05E-08	1.0E-04
^{138}Cs	F	particulate							2.19E+03			2.19E+03
^{67}Cu	M	particulate									1.7E-19	1.7E-19
^{159}Dy	M	particulate									4.72E-15	4.72E-15
^{166}Dy	M	particulate									6.7E-31	6.7E-31
^{169}Er	M	particulate									2.25E-18	2.25E-18
^{253}Es	M	particulate									3.14E-20	3.14E-20
^{254}Es	M	particulate									5.13E-21	5.13E-21
^{255}Es	B	unspecified									1.73E-22	1.73E-22
^{147}Eu	M	particulate									4.26E-24	4.26E-24
^{148}Eu	M	particulate									9.97E-91	9.97E-91
^{149}Eu	M	particulate									1.98E-18	1.98E-18

Table G.1. Radiological airborne emissions from all sources at ORNL, 2023 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total Minor Sources	ORNL Total
^{152}Eu	M	particulate									1.88E-07	1.88E-07
^{152}Eu	F	particulate			9.25E-07							9.25E-07
^{154}Eu	M	particulate									4.86E-07	4.86E-07
^{155}Eu	M	particulate									2.2E-07	2.2E-07
^{156}Eu	M	particulate									2.98E-10	2.98E-10
^{55}Fe	M	particulate									3.11E-07	3.11E-07
^{59}Fe	M	particulate									7.95E-11	7.95E-11
^{60}Fe	M	particulate									1.18E-15	1.18E-15
^{222}Fr	M	particulate									1.18E-28	1.18E-28
^{223}Fr	M	particulate									3.19E-19	3.19E-19
^{67}Ga	M	particulate									8.69E-43	8.69E-43
^{68}Ga	M	particulate									4.08E-26	4.08E-26
^{148}Gd	M	particulate									1.06E-10	1.06E-10
^{149}Gd	M	particulate									8.53E-30	8.53E-30
^{150}Gd	B	unspecified									2.97E-87	2.97E-87
^{151}Gd	M	particulate									5.13E-15	5.13E-15
^{152}Gd	M	particulate									2.03E-23	2.03E-23
^{153}Gd	M	particulate									1.05E-10	1.05E-10
^{68}Ge	M	particulate									7.05E-15	7.05E-15
^{71}Ge	M	particulate									5.9E-19	5.9E-19
^{3}H	V	vapor			9.01E-01	3.81E-02	6.99E-01		6.55E+01	1.25E+03	1.85E+00	1.32E+03
^{172}Hf	M	particulate									4.49E-12	4.49E-12
^{175}Hf	M	particulate									8.95E-12	8.95E-12
^{178m}Hf	M	particulate									3.15E-11	3.15E-11
^{179m}Hf	M	particulate									2.8E-24	2.8E-24
^{181}Hf	M	particulate									6.53E-12	6.53E-12
^{182}Hf	M	particulate									2.9E-15	2.9E-15
^{203}Hg	M	inorganic									2.24E-21	2.24E-21
^{163}Ho	B	unspecified									1.18E-16	1.18E-16
^{166}Ho	M	particulate									1.01E-30	1.01E-30

Table G.1. Radiological airborne emissions from all sources at ORNL, 2023 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								Total Minor Sources	ORNL Total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{166m}Ho	M	particulate									2.81E-13	2.81E-13
^{124}I	F	particulate				3.05E-05					5.38E-36	3.05E-05
^{125}I	F	particulate				5.64E-05					3.91E-17	5.64E-05
^{126}I	F	particulate			5.31E-03	4.81E-03					1.57E-09	1.01E-02
^{129}I	F	particulate				1.21E-05			5.55E-04		9.66E-06	5.77E-04
^{131}I	F	particulate				1.21E-02			1.61E-01		1.68E-08	1.73E-01
^{132}I	F	particulate				1.85E-03			5.53E-01		4.17E-27	5.55E-01
^{133}I	F	particulate							4.59E-01			4.59E-01
^{134}I	F	particulate							6.15E-01			6.15E-01
^{135}I	F	particulate							1.4E+00			1.4E+00
^{111}In	M	particulate									1.45E-39	1.45E-39
^{113m}In	M	particulate									1.54E-08	1.54E-08
^{114}In	B	unspecified									7.8E-18	7.8E-18
^{114m}In	M	particulate									1.41E-10	1.41E-10
^{115}In	M	particulate									8.27E-22	8.27E-22
^{115m}In	M	particulate									1.49E-13	1.49E-13
^{192}Ir	M	particulate									3.05E-11	3.05E-11
^{192n}Ir	B	unspecified									2.32E-20	2.32E-20
^{194}Ir	M	particulate									2.78E-19	2.78E-19
^{194m}Ir	M	particulate									4.66E-18	4.66E-18
^{40}K	M	particulate									3.06E-07	3.06E-07
^{42}K	M	particulate									2.47E-26	2.47E-26
^{81}Kr	B	unspecified									2.0E-07	2.0E-07
^{83m}Kr	B	unspecified									1.78E-09	1.78E-09
^{85}Kr	B	unspecified							6.49E+02		1.5E+02	7.99E+02
^{85m}Kr	B	unspecified							7.94E+00	9.26E+01		1.01E+02
^{87}Kr	B	unspecified							2.87E+01	1.98E+02		2.27E+02
^{88}Kr	B	unspecified							4.06E+01	7.19E+01		1.13E+02
^{89}Kr	B	unspecified							3.54E+01			3.54E+01
^{137}La	M	particulate									3.2E-16	3.2E-16

Table G.1. Radiological airborne emissions from all sources at ORNL, 2023 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								Total Minor Sources	ORNL Total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{138}La	M	particulate									1.81E-20	1.81E-20
^{140}La	M	particulate							8.72E-04		3.88E-07	8.72E-04
^{171}Lu	M	particulate									1.33E-29	1.33E-29
^{172}Lu	M	particulate									1.45E-30	1.45E-30
^{173}Lu	M	particulate									3.1E-13	3.1E-13
^{174}Lu	M	particulate									4.56E-12	4.56E-12
^{174m}Lu	M	particulate									5.79E-17	5.79E-17
^{176}Lu	M	particulate									3.29E-21	3.29E-21
^{177}Lu	M	particulate									2.58E-16	2.58E-16
^{177m}Lu	M	particulate									3.89E-08	3.89E-08
^{52}Mn	M	particulate									7.6E-20	7.6E-20
^{53}Mn	M	particulate									3.49E-15	3.49E-15
^{54}Mn	M	particulate									5.83E-09	5.83E-09
^{93}Mo	M	particulate									1.79E-09	1.79E-09
^{99}Mo	M	particulate									1.74E-08	1.74E-08
^{22}Na	M	particulate									2.69E-11	2.69E-11
^{91}Nb	B	unspecified									9.89E-11	9.89E-11
^{91m}Nb	B	unspecified									1.93E-15	1.93E-15
^{92}Nb	B	unspecified									4.63E-15	4.63E-15
^{92m}Nb	B	unspecified									1.97E-16	1.97E-16
^{93m}Nb	M	particulate									6.67E-09	6.67E-09
^{94}Nb	M	particulate									8.16E-10	8.16E-10
^{95}Nb	M	particulate									2.74E-05	2.74E-05
^{95m}Nb	M	particulate									1.51E-07	1.51E-07
^{96}Nb	M	particulate									9.67E-11	9.67E-11
^{97}Nb	M	particulate									5.95E-11	5.95E-11
^{140}Nd	B	unspecified									4.96E-38	4.96E-38
^{144}Nd	B	unspecified									6.26E-20	6.26E-20
^{147}Nd	M	particulate									2.3E-06	2.3E-06
^{56}Ni	M	particulate									6.49E-57	6.49E-57

Table G.1. Radiological airborne emissions from all sources at ORNL, 2023 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								Total Minor Sources	ORNL Total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{59}Ni	M	particulate									5.81E-10	5.81E-10
^{63}Ni	M	particulate									1.71E-07	1.71E-07
^{66}Ni	M	particulate									5.18E-43	5.18E-43
^{234}Np	M	particulate									3.19E-35	3.19E-35
^{235}Np	M	particulate									5.18E-14	5.18E-14
^{237}Np	M	particulate									2.9E-05	2.9E-05
^{238}Np	M	particulate									8.78E-13	8.78E-13
^{239}Np	M	particulate									1.32E-09	1.32E-09
^{240}Np	M	particulate									1.69E-20	1.69E-20
^{185}Os	M	particulate									4.92E-15	4.92E-15
^{191}Os	M	particulate				2.55E-02						2.55E-02
^{194}Os	M	particulate									2.03E-13	2.03E-13
^{32}P	M	particulate									4.24E-16	4.24E-16
^{33}P	M	particulate									3.26E-18	3.26E-18
^{228}Pa	M	particulate									5.5E-11	5.5E-11
^{230}Pa	M	particulate									3.72E-09	3.72E-09
^{231}Pa	M	particulate									7.54E-16	7.54E-16
^{232}Pa	M	particulate									1.4E-10	1.4E-10
^{233}Pa	M	particulate									4.49E-08	4.49E-08
^{234}Pa	M	particulate									2.99E-14	2.99E-14
^{205}Pb	M	particulate									3.71E-20	3.71E-20
^{209}Pb	M	particulate									2.09E-18	2.09E-18
^{210}Pb	M	particulate									2.0E-09	2.0E-09
^{211}Pb	M	particulate									3.42E-08	3.42E-08
^{212}Pb	M	particulate	1.08E+00	3.38E-01		1.51E-02			2.93E-02		5.79E-08	1.46E+00
^{212}Pb	S	particulate			3.37E+00		3.89E-01				8.49E-02	3.84E+00
^{214}Pb	M	particulate				4.4E-03			3.68E-02		8.07E-19	4.12E-02
^{214}Pb	S	particulate			1.13E+00		1.42E-01				1.09E-04	1.27E+00
^{100}Pd	M	particulate									5.88E-59	5.88E-59
^{103}Pd	M	particulate									1.6E-14	1.6E-14

Table G.1. Radiological airborne emissions from all sources at ORNL, 2023 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								Total Minor Sources	ORNL Total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{107}Pd	M	particulate									5.4E-12	5.4E-12
^{143}Pm	M	particulate									5.05E-20	5.05E-20
^{144}Pm	M	particulate									6.09E-18	6.09E-18
^{145}Pm	M	particulate									2.43E-11	2.43E-11
^{146}Pm	M	particulate									9.68E-12	9.68E-12
^{147}Pm	M	particulate									1.18E-05	1.18E-05
^{148}Pm	M	particulate									5.07E-09	5.07E-09
^{148m}Pm	M	particulate									3.42E-07	3.42E-07
^{208}Po	B	unspecified									2.49E-13	2.49E-13
^{209}Po	B	unspecified									7.8E-10	7.8E-10
^{210}Po	B	inorganic									3.58E-13	3.58E-13
^{143}Pr	M	particulate									8.19E-10	8.19E-10
^{144}Pr	M	particulate									6.13E-05	6.13E-05
^{193}Pt	M	particulate									3.47E-12	3.47E-12
^{236}Pu	M	particulate									3.01E-11	3.01E-11
^{237}Pu	M	particulate									7.81E-13	7.81E-13
^{238}Pu	M	particulate	7.75E-09	3.04E-08		1.13E-09			1.2E-08		6.36E-07	6.87E-07
^{238}Pu	F	particulate			6.46E-07		3.09E-09	5.49E-08			1.42E-09	7.05E-07
^{239}Pu	M	particulate	1.26E-08	2.05E-07		5.25E-10			1.1E-08		1.98E-05	2.01E-05
^{239}Pu	F	particulate			2.31E-07		6.22E-09	1.09E-08			3.42E-10	2.48E-07
^{240}Pu	M	particulate	1.26E-08	2.05E-07		5.25E-10			1.1E-08		5.8E-06	6.02E-06
^{240}Pu	F	particulate			2.31E-07		6.22E-09	1.09E-08			3.42E-10	2.48E-07
^{241}Pu	M	particulate									1.11E-05	1.11E-05
^{242}Pu	M	particulate									3.27E-05	3.27E-05
^{243}Pu	M	particulate									1.86E-18	1.86E-18
^{244}Pu	M	particulate									7.83E-08	7.83E-08
^{246}Pu	M	particulate									7.04E-24	7.04E-24
^{223}Ra	M	particulate									7.3E-08	7.3E-08
^{224}Ra	M	particulate									4.98E-09	4.98E-09
^{225}Ra	M	particulate									1.09E-09	1.09E-09

Table G.1. Radiological airborne emissions from all sources at ORNL, 2023 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								Total Minor Sources	ORNL Total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{226}Ra	M	particulate									5.06E-08	5.06E-08
^{228}Ra	M	particulate									7.45E-12	7.45E-12
^{83}Rb	M	particulate									6.79E-14	6.79E-14
^{84}Rb	M	particulate									2.86E-13	2.86E-13
^{86}Rb	M	particulate									2.34E-11	2.34E-11
^{87}Rb	M	particulate									1.38E-15	1.38E-15
^{183}Re	B	unspecified									3.2E-16	3.2E-16
^{184}Re	M	particulate									5.23E-19	5.23E-19
^{184m}Re	M	particulate									7.94E-16	7.94E-16
^{186}Re	M	particulate									5.02E-19	5.02E-19
^{186m}Re	M	particulate									2.48E-15	2.48E-15
^{187}Re	M	particulate									2.47E-21	2.47E-21
^{188}Re	M	particulate									4.48E-16	4.48E-16
^{99}Rh	M	particulate									3.74E-25	3.74E-25
^{100}Rh	M	particulate									7.73E-59	7.73E-59
^{101}Rh	M	particulate									6.62E-16	6.62E-16
^{101m}Rh	M	particulate									1.88E-31	1.88E-31
^{102}Rh	M	particulate									9.87E-11	9.87E-11
^{102m}Rh	M	particulate									2.42E-11	2.42E-11
^{103m}Rh	M	particulate									2.16E-06	2.16E-06
^{105}Rh	M	particulate									1.41E-07	1.41E-07
^{106}Rh	B	unspecified									2.11E-07	2.11E-07
^{219}Rn	B	unspecified									3.5E-03	3.5E-03
^{222}Rn	B	unspecified									8.13E-09	8.13E-09
^{97}Ru	M	particulate									2.43E-44	2.43E-44
^{103}Ru	M	particulate									2.21E-06	2.21E-06
^{106}Ru	M	particulate									2.24E-05	2.24E-05
^{35}S	M	particulate									6.05E-12	6.05E-12
^{119}Sb	M	particulate									4.0E-40	4.0E-40
^{120m}Sb	M	particulate									1.46E-09	1.46E-09

Table G.1. Radiological airborne emissions from all sources at ORNL, 2023 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								Total Minor Sources	ORNL Total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{122}Sb	M	particulate									3.0E-09	3.0E-09
^{124}Sb	M	particulate				1.08E-03					5.57E-09	1.08E-03
^{125}Sb	M	particulate				1.45E-04					5.44E-07	1.46E-04
^{126}Sb	M	particulate				1.23E-03					2.01E-07	1.23E-03
^{126m}Sb	M	particulate									1.38E-11	1.38E-11
^{127}Sb	M	particulate									8.53E-09	8.53E-09
^{44}Sc	M	particulate									1.41E-33	1.41E-33
^{44m}Sc	M	particulate									1.97E-53	1.97E-53
^{46}Sc	M	particulate									2.19E-14	2.19E-14
^{47}Sc	M	particulate									1.97E-17	1.97E-17
^{72}Se	B	unspecified									1.65E-38	1.65E-38
^{75}Se	F	particulate									3.94E-14	3.94E-14
^{79}Se	F	particulate									4.72E-12	4.72E-12
^{32}Si	M	particulate									3.69E-13	3.69E-13
^{145}Sm	M	particulate									1.85E-15	1.85E-15
^{146}Sm	M	particulate									1.46E-18	1.46E-18
^{147}Sm	M	particulate									1.18E-16	1.18E-16
^{148}Sm	B	unspecified									2.04E-21	2.04E-21
^{151}Sm	M	particulate									2.32E-08	2.32E-08
^{113}Sn	M	particulate									1.52E-08	1.52E-08
^{117m}Sn	M	particulate									9.76E-10	9.76E-10
^{119m}Sn	M	particulate									1.28E-08	1.28E-08
^{121}Sn	M	particulate									1.04E-09	1.04E-09
^{121m}Sn	M	particulate									1.35E-09	1.35E-09
^{123}Sn	M	particulate									3.46E-08	3.46E-08
^{125}Sn	M	particulate									3.63E-09	3.63E-09
^{126}Sn	M	particulate									1.4E-11	1.4E-11
^{82}Sr	M	particulate									2.62E-42	2.62E-42
^{85}Sr	M	particulate									1.41E-14	1.41E-14
^{87m}Sr	M	particulate									6.46E-36	6.46E-36

Table G.1. Radiological airborne emissions from all sources at ORNL, 2023 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								Total Minor Sources	ORNL Total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{89}Sr	M	particulate	4.75E-08	2.56E-06		1.45E-09			8.52E-06		3.79E-06	1.49E-05
^{89}Sr	S	particulate			5.56E-06		1.45E-08				1.51E-08	5.59E-06
^{90}Sr	M	particulate	4.75E-08	2.56E-06		1.45E-09			8.52E-06		1.01E-04	1.12E-04
^{90}Sr	S	particulate			5.56E-06		1.45E-08	1.34E-06			1.66E-08	6.93E-06
^{91}Sr	M	particulate									1.19E-13	1.19E-13
^{179}Ta	M	particulate									7.33E-12	7.33E-12
^{182}Ta	M	particulate									1.61E-10	1.61E-10
^{153}Tb	M	particulate									1.99E-50	1.99E-50
^{155}Tb	M	particulate									3.48E-30	3.48E-30
^{156}Tb	M	particulate									1.24E-28	1.24E-28
^{157}Tb	M	particulate									3.29E-16	3.29E-16
^{158}Tb	M	particulate									9.16E-15	9.16E-15
^{160}Tb	M	particulate									4.51E-09	4.51E-09
^{161}Tb	M	particulate									3.36E-18	3.36E-18
^{95}Tc	M	particulate									2.09E-22	2.09E-22
^{95m}Tc	M	particulate									5.3E-21	5.3E-21
^{96}Tc	M	particulate									1.97E-10	1.97E-10
^{97}Tc	M	particulate									4.78E-18	4.78E-18
^{97m}Tc	M	particulate									1.14E-14	1.14E-14
^{98}Tc	M	particulate									2.14E-16	2.14E-16
^{99}Tc	M	particulate									2.21E-09	2.21E-09
^{99}Tc	S	particulate						3.15E-06				3.15E-06
^{99m}Tc	M	particulate									3.67E-18	3.67E-18
^{118}Te	B	unspecified									4.18E-39	4.18E-39
^{119m}Te	B	unspecified									2.64E-40	2.64E-40
^{121}Te	M	particulate									4.05E-10	4.05E-10
^{121m}Te	M	particulate									5.41E-11	5.41E-11
^{123}Te	M	particulate									1.7E-13	1.7E-13
^{123m}Te	M	particulate									8.17E-11	8.17E-11
^{125m}Te	M	particulate									1.3E-07	1.3E-07

Table G.1. Radiological airborne emissions from all sources at ORNL, 2023 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								Total Minor Sources	ORNL Total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{127}Te	M	particulate									1.28E-07	1.28E-07
^{127m}Te	M	particulate									1.31E-07	1.31E-07
^{129}Te	M	particulate									2.01E-08	2.01E-08
^{129m}Te	M	particulate									3.2E-08	3.2E-08
^{131m}Te	M	particulate									9.13E-10	9.13E-10
^{132}Te	M	particulate									3.03E-09	3.03E-09
^{226}Th	S	particulate									1.07E-19	1.07E-19
^{227}Th	S	particulate									1.61E-07	1.61E-07
^{228}Th	S	particulate	6.48E-09	2.04E-08	1.45E-07	4.84E-09	5.58E-09		1.74E-08		1.07E-06	1.27E-06
^{229}Th	S	particulate									5.31E-10	5.31E-10
^{230}Th	S	particulate	2.11E-10	6.12E-09		4.74E-09			2.66E-07		3.31E-09	2.8E-07
^{230}Th	F	particulate			8.75E-09		2.36E-09				1.96E-09	1.31E-08
^{231}Th	S	particulate									2.24E-12	2.24E-12
^{232}Th	S	particulate	4.74E-10	3.37E-09		9.11E-10			4.01E-09		1.9E-07	1.98E-07
^{232}Th	F	particulate			1.27E-08		8.2E-10				2.15E-09	1.57E-08
^{234}Th	S	particulate									1.2E-09	1.2E-09
^{44}Ti	M	particulate									7.63E-12	7.63E-12
^{204}Tl	M	particulate									2.29E-16	2.29E-16
^{208}Tl	B	unspecified									7.02E-09	7.02E-09
^{166}Tm	M	particulate									1.44E-60	1.44E-60
^{167}Tm	M	particulate									6.95E-26	6.95E-26
^{168}Tm	B	unspecified									1.52E-16	1.52E-16
^{170}Tm	M	particulate									9.68E-12	9.68E-12
^{171}Tm	M	particulate									1.88E-09	1.88E-09
^{172}Tm	M	particulate									7.36E-38	7.36E-38
^{230}U	M	particulate									1.06E-19	1.06E-19
^{231}U	M	particulate									7.73E-33	7.73E-33
^{232}U	M	particulate	4.26E-10	3.04E-10							5.38E-13	7.31E-10
^{233}U	M	particulate	2.44E-08	1.34E-07		1.76E-09			9.67E-09		3.12E-07	4.82E-07
^{233}U	S	particulate			2.88E-05		6.02E-09				1.3E-09	2.88E-05

Table G.1. Radiological airborne emissions from all sources at ORNL, 2023 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								Total Minor Sources	ORNL Total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{234}U	M	particulate	2.44E-08	1.34E-07		1.76E-09			9.67E-09		9.59E-04	9.59E-04
^{234}U	S	particulate			2.88E-05		6.02E-09				1.3E-09	2.88E-05
^{235}U	M	particulate	1.76E-10	2.6E-09		4.0E-10			2.24E-09		2.65E-05	2.65E-05
^{235}U	S	particulate			1.72E-08						9.47E-11	1.73E-08
^{236}U	M	particulate									4.69E-11	4.69E-11
^{237}U	M	particulate									1.81E-10	1.81E-10
^{238}U	M	particulate	1.2E-09	2.37E-08		1.21E-09			1.22E-08		2.27E-03	2.27E-03
^{238}U	S	particulate			2.22E-07		1.45E-09				2.37E-09	2.26E-07
^{240}U	M	particulate									1.49E-17	1.49E-17
^{48}V	M	particulate									6.51E-18	6.51E-18
^{49}V	M	particulate									9.37E-11	9.37E-11
^{50}V	B	unspecified									7.32E-25	7.32E-25
^{181}W	M	particulate									1.45E-11	1.45E-11
^{185}W	M	particulate									8.41E-10	8.41E-10
^{188}W	M	particulate									3.54E-08	3.54E-08
^{123}Xe	B	unspecified								1.23E+02		1.23E+02
^{125}Xe	B	unspecified								6.63E+01		6.63E+01
^{127}Xe	B	unspecified								2.77E-03		2.77E-03
^{131m}Xe	B	unspecified							1.72E+02		1.97E-07	1.72E+02
^{133}Xe	B	unspecified							1.11E+01			1.11E+01
^{133m}Xe	B	unspecified							2.81E+01			2.81E+01
^{135}Xe	B	unspecified							8.86E+01			8.86E+01
^{135m}Xe	B	unspecified							6.65E+01			6.65E+01
^{137}Xe	B	unspecified							2.01E+02			2.01E+02
^{138}Xe	B	unspecified							3.99E+02			3.99E+02
^{87}Y	M	particulate									6.13E-36	6.13E-36
^{88}Y	M	particulate									9.34E-08	9.34E-08
^{90}Y	M	particulate									5.03E-06	5.03E-06
^{91}Y	M	particulate									7.81E-06	7.81E-06
^{166}Yb	M	particulate									1.25E-60	1.25E-60

Table G.1. Radiological airborne emissions from all sources at ORNL, 2023 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total Minor Sources	ORNL Total
^{169}Yb	M	particulate									1.0E-08	1.0E-08
^{65}Zn	M	particulate									8.65E-10	8.65E-10
^{88}Zr	M	particulate									1.43E-16	1.43E-16
^{89}Zr	M	particulate									1.18E-30	1.18E-30
^{93}Zr	M	particulate									1.26E-10	1.26E-10
^{95}Zr	M	particulate									1.32E-05	1.32E-05
^{97}Zr	M	particulate									3.72E-11	3.72E-11
Totals			**1.08E+00**	**3.38E-01**	**5.41E+00**	**1.04E-01**	**1.23E+00**	**5.16E-06**	**4.95E+03**	**1.19E+04**	**1.52E+02**	**1.7E+04**

[a] *Emissions given in curies (Ci). 1 Ci = 3.7E+10 Bq*

[b] *The designations of F, M, and S refer to the lung clearance type: fast (F), moderate (M), or slow (S) for the given radionuclide. G stands for gaseous, V stands for vapor, and B stands for blank, unspecified form.*