TENNESSEE DEPARTMENT
OF
ENVIRONMENT AND CONSERVATION

DIVISION OF REMEDIATION
OAK RIDGE OFFICE

ENVIRONMENTAL MONITORING REPORT
For Work Performed:
July 1, 2022, through June 30, 2023

April 2025

Tennessee Department of
Environment and Conservation,
Authorization No. 327023

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ACRONYMS

A	ANOVA	Analysis of variance in statistics
	ARARs	Applicable or Relevant and Appropriate Requirements
	As	Arsenic (metal)
	ASER	Annual Site Environmental Report (DOE)
	AWQC	Ambient Water Quality Criteria (*General Water Quality Criteria Chapter 0400-40-03-.03)*
B	Ba	Barium (metal)
	Background site	Reference site located outside of an area of potential impact from the Oak Ridge Reservation (ORR)
	BCAP	Bear Creek Assessment Project
	BC/BCK/BCV	Bear Creek/Bear Creek kilometer or station/Bear Creek Valley
	BCBGs	Bear Creek Burial Grounds
	Be-7	Beryllium-7 (metal)
	Benthic Life	Organisms that live on or in the streambed (insects, amphibians, spiders, worms, etc.)
C	CAA	Clean Air Act
	CC/CCK	Clear Creek/Clear Creek kilometer (background stream)
	Cd	Cadmium (metal)
	CEC	Civil and Environmental Consultants, Inc.
	CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (commonly known as Superfund) enacted by Congress on December 11, 1980
	Co-60	Cobalt-60
	COC	Contaminants of Concern
	COND	Conductivity
	CR/CRK	Clinch River/Clinch River kilometer
	Cs-137	Cesium-137 (metal)
	CSU	Combined Standard Uncertainty
	Cu	Copper (metal)
D	D&D	Decontamination and Decommissioning
	DO	Dissolved oxygen
	DOE	US Department of Energy
	DoR	Division of Remediation

	DOR-OR	Division of Remediation – Oak Ridge
	DWR	Division of Water Resources
E	EFPC/EFK	East Fork Poplar Creek/East Fork Poplar Creek Kilometer
	EFPCAP	East Fork Poplar Creek Assessment Project
	EMDF	Environmental Management Disposal Facility
	EMP	Environmental Monitoring Plan
	EMR	Environmental Monitoring Report
	EMWMF	Environmental Management Waste Management Facility
	EPA	US Environmental Protection Agency
	ESOA	Environmental Surveillance Oversight Agreement
	ETTP	East Tennessee Technology Park (formerly K-25)
F	FCAP	Filled Coal Ash Pond
	FDA	US Food and Drug Administration
	FFA	Federal Facilities Agreement
	FRMAC	Federal Radiological Monitoring and Assessment Center
	FY23	Fiscal Year 2023
G	GPS	Global Positioning System
H	H-3	Tritium
	HFIR	High Flux Isotope Reactor
	Hg	Mercury (metal)
	HQ	Hazard Quotient (noncarcinogenic risk equations)
I	I-129	Iodine-129
	IC25	Inhibition Concentration 25% reduction in survival, growth, and reproduction of test organism
	ISM	Incremental Sampling Methodology
	ITRC	Interstate Technology Regulatory Council
J	J qualifer	Estimated result less than MQL but greater than or equal to MDL
K	K-25	Former site of Gaseous Diffusion Plant closed in 1987, now ETTP
	K-40	Potassium-40

L	LLRW	Low-level radioactive waste
M	MB/MBK	Mill Branch/Mill Branch kilometer (background stream)
	MCL	Maximum Contaminant Level see NPDWR
	MDC	Minimum Detectable Concentration
	MDL	Minimum Detection Limit
	MeHg	Methylmercury
	MH	manhole 1 (MH-1), manhole 2 (MH-2) at Y-12
	MIK	Mitchell Branch/Mitchell Branch kilometer
	MQL	Minimum/Method Quantification Limit
	MSRE	Molten Salt Reactor Experiment
N	NaI	Sodium Iodide (used in gamma scintillator probe)
	NBG	North Boundary Greenway
	NCP	National Oil and Hazardous Substances Pollution Contingency Plan
	Ni	Nickel (metal)
	NNSA	National Nuclear Security Administration
	NAREL	National Air and Radiation Environmental Laboratory (EPA)
	NCBI	North Carolina Biotic Index
	NESHAPS	National Emissions Standards for hazardous Air Pollutants
	NOAA	National Oceanic and Atmospheric Administration
	NORM	Naturally Occurring Radioactive Materials
	NPDWR	National Primary Drinking Water Regulations
	NPL	National Priority List
	NRC	Nuclear Regulatory Commission
	NSC	(Y-12) National Security Complex
	NSDWR	National Secondary Drinking Water Regulations
	NT-5	Bear Creek Northwest Tributary 5
	NTU	Nephelometric turbidity units
	NUREG	US Nuclear Regulatory Commission Regulations
O	OF-200 MTF	Outfall 200 Mercury Treatment Facility at Y-12
	ORAU	Oak Ridge Associated Universities
	OREIS	Oak Ridge Environmental Information System

	ORNL	Oak Ridge National Laboratory, also known as X-10
	ORP	Oxygen Reduction Potential
	ORR	Oak Ridge Reservation
P	Pb	Lead, Pb-212/214
	PC/PCK/PCM	Poplar Creek/Poplar Creek kilometer/Poplar Creek mile
	PCBs	Polychlorinated Biphenyls
	PFAS	Per- and Polyfluoroalkyl Substances
	PFBA	Perfluorobutanoic acid
	PFOS	Perfluorooctanesulfonic acid
	PPE	Personal Protective Equipment
	Pu	Plutonium-238/239/240 (transuranic isotope)
Q	QA/QC	Quality Assurance/Quality Control
	QAPP	Quality Assurance Project Plan
	QEC	Quality Environmental Containers (Beaver, WI)
R	RADCON	Radiation Control Program
	RAIS	Risk Assessment Information System
	RCS	Roving Creel Survey
	RER	Remedial Effectiveness Report
	ROD	Record of Decision
	RSLs	Regional Screening Levels
	RWP	Radiation Work Permit
S	SL	Screening level
	SNS	Spallation Neutron Source
	SOP	Standard Operating Procedure
	Sr-90	Strontium-90
	Station	A specific location where environmental sampling or monitoring takes place.
	SU	Standard units
	SMCLs	Secondary Maximum Contaminant Levels
	SWSA	Solid Waste Storage Area
T	TEDE	Total Effective Dose Equivalent
	TENORM	Technically Enhanced Naturally Occurring Radioactive Materials

	TR	Target Risk
	Tc-99	Technetium - 99
	TDEC	Tennessee Department of Environment and Conservation
	TDEC-DoR	TDEC-Division of Remediation
	TDH	Tennessee Department of Health
	TDH-NEL	TN Dept. of Health-Nashville Environmental Laboratory
	Th	Thorium-228/230/232
	THI	Target Hazard Index
	THQ	Target Hazard Quotient
	Tl-208	Thallium-208
	TMI	Tennessee Macroinvertebrate Index
	TN AWQC	State of Tennessee Ambient Water Quality Criteria (*General Water Quality Criteria Chapter 0400-40-03-.03)*
U	U qualifier	Result is less than Method Detection Limit (MDL)
	U-234/235/238	Uranium-234/235/238
	UCOR	United Cleanup Oak Ridge, LLC
	USDI	US Department of the Interior
V	VOCs	Volatile organic compounds
W	WC/WOC/WCK	Whiteoak Creek/White Oak Creek/White Oak Creek kilometer
	WOL	White Oak Lake
X	X-10	Historical name, renamed Oak Ridge National Lab (ORNL)
Y	Y-12	Y-12 National Security Complex (Building 9213, 9219, 9723-28)

UNITS OF MEASURE AND THEIR ABBREVIATIONS

°C	degrees Celsius/Centigrade
µg/g	micrograms per gram (parts per million)
µg/L	micrograms per liter (parts per billion)
µrem/hr	microrem per hour
µS/cm	micro-Siemens per centimeter
aCi/m^3	attocurie per cubic meter (attocurie represents 10E-18 curies)
cfs	cubic feet per second
DO	dissolved oxygen
dpm/ 100 cm^2	disintegrations per minute per square centimeter
g	gram
g/day	grams per day
kg/day	kilograms per day
kg/yr	kilograms per year
m^2	square meter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter (parts per million)
mrem	millirem (unit of absorbed radiation dose)
mV	millivolts
ng/g	nanograms per gram (parts per billion)
ng/L	nanograms per liter
pCi/g	picocuries per gram
pCi/L	picocuries per liter
pCi/m^3	picocuries per cubic meter
pH	scale of acidity from 0 to 14 (measured in standard units [SU])
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
rem	A rem is the unit of effective absorbed dose of ionizing radiation in human tissue, equivalent roentgen of X-rays

Executive Summary

The Tennessee Department of Environment and Conservation (TDEC), Division of Remediation, Oak Ridge (DoR-OR), provides the annual Fiscal Year 2023 (FY23) Environmental Monitoring Report (EMR) for the period of July 1, 2022, through June 30, 2023. This report is submitted as a comprehensive report of DoR-OR's monitoring and assessment activities across the Oak Ridge Reservation (ORR) in accordance with the terms of both the *Environmental Surveillance and Oversight Agreement* (ESOA), as well as in support of activities being conducted under the *Federal Facilities Agreement* (FFA).

TDEC DoR-OR performs independent monitoring and verification sampling as well as conducting oversight of current US Department of Energy (DOE) activities across the ORR to confirm comparable DOE monitoring results, to support environmental restoration decisions, to evaluate performance of existing remedies, and to investigate the extent and movement of legacy contamination. Independent monitoring and oversite are conducted to assure the residents of Tennessee that DOE's active operations and legacy clean-up work are being performed in a manner that is protective of human health and the environment.

This independent State of Tennessee program is designed to assess current conditions for all ORR related environmental media (i.e., air, surface water, soil, sediment, ground water, drinking water, and biota including food crops, fish and wildlife, and biological systems). Much of the data collected verifies or supplements DOE's data sets. This State-lead program is intended to provide independent assessment, where necessary, for potential emissions of any materials (i.e. hazardous, toxic, chemical, or radiological) from the ORR to its surrounding environment and to support efficient State protectiveness reviews.

This FY23 EMR presents the results of eighteen (18) independent projects proposed in the FY23 *Environmental Monitoring Plan* (EMP). Project focus areas included Air Monitoring, Biological Monitoring, Landfill Monitoring, Radiological Monitoring, Sediment Monitoring, Stormwater/Water Discharge Monitoring, Surface Water, Storm Water / Water Discharge Monitoring, and Watershed Assessment (Holistic) Monitoring.

State monitoring during FY23 was effective in confirming DOE sampling results showing regulatory compliance for environmental media including air, precipitation, surface water, etc. These projects were also instrumental in gathering further data to support future state assessment of ecological health, resource usage, and potential impairment or other impacts to environmental systems.

Summaries of these FY23 independent monitoring projects are as follows:

Air Monitoring:

1. FUGITIVE RADIOLOGICAL AIR EMISSIONS

The project team sampled air particulates at nine (9) ORR stations plus one background station. Air samples were screened for radiological emissions which may have originated from ORR remedial actions and/or waste disposal activities. All data was evaluated for compliance within Federal Regulatory Standards. The main goal of this project was to identify any air emissions that may have the potential to cause a member of the public to receive an effective dose greater than 10 millirem (mrem) per year (per Federal Regulatory Standards, 10CFR 20, 2024). The resulting data were also compared with DOE air monitoring data for compliance verification. There were no documented exceedances of regulatory limits during FY23.

2. RADNET AIR

RadNet is a national program funded by the US Environmental Protection Agency (EPA). In FY23, this federal program monitored the air, precipitation, and drinking water across the US to track radiation in the environment. Air monitoring stations were placed at Oak Ridge National Laboratory's (ORNL) Bethel Valley and Melton Valley, and at the west end of the Y-12 campus. After samples were collected, these air filters were sent to EPA's National Air and Radiation Environmental Laboratory (EPA NAREL) in Montgomery, Alabama, for gross beta analysis. All the data during this period was well below the levels which would warrant further analysis, and none of the results indicated that activities on the ORR posed a significant impact on the environment or public health.

3. RADNET PRECIPITATION

The RadNet Team performed radiochemical analysis on precipitation samples taken from monitoring stations at three (3) locations on the ORR. These samplers were co-located with RadNet Air stations. The DoR-OR project team collected water samples and shipped them to EPA NAREL where the samples were composited monthly at the EPA laboratory and analyzed for gamma radionuclides. Precipitation monitoring is extremely important in and around both ORNL and Y-12 as Decontamination and Decommissioning (D&D) activities have begun to focus on these two campuses. All results from FY23 were compared to drinking water limits. These conservative reference values are used for comparison because of the absence of regulatory limits for radionuclides in precipitation. Results were found to be well below the EPA Maximum Contaminant Levels (MCLs).

BIOLOGICAL MONITORING:

4. BENTHIC ECOLOGICAL COMMUNITY HEALTH

This project consists of benthic macroinvertebrate monitoring to assess the benthic macroinvertebrate population health of the four (4) main ORR watersheds. Aquatic macroinvertebrate species serve as both quantitative and qualitative indicators to assess biotic responses to environmental stressors (Holt, 2010). Past studies have indicated that most of the benthic community sampling sites located in ORR streams have been negatively impacted when compared to healthy communities in unimpacted reference streams (TDEC 2021, DOE 2021).

Overall, the health of the benthic macroinvertebrate communities in ORR streams has improved since the 1980's. The improvement has plateaued for the past few years. The two Y-12 watersheds continue to show impairment at their headwaters, which are located near DOE facilities and industrial activities. In the Bear Creek Watershed, BCK 12.3 had the lowest Tennessee Macroinvertebrate Index (TMI) score out of all the ORR sites sampled in 2022. On the other hand, BCK 3.3 continues to express TMI scores above bio-criteria guidelines and comparable to scores seen at reference sites. In the East Fork Poplar Creek (EFPC) Watershed, EFK 6.3 had the lowest TMI score of all the EFPC sites. In previous years, EFPC macroinvertebrate communities tended to improve downstream. The farther the site was from the source of contamination, the higher the TMI. Unfortunately, EFK 6.3 did not show this trend in 2022. The ORNL watershed (White Oak Creek [WOC]) has been relatively static over the past decade, with only slight variations from year-to-year, with a slight increase in TMI scores this year, though this score does not represent a statistically significant change from historical trends. The East Tennessee Technology Park (ETTP) watershed, Mitchell Branch, expressed a sharp decrease in its TMI scores for both the reference site and impacted site, and exact cause is unknown at this time.

5. ORR ROVING CREEL AND NORTH BOUNDARY GREENWAY SURVEYS

The Roving Creel Survey (RCS) is an ongoing project that measures angling effort at three (3) key locations along the Clinch River and Poplar Creek where impaired ORR watersheds drain into publicly accessible waters. Angler interviews were conducted at these confluences: White Oak Lake (WOL) with the Clinch River, Poplar Creek with the Clinch River, EFPC with Poplar Creek. Both catch-and-release fishing and fishing for consumption were documented at the confluence points. Additionally, a survey box was installed at the Gallaher boat ramp to passively collect digital and paper surveys. During FY23, the scope of this project was extended to also measure fishing and recreational activities along the North Boundary

Greenway (NBG). The lower reaches of Bear Creek and EFPC flow near the trails of the NBG and feed into Poplar Creek. The NBG is a popular recreation attraction for Oak Ridge residents, and recreators have been observed there year-round. In FY23, DoR-OR personnel interviewed recreators along the NBG to determine how they spend their time at the greenway. Both paper and digital surveys were collected at project survey stations placed along the NBG. Sixty-nine percent (69%) of the individuals who participated in the RCS portion of this study described themselves as locals. Ninety-seven percent (97%) of those that were interviewed along the NBG described themselves as locals. Many locals reported that they fish frequently and often angle in these areas, with some reporting that they also consume fish caught in this area.

6. RADIOLOGICAL UPTAKE IN FOOD CROPS

This project assessed the possible radiological impacts of DOE ORR activities on food crops grown by local farmers and gardeners. While the project mirrors a similar DOE project, DoR-OR sampling was conducted independently to verify and correlate with DOE sample results. This food crops project collected vegetables, hay, and milk samples within a five (5) mile radius of the ORR. For each sample type, a corresponding background location outside the study area was analyzed to establish background (i.e. reference) levels. The samples were analyzed for radiological contaminants and compared to levels seen at reference locations. In addition, samples were also compared with the results from DOE's most recent similar sampling with 2016 milk, 2021 vegetables, and 2020 hay (DOE, 2017; DOE, 2022b; DOE, 2021). The TDEC DoR-OR FY23 vegetable, hay, and milk sampling results did not indicate that DOE ORR activities are significantly impacting radionuclide concentrations in food crops in the areas surrounding the ORR, and these results were similar to the corresponding DOE data from the current DOE Annual Site Environmental Report (ASER).

7. MERCURY UPTAKE IN BIOTA

Mercury is found in elevated levels throughout the ORR resulting from processes and spills dating back to Manhattan Project and Cold War era activities. Mercury in streams and wetlands often undergoes methylation and is transformed into toxic methylmercury (MeHg) in conjunction with the activity of microorganisms (Kalisinska et al, 2013). Methylmercury is particularly bioavailable to wildlife (and humans) and, if ingested, may cause serious neurological, reproductive, and other physiological damage (Standish, 2016). Decreases in reproductive success of 35–50% have been observed in birds with high dietary methylmercury uptake including reduced hatching and fledging success (USDI, 1998; Hallinger et al, 2011). With this project, TDEC DoR-OR monitors key species from multiple trophic strata to assess the movement of contaminants through the food web. This project consists of collection and laboratory analysis of mercury and methylmercury in songbird eggs, adult flying insects, and wolf spiders throughout the Bear Creek Valley watershed. To support the Bear Creek Assessment Project (BCAP), these samples were analyzed for mercury and methylmercury, as well as arsenic, cadmium, uranium metals, and polychlorinated biphenyls (PCBs). This data collection event is part of a larger undertaking, supporting the BCAP and helps the State understand impacts to ecological receptors, supports future ecological risk discussions, and provides information on the impacts of both legacy contamination and current remediation efforts.

Groundwater Monitoring

8. GROUNDWATER MONITORING OFFSITE

Offsite groundwater downgradient of the ORR is monitored by both the TDEC DoR-OR and the DOE. The purpose of TDEC's DoR-OR *Offsite Groundwater Monitoring Project* is to protect human health and the environment through monitoring offsite groundwater for possible migration of ORR legacy contamination into the adjacent surrounding area. Sampling areas vary over time, but for FY23, the location of sampling efforts were private residential water wells and springs located downgradient, to the southwest and along strike, of the ETTP. Samples were collected from eight (8) residential wells and five (5) offsite springs during FY23. No significant results were noted in any of the residential well or springs samples that were analyzed.

Landfill Monitoring

9. EMDF SURFACE WATER PARAMETERS MONITORING

The scope of the FY23 *Environmental Management Disposal Facility (EMDF) Monitoring Project* encompasses seven (7) water quality parameter monitoring locations within the central Bear Creek watershed, where temperature, pH, conductivity and dissolved oxygen were recorded monthly. These sites along Bear Creek tributaries are in and around the EMDF Landfill footprint. This project also proposed collecting semi-annual discrete water samples from four (4) locations: three (3) locations downgradient of the EMDF Surface Water Flume sites (SF-1, SF-5, and SF-6) and one (1) upgradient location (Spring D10W) to better understand contaminant conditions prior to EMDF construction and operation.

Radiological Monitoring:

10. HAUL ROAD SURVEYS

TDEC DoR-OR periodically surveyed the Haul Road and all associated landfill access roads utilized by DOE to transport waste to the landfills from the site. Surveys of these ORR routes corresponded with planned and active waste hauling operations. The main goal behind road surveys is to find any waste items that may have fallen from trucks. Eleven (11) anomalous items were observed during Haul Road surveys conducted in FY23; items were scanned by both TDEC and DOE personnel, and none of the items were found to be radiologically contaminated.

11. REAL TIME MEASUREMENT OF GAMMA RADIATION

Gamma radiation concentrations were measured in real time at four (4) locations across the ORR associated with active operations, areas with known contamination, waste management/disposal sites, and at one (1) background location. Previous sampling conducted at these stations served to document that the concentration of gamma radiation may fluctuate over time at these locations. During FY23, no monitored location exceeded the 2 mrem limit in any single-hour period, nor did any location exceed the 100 mrem per year (mrem/yr) dose limit. Monitoring will continue in the coming years as D&D of radiologically contaminated facilities accelerates at ORNL and Y-12.

12. SURPLUS SALES VERIFICATION

At the request of either Y-12 or ORNL's Excess Properties Sales Group, TDEC DoR-OR provided verification surveys of auction items for radiological contamination. These supplemental scans provide an additional measure in the release process to assure no contaminated items are sold to the public. This redundancy helps to reduce the possibility for human error. TDEC responded to two (2) pre-auction survey requests from DOE during FY23 and identified two (2) items with elevated radiological activity above background. Elevated radiological activity on these items was determined to be associated with NORM and radon, and not a result of contamination.

SURFACE WATER MONITORING:

13. AMBIENT SURFACE WATER PARAMETERS

To ascertain impacts to surface water, DoR-OR collects physical water quality data along three (3) ORR exit pathway streams (DOE, 2021) once a month. These streams included EFPC, Bear Creek, Mitchell Branch, while Mill Branch served as an offsite reference stream. The Ambient Surface Water Project is part of an ongoing State monitoring program which began in 2005. TDEC collects field parameters including conductivity, dissolved oxygen, pH, and temperature monthly from seven (7) monitoring locations. These data serve to populate a database and baseline for surface water conditions for many streams in the ORR as well as help to assess impact of remediation efforts and identify accidental releases. Though statistically significant findings were identified for conductivity and dissolved oxygen in FY23, measured parameters generally followed expected seasonal trends, and all readings were within the TDEC's *General Water Quality Criteria Chapter 0400-40-03-.03* Ambient Water Quality Criteria [AWQC] (TDEC, 2019).

14. AMBIENT SURFACE WATER SAMPLING

The purpose of the current *DOE Surface Water Monitoring Project* is to assess the impacts from both past and present site operations to surface water bodies. This similar State-led project, the *DoR-OR Ambient Surface Water Sampling Project,* supplements DOE's study of the Clinch River to support State understanding of impacts of exit-pathway streams discharging into the Clinch River. DoR-OR focused sampling efforts on the main channel of the Clinch River and its ORR exit pathway streams, which included Poplar Creek and its two (2) primary tributaries, Bear Creek and EFPC.

EFPC has been shown to receive high concentrations of both mercury and uranium. Concentrations of these metals tend to be higher near upstream locations closest to Y-12 and decrease downstream. As discharge increases downstream, the loading of metals can increase, resulting in a range of 2 to 11 grams per day (g/day) of mercury under normal flows and up to 1 to 2 kilograms per day (kg/day) of uranium during storm events. EFPC was also shown to be elevated for nutrients, with phosphorus and nitrate/nitrite above the 90th percentile for streams within ecoregion 67f (the valley and ridge region of eastern Tennessee). EFPC was shown to have elevated levels of PCBs with concentrations well over the AWQC. Location EFK 23.3 yielded total PCB concentrations at over 8 nanograms per liter (ng/L), with PCB concentrations generally decreasing downstream of Y-12.

Sampling efforts have shown that Bear Creek tends to have elevated concentrations of uranium, especially in its upper reaches. Uranium was the only metal that exceeded screening criteria in Bear Creek. Concentrations at BCK 12.3 reached 200 micrograms per liter (μg/L) on a September 2022 sampling event. Loading of uranium during fall months was found to produce nearly 300 to 900 g/day (increasing downstream). Bear Creek, an exit pathway stream, has the potential to transport uranium from the ORR to downstream receptors. In addition to uranium, Bear Creek had elevated nitrate/nitrite concentrations at BCK 12.3, with concentrations of nearly 14 milligrams per liter (mg/L). These high nitrate values are well above the 90th percentile for eco region 67f, (set at 1.22 mg/L). PCB concentrations were also elevated in Bear Creek, above TDEC's *General Water Quality Criteria Chapter 0400-40-03-.03* Ambient Water Quality Criteria (AWQC) of 0.64 ng/L downstream of BCK 9.2.

15. WHITE OAK CREEK RADIONUCLIDES MONITORING

The goal of the *White Oak Creek Radionuclides Monitoring Project* is to evaluate the impacts of DOE ORR radiological contamination to WOC, its tributaries, and the CR at the WOC confluence. Surface water samples were collected quarterly at seven (7) monitoring sites. Water samples were submitted for laboratory analysis of strontirum-90 (Sr-90), isotopic uranium, isotopic plutonium, and gamma isotopes. Elevated activities of Sr-90 were observed in surface water samples collected from six (6) of the seven (7) sampling stations.

While DOE has had ongoing projects seeking to define the sources of the strontium releases to WOC, those sources have not been fully identified, and releases are not yet mitigated. This TDEC sampling effort allows the State to continue to complete independent assessments of the impacts of contaminants in the creek. WOC ultimately discharges into the publicly accessible portions of the Clinch River including into the fishing areas addressed in the Roving Creel Survey projects described above.

16. WETLAND AT THE FILLED COAL ASH POND (FCAP)

The FCAP project focused on the engineered passive treatment wetland southeast of the Filled Coal Ash Pond, which relies on cattails for removal of coal combustion residual contaminants. Sampling was conducted to determine if the engineered wetland, which was cleaned up and rebuilt following an increasing trend in arsenic discharging from the FCAP observed during the 2016 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA [commonly known as Superfund]) Five Year Review, showed seasonal differences in contaminant uptake/removal efficiency that may be associated with seasonal die-off of cattails each year. Cattails, sediment, and surface water were collected from the wetland twice, once in the growing season and once in the dormant season. Samples were analyzed for arsenic and other coal ash contaminants. Sample sizes were low, but results are suggestive of potentially large differences in wetland efficiency across seasons.

17. BEAR CREEK ASSESSMENT PROJECT (BCAP) PHASE 4:

Bear Creek is an ORR exit pathway stream. The complete BCAP Project has gathered and compiled environmental monitoring data for a holistic assessment of the health of the watershed. This Phase 4 portion of that work scope included additional sampling data addressing toxicity and/or biomonitoring of surface water and sediment obtained to fill identified data gaps from Phase 2 sampling. Phase 4 was the final phase to conclude the complete BCAP project.

Although mercury is present in Bear Creek sediments, the concentrations do not exceed human health risk levels. Uranium sediment concentrations exceeded the resident soil screening levels (15.6 milligrams per kilogram [mg/kg]) at BCK 7.6 in June of 2022. Surface water toxicity testing results from March of 2022 showed no toxicity or inhibition of reproduction (*Ceriodaphnia dubia*) or growth (*Pimephales promelas*) at any of the sampling locations. This contrasts with the results obtained from other sampling events where we have documented toxicity impacts in prior work.

Uranium and nitrates were also observed to be elevated at the same location where the toxicity measurements were collected (BCK 12.3) at concentrations above MCL levels. (Note, MCLs are for reference only as this surface water body is not a drinking water source).

The final BCAP report provides insights of Bear Creek watershed conditions and risks prior to the construction and operation of the new EMDF landfill. This report is expected to be available in Fiscal Year 2025.

18. EAST FORK POPULAR CREEK ASSESSMENT PROJECT (EFPCAP) PHASE 2:

EFPC is also an exit pathway stream that leaves the ORR and runs directly through the City of Oak Ridge. The headwaters of EFPC are located within the Y-12 National Security Complex where the primary contaminants of concern (COCs) are mercury and uranium. The EFPCAP project team completed Phase 2 of this holistic watershed assessment during FY23. Phase 2 included sampling of surface water, biota, soils and sediments, and surface water toxicity in the EFPC. The goal was to better understand the current EFPC watershed conditions and the impacts from ORR contaminants to receptors within the watershed. It is intended that this complete effort will provide an updated "snapshot" of conditions and remaining potential risks to human health and the environment. The final EFPCAP report, planned for Fiscal Year 2025- Fiscal Year 2026, will provide insights about EFPC watershed conditions and risks given ongoing discharges of mercury from Y-12. This effort will occur prior to operation of the future OF-200 Mercury Treatment Facility.

Appendix A, Supplemental Sampling:

As reflected in the Contractual Section of the FFA Budget Narrative in the FY23 Annual Grant Application, sampling and monitoring are occasionally conducted in addition to projects planned within the published EMP. This sampling is conducted in response to new information, to assist in the State's required independent oversight, or to evaluate the effectiveness of completed remedies. During FY23 this work included storm drain sampling at the ETTP, treated wastewater sampling for PCBs, and baseline surface water sampling of streams adjacent to the EMDF site. Those results are included in Appendix A.

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1.0 INTRODUCTION

1.1 PURPOSE OF THE ENVIRONMENTAL MONITORING REPORT

The Tennessee Department of Environment and Conservation (TDEC), Division of Remediation, Oak Ridge Office (DoR-OR), provides the annual *Environmental Monitoring Report* (EMR) for fiscal year 2023 (FY23) with a period of performance from July 1, 2022, through June 30, 2023.

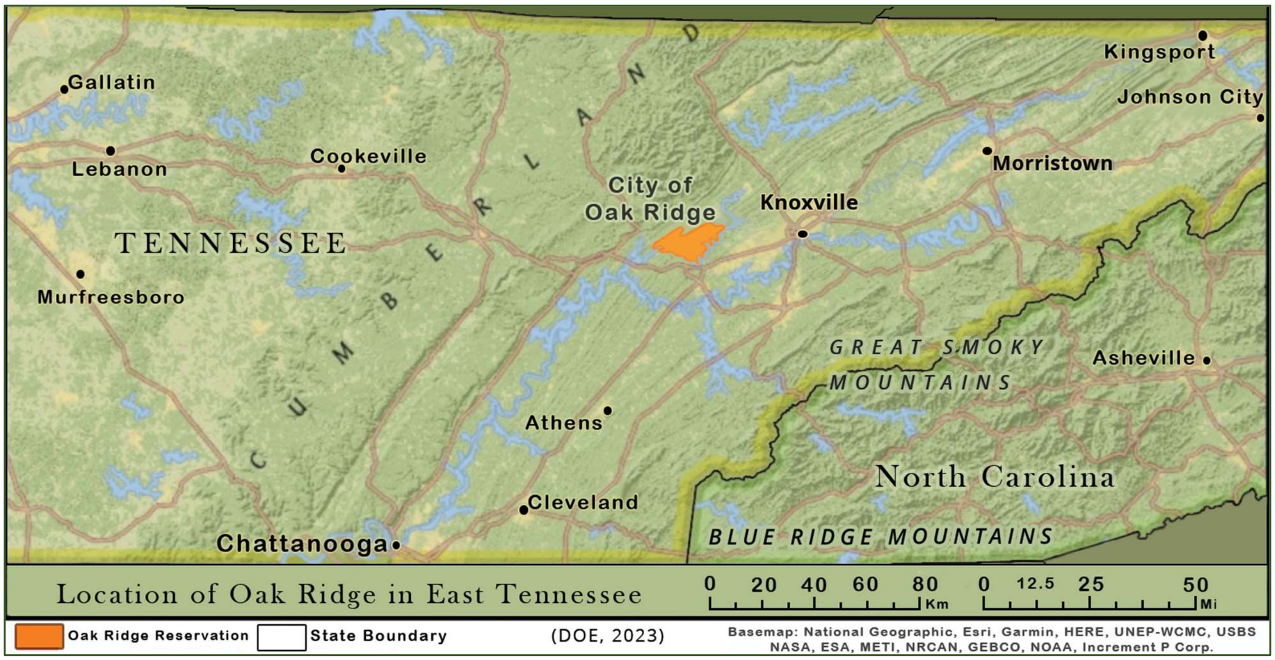


FIGURE 1.1.1: LOCATION OF OAK RIDGE IN EAST TENNESSEE

All projects defined in this EMR are found to be consistent with 40 CFR Part 300, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), and are intentionally designed to comply with the administrative and operational requirements of the *Environmental Surveillance and Oversight Agreement* (ESOA) and, additionally, in support of the *Federal Facility Agreement (FFA*). DoR-OR monitoring of current and upcoming US Department of Energy (DOE) Oak Ridge Reservation (ORR) activities is outlined in the ESOA, while the monitoring of DOE's legacy contamination management is addressed in the FFA.

DoR-OR works collaboratively co-sampling and conducting oversight of field actions with the Office of Science, National Nuclear Security Administration (NNSA), and DOE Environmental Management and their contractors. All collected data is available to the public, including to DOE or US Environmental Protection Agency (EPA) for triparty consideration, where appropriate. State sampling is conducted by DoR-OR to support comparison and correlation of results with DOE's monitoring programs. DoR-OR's monitoring program is intentionally designed and reviewed annually (1) to support active and ongoing environmental restoration decisions, (2) to help evaluate the performance of existing remedies, and (3) to make effective decisions going forward. These DoR-OR monitoring projects have been key to the State's success in this role. Project data analyses enable the State to provide decisions effectively and efficiently for the FFA Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA [commonly known as Superfund]) projects as well as to verify protectiveness to Tennesseans regarding active processes conducted at the ORR under the ESOA work scopes.

Regarding the TDEC's primary focus on ensuring protectiveness of human health and the environment within Tennessee, all DoR-OR environmental monitoring is performed to meet this mission statement. All work outlined in this EMR was performed in accordance with the *TDEC DoR-OR Technical Standard Operating Procedures* (SOPs).

Under Federal Guidelines, and to fulfill TDEC mission goals, stakeholder interests take a priority in project planning (Table 1.1.1). The key Stakeholders for this EMR include:

Table 1.1.1: Stakeholders

Stakeholders	
Citizens of Tennessee (Tennesseans)	External
Tennessee Department of Environment and Conservation (TDEC)	External and Internal
Local Governments	External
DOE and Contractors	External

1.2 Objective

The overarching objective of the DoR-OR, as outlined in this EMR, is to perform State led environmental monitoring as well as evaluate monitoring data for State oversight of current DOE activities throughout the ORR. Comparable DoR-OR monitoring results will be used to confirm yearly DOE data, as published in their Annual Site Environmental Report (ASER). This comparison will be used to gauge the performance of existing DOE remedies, and to investigate movement of legacy contamination in selected areas to evaluate the efficacy of DOE best management practices.

The DoR-OR data will be used to corroborate existing State assessment data and, if necessary, to augment DOE's separate environmental monitoring datasets. DoR-OR project teams collect data in areas where there is a higher potential for ORR emissions of any materials (i.e. hazardous, toxic, chemical, or radiological) which could impact the surrounding biota.

Each of the independent monitoring projects fall within the project areas identified below (Table 1.2.1).

Table 1.2.1: Types of Monitoring

<table>
<tr><th>Project Areas</th><th>Medium/Media</th><th>Contaminants of Concern Assessed</th></tr>
<tr><td>Air</td><td>Particulates (on RadNet and fugitive air filters)
Particulates in Precipitation</td><td rowspan="8">Radiological Materials:
Gamma spectrometry
Uranium-234/235/238
Strontium 89/90
Technetium
Transuranic isotopes, Others
Chemical Pollutants:
Polychlorinated Biphenyls and Pesticides
Volatile Organic Compounds
Semi-volatile organic compounds
Nitrates/Nitrates
Nutrients
Mixed Waste
Mercury
Metals:
Chromium
Arsenic
Cadmium
Uranium</td></tr>
<tr><td>Biota</td><td>Benthic Macroinvertebrate Taxa Health
Fish Surveys, Fish Tissue Sampling [DOE data used]
Fathead Minnow and Water Flea - toxicity study
Fish Consumption (Creel Surveys)
Food Crops/Milk/Hay
Bird egg, flying insects, ground spiders</td></tr>
<tr><td>Landfill</td><td>Surface water
Stormwater
Groundwater
Soil
Sediment</td></tr>
<tr><td>Radiological</td><td>Landfill drainage ditch (soil)
Haul Road – dropped waste
Gamma (Air)
Surplus Sales</td></tr>
<tr><td>Surface Water</td><td>Surface Water Parameters
Stream Water Sampling
Stormwater (rain event)
Accumulated water</td></tr>
<tr><td>Soil</td><td>Landfill surveys</td></tr>
<tr><td>Sediment</td><td>Suspended Sediment
Sediment (landfill runoff)</td></tr>
<tr><td>Watershed
Holistic</td><td>All sampling</td></tr>
</table>

1.3 The Oak Ridge Reservation

The ORR is comprised of three (3) major campuses:

1) **ORNL**: Oak Ridge National Lab (Formerly X-10)
2) **Y-12**: Y-12 National Security Complex (NSC)
3) **ETTP**: East Tennessee Technology Park (Formerly K-25)

ORNL currently conducts leading-edge research in advanced materials, alternative fuels, climate change, and supercomputing. Previous and ongoing ORNL research has been responsible for producing a fair amount of industrial waste. The following is a list of projects and processes that have been the source of accidental releases of contaminants into the environment:

- fuel reprocessing
- isotopes production
- waste management
- radioisotope applications
- reactor developments
- multi-program laboratory operations

Y-12 continues to be 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. As with ORNL, Y-12 operational processes have also resulted in the accidental release of radionuclides and hazardous chemicals into the environment. Additionally, as decontamination and decommissioning (D&D) remedial activities move forward, legacy contaminants may be disturbed and migrate into the surrounding environment.

ETTP, in contrast, has undergone a transition from a gaseous diffusion facility into an industrial technology park. Remediation activities continue and have reduced the amounts of legacy contaminants. DOE recently released portions of this area back to the local government and now private businesses operate businesses in this region of the ORR.

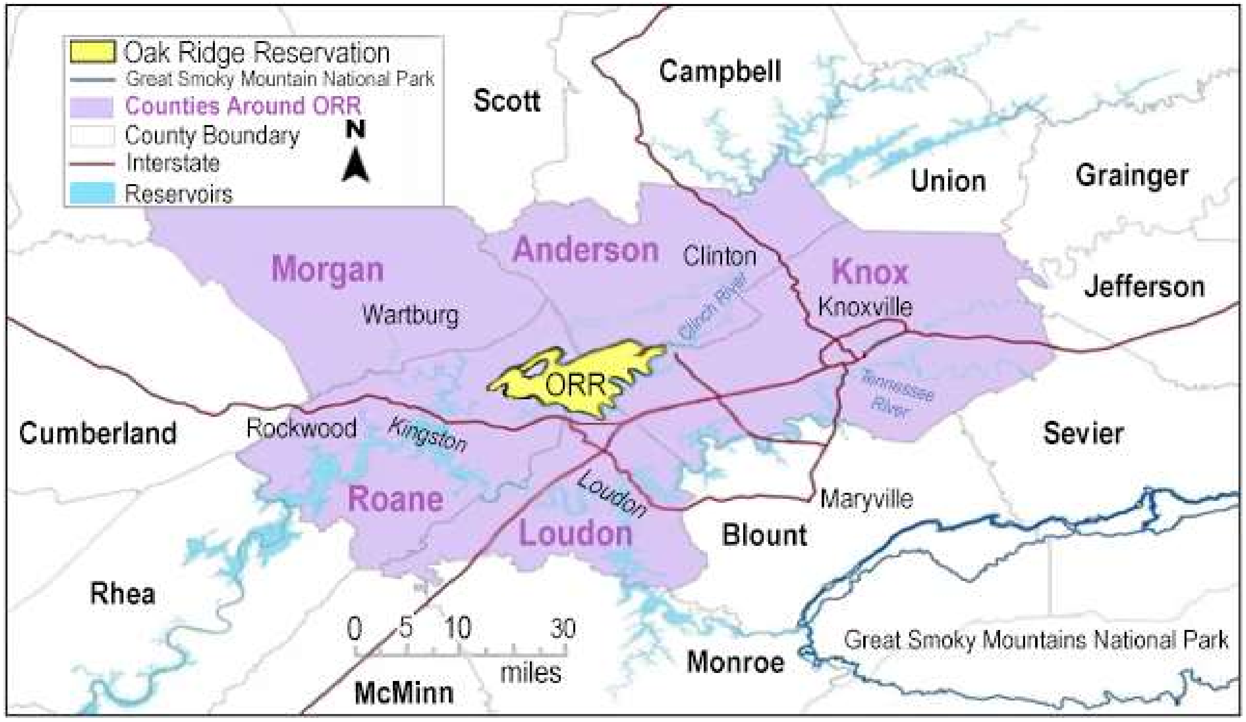


Figure 1.3.1: Location of the ORR in Relation to Surrounding Counties

1.3.1 Geography of the ORR Area

Located in the Big Valley of East Tennessee, between the Cumberland Mountains and the Great Smoky Mountains, the ORR is partially bordered to the southeast and southwest by the Clinch River. The ORR is in the southwest corner of Anderson County and the northeast region of Roane County, having one section within the corporate boundaries of the City of Oak Ridge. Counties adjacent to the reservation include Knox, Loudon, and Morgan Counties. Knox County resides east of Anderson County and is just across the Clinch River from the ORR. Also, portions of Meigs and Rhea counties reside immediately downstream from the ORR on the Tennessee River. The nearest cities to the ORR include Oak Ridge, Oliver Springs, Clinton, Kingston, Harriman, Farragut, and Lenoir City. The nearest metropolitan area, Knoxville, lies approximately 20 miles to the east.

The ORR encompasses approximately 32,500 acres of mostly contiguous land of alternating ridges and valleys in a southwest-to-northeast orientation. This section of the Valley and Ridge Province is a zone of complex geologic deposits dominated by a series of thrust faults. Sandstone, limestone, and dolomite form the underlying structure of the ridges, which themselves are relatively resistant to erosion. Weaker shales and more soluble carbonate rocks form a less stable basin for the valleys. Also, valley wind currents can differ substantially in speed and direction from the winds at higher elevations along the ridges.

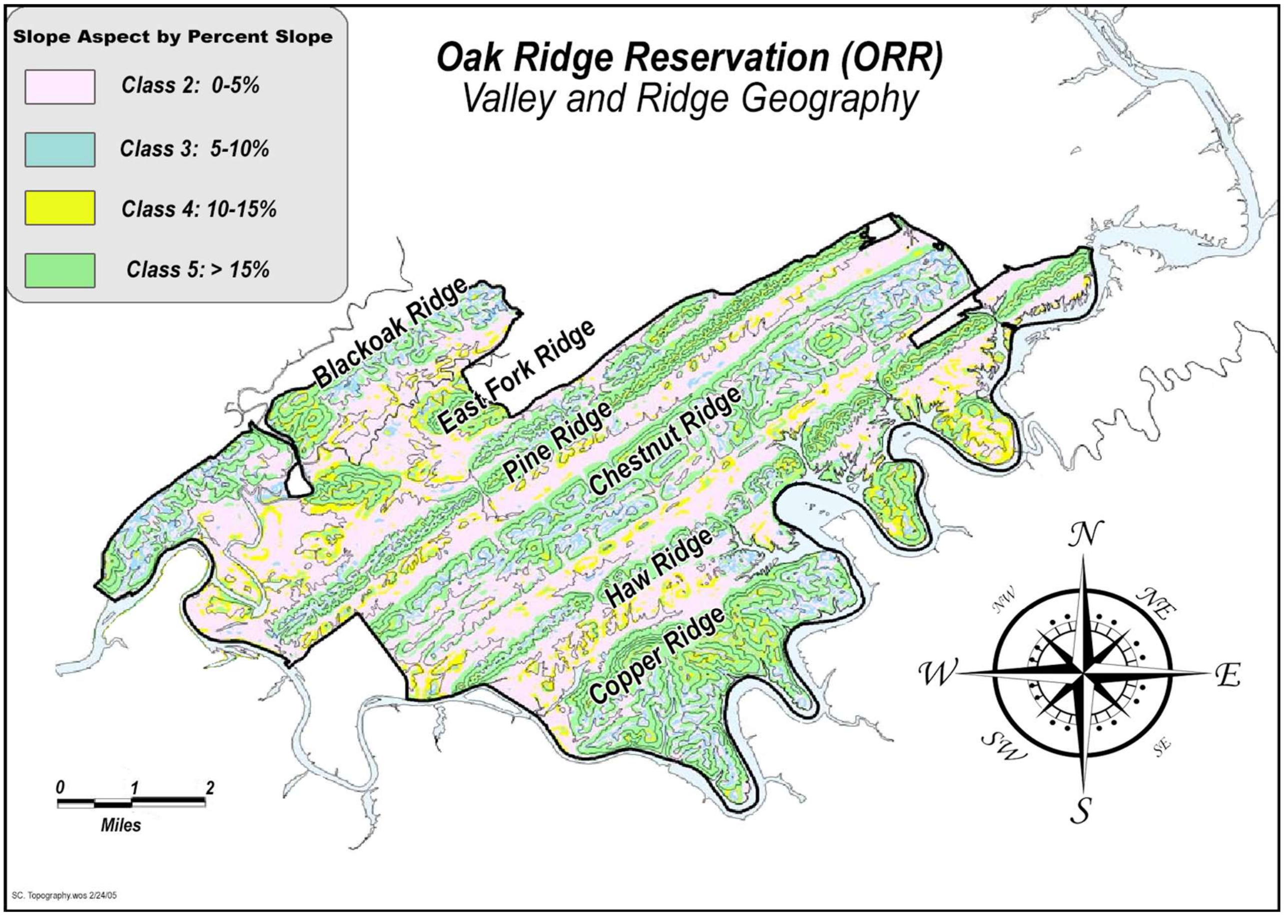


Figure 1.3.1.1: ORR Ridges (*southwest-to-northeast orientation*)

1.3.2 Climate of the ORR Area

The climate of the ORR region is classified as humid and subtropical. Local climate is characterized by a wide range of seasonal temperature changes between the summer and winter months. According to DOE (DOE, 2023),

> *…the total average rainfall in the ORR area during FY 2022 was 56.4 in. based on a composite of four rain gauge stations located throughout the ORR and at one located in Oak Ridge. The total rainfall during FY 2022 was only 0.1 in. more than the 56.3 in. determined as the 30-year moving average of rainfall measured in the City of Oak Ridge.*

The geography of this region of *The Great Valley of East Tennessee* is shaped by the Ridge-and-Valley physiography, the Cumberland Plateau, and two (2) mountain chains. These major landscape features also affect the wind flow regimes of Eastern Tennessee. Topography and climate are major factors in determining the potential for migration of contaminated media away from the ORR and into the surrounding areas.

1.3.3 Population of the ORR Area

More than one (1) million Tennesseans reside in the counties immediately surrounding the ORR. Knoxville, in Knox County, is the only major metropolitan area near the ORR. Excluding Knoxville, land use is semi-rural and made up of residences, small farms, and pastures. Popular recreation includes fishing, hunting, boating, water skiing, and swimming.

1.4 Tennessee's Commitment to Tennesseans

In accordance with the ESOA Agreement, the FFA Agreement and in line with TDEC's mission statement, DoR-OR will conduct oversight of DOE ORR activities. Our purpose is to reassure all Tennesseans that activities on and around the ORR are being managed or performed in a manner protective of human health and the environment.

2.0 Air Monitoring

2.1 Fugitive Radiological Air Emissions

2.1.1 Background

The ORR began operations in World War II as part of the Manhattan Project. Each of the three (3) ORR sites has its own contamination issues due to historical operations. While the D&D of the contaminated buildings at ETTP has been completed, cleanup and monitoring of contaminated soil and water continues. Uranium isotopes are the primary contaminants of concern (COC), but technetium-99 (Tc-99) and other fission and activation products are also present. D&D and related remediation activities across the ORR have the potential to generate fugitive airborne contamination that could pose a risk if transported offsite or pose a risk to workers on the ORR.

2.1.2 Problem Statements

Many of the ORR facilities slated for D&D are contaminated. D&D operations at these facilities, as well as removal of waste for disposal at the Environmental Management Waste Management Facility (EMWMF), could potentially result in fugitive (i.e., non-point source) dispersal of legacy contaminants. This dispersion is aided by winds traveling up and down the valleys between the ridges of the ORR. The most concerning of these legacy contaminants at the ORR sites include:

1. ETTP: uranium isotopes, Tc-99, fission and activation products
2. ORNL: uranium and plutonium isotopes, fission and activation products
3. Y-12: mercury, uranium
4. EMWMF: hazardous and low-level radioactive wastes disposal

2.1.3 Goals

To verify protectiveness of human health and the environment, DoR-OR conducted independent air sampling and compared these results to published DOE air sampling data to confirm that DOE is adequately monitoring airborne emissions of radiological contaminants. This independent monitoring is used to verify if DOE is compliant with Federal Regulatory Standards requiring that no member of the public receives an effective dose greater than 10 millirem (mrem) per year (10 CFR 20, 2024). Monitoring areas with remedial activities in progress at each of the ORR sites is the central focus of this project.

2.1.4 Scope

DoR-OR conducted the Fugitive Radiological Air Emissions Monitoring Project with continuous air monitoring at each of the ORR sites plus a comparable background location.

Sampling was conducted to check that DOE ORR radiological emissions would not cause a member of the public to receive an effective dose greater than 10 mrem per year, specifically in the areas of remedial or waste management activities. Sampler locations were selected to maximize the likelihood of collecting representative samples from potential sources of airborne contamination.

2.1.5 Methods, Materials, Metrics

The Fugitive Radiological Air Emissions Monitoring Project operated nine (9) high volume air samplers to conduct continuous air monitoring, with eight (8) on the ORR, and one (1) sampler stationed at Fort Loudoun Dam in Loudon County to collect background data for comparison and is co-located with a similar air sampler run by DOE for their ORR Ambient Air program. The remaining samplers were placed at ORR locations where the potential for release of fugitive airborne emissions was high. For example, samplers were placed near locations where contaminated soils were being excavated, contaminated structures were being demolished, or near waste disposal operations. Each of the high-volume air samplers used 8 x 10-inch glass-fiber filters to collect particulates from the air. Air was drawn through the unit at a rate of approximately 35 cubic feet per minute. To ensure accuracy, airflow through each air sampler was calibrated quarterly, using a Graseby General Metal Works variable resistance calibration kit, in accordance with the guidelines published for the air samplers.

Samples were collected from each air sampler weekly, with samples being composited every four (4) weeks and analyzed by the Tennessee Department of Health Nashville Environmental Laboratory (TDH-NEL). The analyses performed were based on the contaminants of concern and previous findings for the location being monitored.

To assess contaminant concentrations measured at each location, results were compared with the background data and the standards provided in the National Emission Standards for Hazardous Air Pollutants (NESHAPs) National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities (40 CFR 61 Subpart H, 2017), required by the EPA under the Clean Air Act. These standards associate radiological emissions to quantities that would not cause a member of the public to receive an effective dose equivalent greater than 10 mrem per year. Associated findings are reported to DOE, its contractors, and the public in this annual monitoring report.

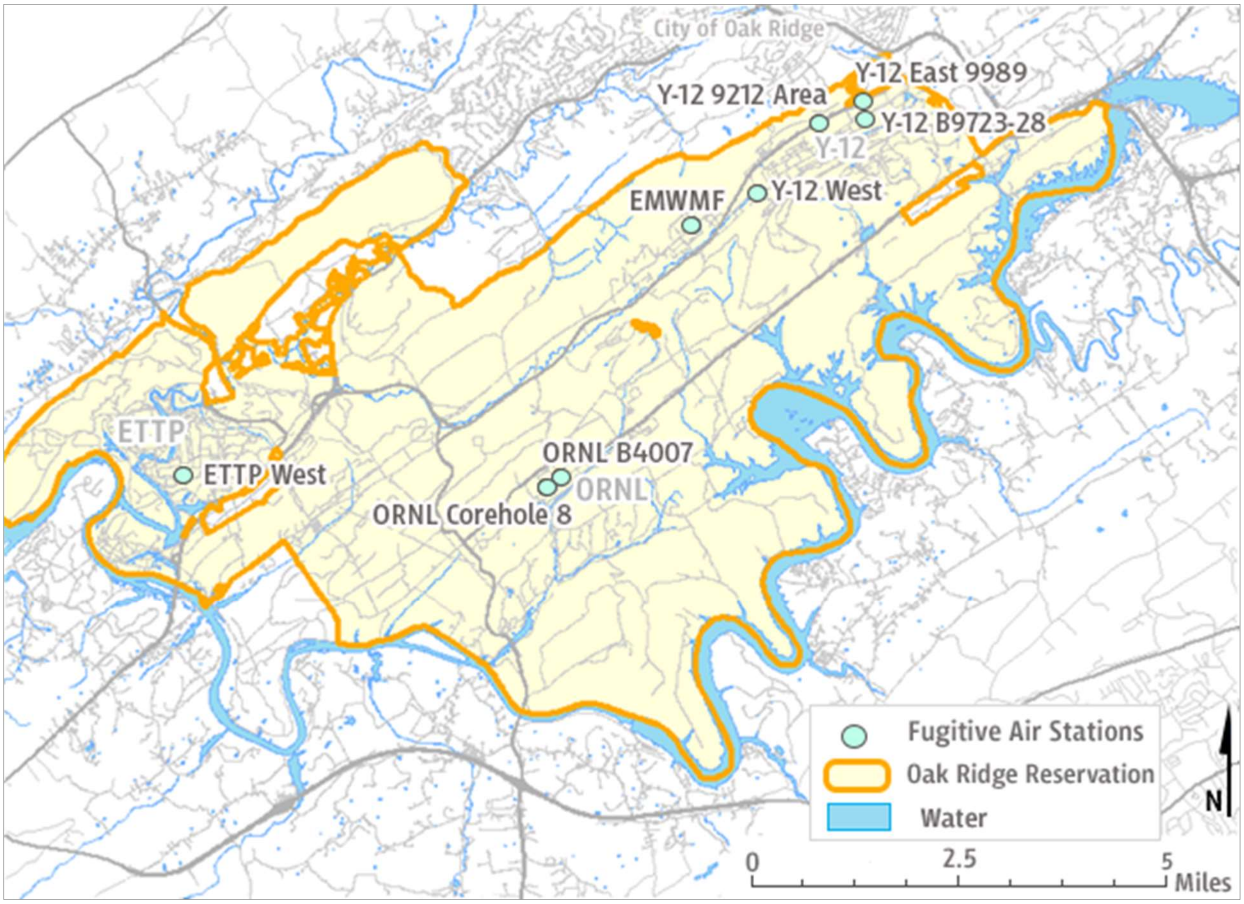


Figure 2.1.5.1: Fugitive Radiological Air Emission Monitoring Locations

2.1.6 Deviations from the Plan

The original project plan was to collect and report on the full year's data, thirteen (13) four-week composite samples per station, every month of FY23 through June 2023. However, the electrical power was turned off by Y-12 at the Y-12 East 9989 sampling location after the 11/2/2022 sampling event. The power remained off for the rest of FY23 and was not fully restored until early October of 2023.

A further deviation was the addition of another sampler at the K-25 K-11 location at ETTP as work was being done in the area, and planned funds for analysis were available due to the lack of sampling at the Y-12 East 9989 location. However, since the first results for this sampler were from 4/12/23, and a full year of data has yet to be collected, the results from this station will be included in the next EMR and are not included in this report.

2.1.7 Results and Analysis

All air monitor samples were analyzed for three (3) isotopes of uranium (U-234, U-235, U-

238). Samples from ETTP, Y-12, EMWMF, and the reference location were analyzed for Tc-99. Samples from ORNL, EMWMF, and the reference location were analyzed for gamma, but only naturally occurring isotopes (mostly naturally occurring daughter products of radon) were detected and were not included in sum of fractions calculations. Results are shown in the tables below. When the sum of fractions is less than one, no regulatory limits were exceeded.

ETTP

One (1) fugitive radiological air monitor was placed at ETTP southwest of the original site of the K-25 Gaseous Diffusion Plant and at the current west end of the ETTP site. The results show that no radiological limits were exceeded. A sampler was also placed at the K-25 K-11 area at ETTP, but the first results from this sampler were from 4/12/23 and will be included in the next EMR, once there is a year's worth of data to average.

Table 2.1.7.1: ETTP West Air Monitoring Average Results for (pCi/m^3)

ETTP West Sampling location	U234	U235	U238	Tc-99	SOF
Average FY23 (July 2022 - June 2023)	8.88E-05	1.44E-05	5.02E-05	4.86E-04	
Average background	6.04E-05	1.57E-05	4.73E-05	7.21E-04	
Net Activity (Avg. minus background)	2.85E-05	-1.29E-06	2.89E-06	-2.35E-04	
40CFR Part 61 Limit, Appendix E, Table 2	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of Limit (Net/Limit)	3.70E-03	0	3.48E-04	0	0.00404

Note: Levels < background ≈ zero; no negative values and no effect on sum of fractions (SOF)

Y-12

Four (4) air samplers were located at Y-12 in FY23. Results are listed in Table 2.1.7.2 for the Y-12 building 9212 area. The sum of fractions of less than one indicates that regulatory limits were not exceeded.

Table 2.1.7.2: Y-12 Building 9212 Area Air Monitoring Average Results (pCi/m^3)

Y-12 9212 Sampling Location	U-234	U-235	U-238	Tc-99	SOF
Average FY23 (July 2022 - June 2023)	6.84E-04	2.49E-04	2.04E-04	2.14E-04	
Average background	6.04E-05	1.57E-05	4.73E-05	7.21E-04	
Net Activity (Avg. minus background)	6.24E-04	2.33E-04	1.56E-04	-5.06E-04	
40CFR Part 61 Limit, Appendix E, Table 2	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of Limit (Net/Limit)	8.10E-02	3.28E-02	1.88E-02	0	0.133

Note: Levels < background ≈ zero; no negative values and no effect on sum of fractions (SOF)

In table 2.1.7.3, the results are shown from the Y-12 Building 9723-28 area. The sum of fractions of less than one indicates that regulatory limits were not exceeded.

Table 2.1.7.3: Y-12 Building 9723-28 Area Air Monitoring Average Results (pCi/m³)

Y-12 B9723-28 Sampling Location	U-234	U-235	U-238	Tc-99	SOF
Average FY23 (July 2022 - June 2023)	8.28E-05	7.44E-05	8.39E-05	1.08E-04	
Average background	6.04E-05	1.57E-05	4.73E-05	7.21E-04	
Net Activity (Avg. minus background)	2.25E-05	5.87E-05	3.67E-05	-6.13E-04	
40CFR Part 61 Limit, Appendix E, Table 2	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of Limit (Net/Limit)	2.92E-03	8.27E-03	4.42E-03	0	0.0156

Note: Levels < background ≈ zero; no negative values and no effect on sum of fractions (SOF)

A full year's worth of data was not available for the Y-12 East 9989 area sampling location due to a long power outage. The sampler only ran for 18 weeks in FY23. The averaged available data did not indicate any exceedances for the time run.

Table 2.1.7.4 shows the results from the samples taken at the Y-12 West area. The sum of fractions of less than one indicates that regulatory limits were not exceeded.

Table 2.1.7.4: Y-12 West Air Monitoring Average Results (pCi/m³)

Y-12 West Sampling Location	U-234	U-235	U-238	Tc-99	SOF
Average FY23 (July 2022 - June 2023)	7.53E-05	1.22E-05	5.22E-05	4.48E-04	
Average background	6.04E-05	1.57E-05	4.73E-05	7.21E-04	
Net Activity (Avg. minus background)	1.49E-05	-3.46E-06	4.93E-06	-2.73E-04	
40CFR Part 61 Limit, Appendix E, Table 2	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of Limit (Net/Limit)	1.93E-03	0	5.94E-04	0	0.00252

Note: Levels < background ≈ zero; no negative values and no effect on sum of fractions (SOF)

EMWMF

One (1) station is located at EMWMF mixed waste disposal facility in Bear Creek Valley west of Y-12. Analyses for these samples included isotopic uranium, Tc-99, and gamma analysis. No elevated impacts were noted (Table 2.1.7.5) and the sum of fractions of less than one indicates that regulatory limits were not exceeded.

Table 2.1.7.5: EMWMF Air Monitoring Average Results (pCi/m³)

EMWMF Sampling Location	U-234	U-235	U-238	Tc-99	SOF
Average FY23 (July 2022 - June 2023)	7.63E-05	6.67E-05	7.43E-05	1.13E-04	
Average background	6.04E-05	1.57E-05	4.73E-05	7.21E-04	
Net Activity (Avg. minus background)	1.59E-05	5.10E-05	2.70E-05	-6.07E-04	
40CFR Part 61 Limit, Appendix E, Table 2	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of Limit (Net/Limit)	2.07E-03	7.19E-03	3.26E-03	0	0.01251

Note: Levels < background ≈ zero; no negative values and no effect on sum of fractions (SOF)

ORNL

Two (2) fugitive air monitors were operated at ORNL. Analyses for samples from these stations included isotopic uranium and gamma spectrometry. The gamma spectrometry results are not shown below because only naturally occurring daughter products of radon were detected. No instances of elevated levels were noted, and the sum of fractions of less than one indicates that regulatory limits were not exceeded.

Table 2.1.7.6: ORNL B4007 Air Monitoring Average Results (pCi/m³)

ORNL B4007 Sampling Location	U-234	U-235	U-238	SOF
Average FY23 (July 2022 - June 2023)	5.04E-05	9.48E-06	4.13E-05	
Average background	6.04E-05	1.57E-05	4.73E-05	
Net Activity (Avg. minus background)	-1.00E-05	-6.21E-06	-5.96E-06	
40CFR Part 61 Limit, Appendix E, Table 2	7.70E-03	7.10E-03	8.30E-03	
Fraction of Limit (Net/Limit)	0	0	0	0

Note: Levels < background ≈ zero; no negative values and no effect on sum of fractions (SOF)

Table 2.1.7.7: ORNL Corehole 8 Air Monitoring Average Results (pCi/m³)

ORNL Corehole 8 Sampling Location	U-234	U-235	U-238	SOF
Average FY23 (July 2022 - June 2023)	5.18E-05	6.68E-06	4.35E-05	
Average background	6.04E-05	1.57E-05	4.73E-05	
Net Activity (Avg. minus background)	-8.55E-06	-9.01E-06	-3.81E-06	
40CFR Part 61 Limit, Appendix E, Table 2	7.70E-03	7.10E-03	8.30E-03	
Fraction of Limit (Net/Limit)	0	0	0	0

Note: Levels < background ≈ zero; no negative values and no effect on sum of fractions (SOF)

2.1.8 Conclusions

The average annual concentrations, minus background, for all sites, were below the federal standards for each isotope measured.

This project's shorter composite interval of every four (4) weeks can result in a timelier observation of potential problems than other available sampling programs such as the DOE program which analyzes quarterly composite samples. Their program averages four (4) composite samples per station annually, versus the thirteen (13) annual composites analyzed per station annually with the DoR-OR project.

In the past, the TDEC DoR-OR independent monitoring project's Tc-99 analysis was useful in identifying a calculation error in DOE's ETTP Perimeter Sampling Program (with the error on the part of DOE's contracted laboratory) that reported results that were ten percent (10%) of the actual calculated values. Results from this program continue to be used by DOE contractors for comparison purposes.

2.1.9 Recommendations

DoR-OR should continue routine fugitive radiological air monitoring on the ORR and should review the current monitoring locations as well as consider sampling modifications according to DOE activities on the ORR. The air monitoring plan for the DOE's EMP was reviewed. This project team suggests more frequent analysis and high-volume site-specific monitoring by DOE at Y-12 and ORNL in addition to the ORR ambient air perimeter monitoring.

2.1.10 References

40 CFR 61, Subpart H. 2023. *Title 40 of the Code of Federal Regulations, Chapter 1, Subchapter C, Part 61 National Emission Standards for Hazardous Air Pollutants (NESHAPS)*, Subpart H *National Emission Standards for Emissions of Radionuclides Other than Radon From Department of Energy Facilities*. National Archives. Washington, DC. https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-61/subpart-H

DOE. 2022. Oak Ridge Reservation Annual Site Environmental Report (ASER). DOE-SC-OSO/RM-2022-01. https://doeic.science.energy.gov/ASER/aser2021/index.html

ORAU. 2003. NIOSH Dose Reconstruction Project. Oak Ridge National Laboratory (ORNL). Oak Ridge, TN. ORAUT-TKBS-0012-2. https://www.cdc.gov/niosh/ocas/pdfs/arch/ornl2.pdf

2.2 RadNet Air

2.2.1 Background

The average adult inhales about 16,000 liters of air per day. By this measure, good air quality is essential to human health (EPA, 2011). To evaluate this health concern, TDEC DoR-OR implemented three (3) historical and ongoing air monitoring projects to assess the potential impacts of ORR air emissions. The effectiveness of DOE controls and monitoring systems were also verified. The *RadNet Air Monitoring Project* provides additional monitoring to DOE along with independent third-party air quality analysis.

This ORR project began in 1996 and currently provides radiochemical analysis of air particulate samples, which were collected twice weekly from four (4) air monitoring stations. Stations were constructed near potential sources of radiological air emissions on the ORR campuses. RadNet samples were collected by project staff and analysis was performed at the EPA National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama.

2.2.2 Problem Statements

The three (3) campuses on the ORR (ORNL, Y-12, and ETTP), could potentially release legacy contaminants due to D&D or general deterioration of contaminated buildings and become airborne. Radioactive contaminants could also be released into the air from current operations. As the known contaminated buildings at ETTP have been removed, this project now focuses sampling at Y-12 and ORNL.

2.2.3 Goals

1) Protect human health and the environment by continuous evaluation of airborne gross beta activity on the ORR, confirming levels do not go above EPA regulatory levels.
2) Provide a more thorough data set by compiling RadNet Air data with the data from the Fugitive Air project, using RadNet's analysis for airborne gross beta analysis to supplement evaluations. RadNet when triggered, also provides further gamma analysis.
3) Provide DOE with additional airborne radiochemical analysis data to add to their own data set.

2.2.4 Scope

The scope of this project includes the continuous monitoring for airborne gross beta contamination on the ORR at nine (9) sampling stations plus one (1) background site. Stations were sampled twice per week and compared with background samples (Fort Loudon Station or EPA's Knoxville Station). These stations are located on each of the three (3) campuses.

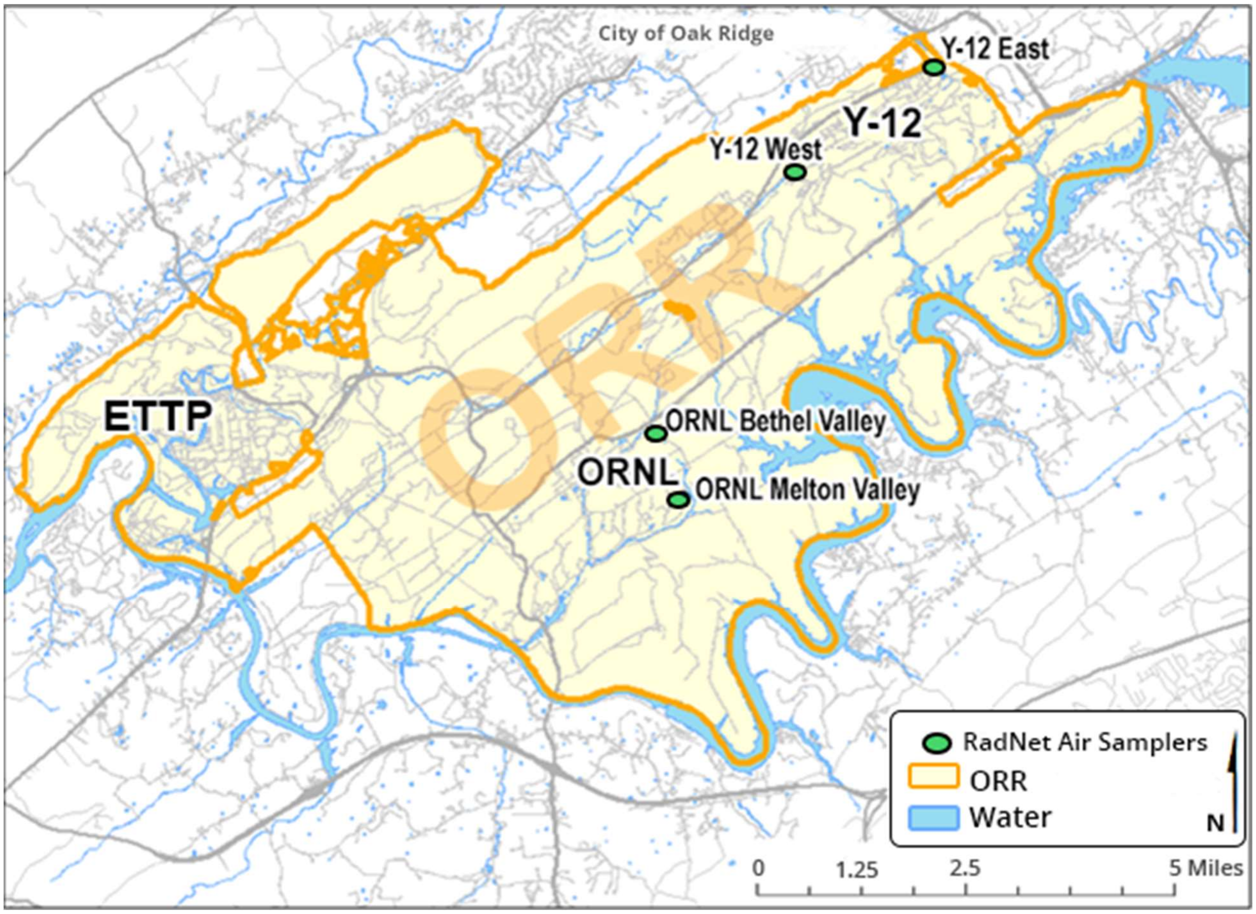


Figure 2.2.4.1: *RadNet Air Monitoring Stations* on the ORR

2.2.5 Methods, Materials, Metrics

The *RadNet Air Monitoring Project* uses nine (9) high-volume air samplers to monitor for airborne radiological contamination (Figure 2.2.4.1). The RadNet Air samplers were run continuously, and suspended particulates were collected on synthetic fiber filters (10 centimeter diameter). Air was drawn through the units by a pump at approximately 35 cubic feet per minute (60 cubic meters per hour). Project personnel collected the filters twice weekly from each ORR sampler on Mondays and Thursdays. Following EPA protocol (EPA, 1988; EPA, 2006), the filters were then shipped to NAREL in Montgomery, Alabama, for analysis.

EPA NAREL performed gross beta analysis on each sample collected. If the gross beta result for a sample exceeded 1 pCi/m^3, then gamma spectrometry was performed on that sample. Additionally, gamma spectrometry was performed on the annually composited sample for FY23 at each station. Once every four (4) years, EPA performs uranium and plutonium isotopic analysis on these yearly composites.

The analytical results of all RadNet Air data are available at NAREL's website. The Envirofacts RadNet page has a searchable database which allows for simple or advanced searches (EPA, 2023).

The gross beta data from each ORR air monitor was compared to data from the Knoxville Station. This data was also compared to the EPA Clean Air Act (CAA) environmental limit for strontium-90 (a pure beta emitter with a conservative limit) (EPA, 2023).

Each year nearly 400 ORR samples are analyzed for this project. While gross beta analysis is used as a screening tool, much lower levels were seen overall, with an average minimum detectable concentration of about 0.000292 pCi/ m^3 from 2013 through 2023 and gross beta results averaging .01037 pCi/ m^3.

Table 2.2.5.1: RadNet Air Analyses and Frequencies

	FREQUENCY
Gross Beta	Each twice weekly sample is analyzed by EPA
Gamma Scan	As needed on samples showing greater than 1 pCi/m^3 of gross beta and annually on composite samples
Plutonium-238, 239, 240 Uranium-234, 235, 238	Every four (4) years on an annual composite from each station (started in 2014, previously analyzed annually)

2.2.6 Deviations from the Plan

There were no deviations from the planned work for the ORR RadNet Air Monitoring Project.

While the Knoxville RadNet Air monitor is not a part of the ORR RadNet Air project and is only used for comparison as a background location, it only ran at the same flow rate used at the ORR stations for the last three (3) months of FY23.

2.2.7 Results and Discussion

As noted, the results of NAREL's analyses of the nationwide RadNet Air sampling are available on the Envirofacts RadNet webpage (EPA, 2023).

The ORR gross beta results for the *RadNet Air Monitoring Project* from July 2022 through June 2023 were all well below 1.0 pCi/m^3, which is the screening level that triggers further analysis. As seen in Figure 2.2.7.1, the FY23 results for the gross beta analysis were similar for all four (4) ORR RadNet stations and the Knoxville RadNet Air station. The variations during the different sample periods are largely attributable to natural phenomena (wind and rain) that influence the amount of particulate suspended in the air and ultimately deposited on the filters.

While fluctuations were similar between results from the ORR and Knoxville stations, one can see that the gross beta activity was generally higher at ORR stations than at the background station. Some of the differences between the ORR RadNet Air stations and the background station in Knoxville may be attributed to differences in weather as well as the collection schedules and the distance between the locations. However, the largest contributor to this difference was that the Knoxville Station ran at a reduced flow rate for most of FY23, resulting in less air particulate collected and less beta activity. The results from the Knoxville station are more comparable once the levels were adjusted to run at the standard air flow used at the ORR locations, which was re-adjusted in March 2023.

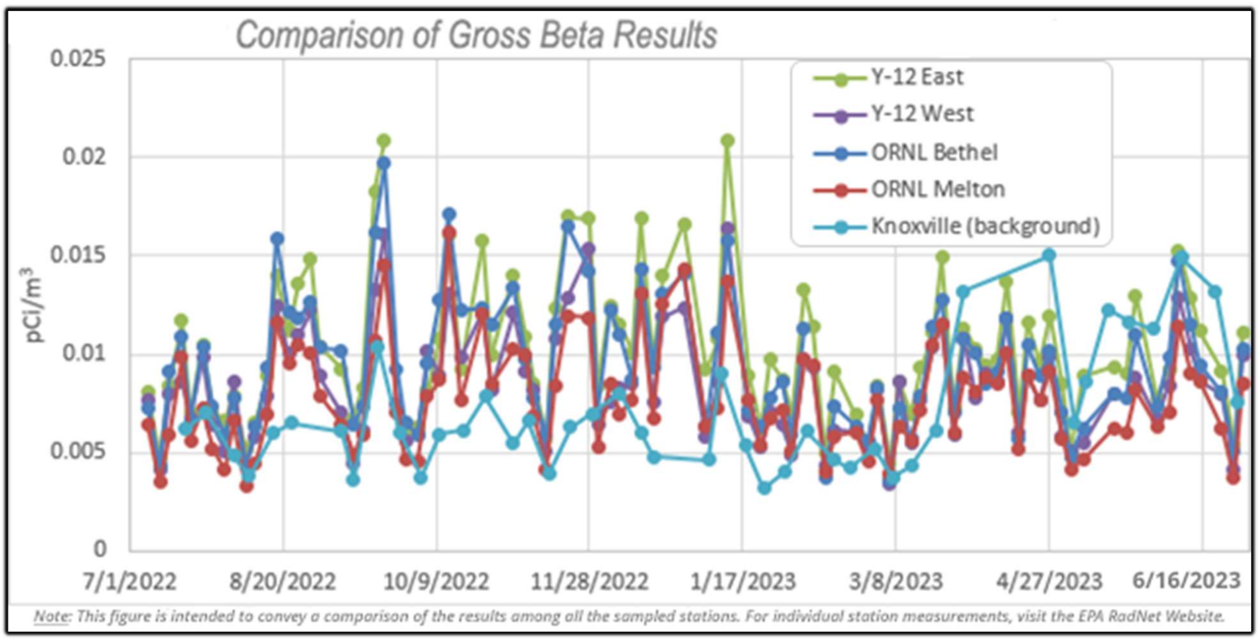
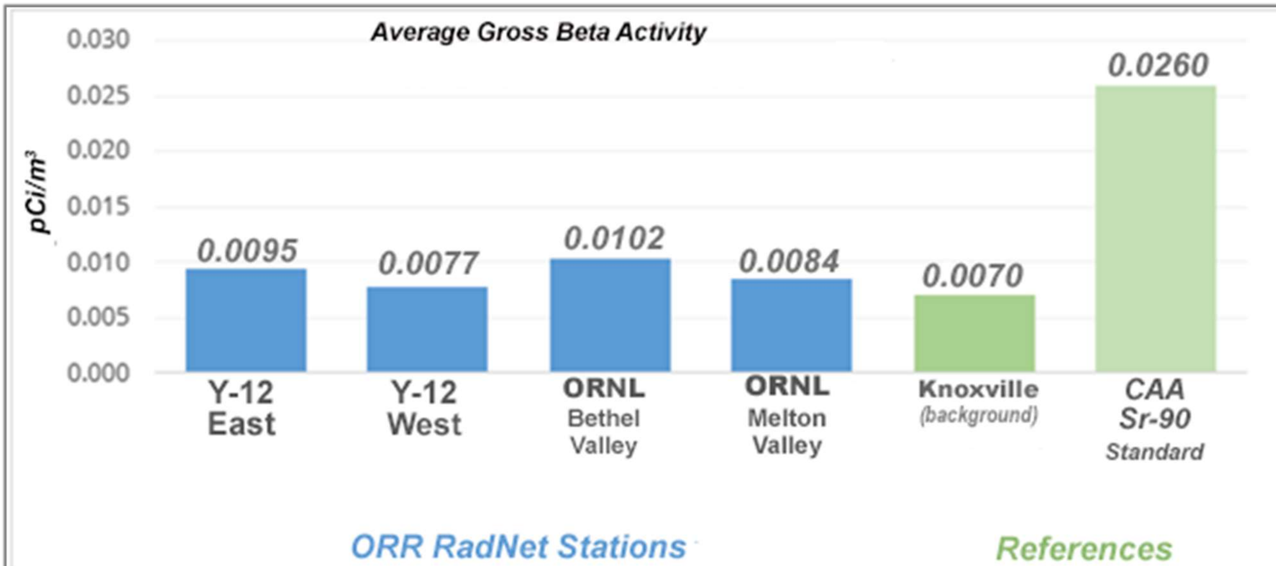


Figure 2.2.7.1: FY23 *RadNet Air Monitoring Project* Gross Beta Results

Figure 2.2.7.1 depicts the FY23 average gross beta results for each of the four (4) stations in the ORR *RadNet Air Monitoring Project*. This figure also shows the average background concentration measured at the Knoxville RadNet location and the CAA environmental limit for strontium-90. The average gross beta activity at all four (4) ORR stations was higher than the average activity at the background Knoxville location; however, much of this appears to be due to that air monitor running at a reduced flow rate for much of FY23.

The CAA specifies that exposures to the public from airborne radioactive materials released from DOE facilities shall not cause members of the public to receive an effective dose equivalent greater than 10 mrem above background measurements per year. For point-source emissions, compliance is usually determined with air dispersion models that predict the dose at offsite locations, where the public could be exposed. The CAA via NESHAPS also provides environmental concentrations for non-point source radionuclides that would result in an equivalent dose of 10 mrem per year (40 CFR 61 H, 2023) to determine compliance.



Note: typical background values for gross beta range from 0.005 to 0.1 pCi/m³ (ORISE, 1993). The standards provided by the Clean Air Act (CAA) apply to the dose above background; therefore, the standard provided for reference in this figure has been adjusted to include the average of all background measurements taken from the RadNet Station in Knoxville for the sample time period. Knoxville Station's Sr-90 is 0.019 pCi/m³ + the annual average of gross beta at the background station = CAA environmental standard for Sr-90. This standard is used as a screening limit and is provided here for comparison.

Figure 2.2.7.2: FY23 *RadNet Air Monitoring Project* Average Gross Beta Results

To evaluate this air quality data, the *RadNet Air Monitoring Project* compared the average gross beta results to the CAA limit for strontium-90. This strontium-90 limit is one of the most stringent standards out of all the beta-emitting radionuclides. The CAA standards apply to the dose above background, so the limit represented in Figure 2.2.7.2 was adjusted to include the average gross beta measurement taken at the Knoxville Station. An important detail to note is that strontium-90 is unlikely to be a large contributor to the total beta measurements reported here and is used only as a reference point to determine if further analysis is warranted.

While the FY23 results at all the RadNet Air stations showed that sites responded in a similar pattern during sampling, the average gross beta results were lower at the Y-12 West and the ORNL Melton Valley stations. Slightly higher average gross beta levels were found at the other two (2) ORR locations. The average results from each of the ORR RadNet monitoring stations were well below the strontium-90 limit (Figure 2.2.7.2).

In FY 23, none of the ORR gross beta results exceeded the screening level (1.0 pCi/m^3). And results from 2013 through 2022, showed an average minimum detectable concentration (MDC) of 0.000292 pCi/ m^3. In this case, while a concentration at or above 1 pCi/m^3 triggers gamma spectrometry, concentration levels as low as 0.000292 pCi/m^3 can be detected and comparisons can be made. The actual MDC for each sample is sample-specific but it is usually close to the average MDC across samples.

The 4-year analysis for isotopic uranium and plutonium was performed in 2018 and, more recently, in 2022. Each of the four (4) yearly composite samples from the ORR were analyzed. The previous FY 2018 composite results, presented in a prior report, included the 2020 gross beta data. All values for each isotope were below the limits established by the CAA. The composite analysis of the 2022 samples was completed recently. The results are listed in Table 2.2.7.1 with units in aCi/m^3. An attocurie (aCi) represents 10E-18 curies, while a picocurie (pCi) represents 10E-12 curies. This table lists individual values for each of the ORR sites as well as some reference values: the average and maximum values for the ORR, background locations (Knoxville, Memphis, and an average of the corresponding national stations), as well as the CAA standard limits. The CAA standard limits refer to the concentration level allowable above background and were much higher than any of the Tennessee results, or even the national results. In Tennessee, all stations' isotopic plutonium results (Pu-238, Pu-239) were less than the associated MDCs. For isotopic uranium (U-234, U-235, U-238), the ORR average results were comparable to or less than the background results.

The highest results (highlighted in light yellow in Table 2.2.7.1) were almost always from background locations far from ORR. The one exception was the composite U-234 from the Y-12 West location (32.3 aCi/m^3). Overall, the ORR composite results for isotopic plutonium and uranium were well below limits established by the CAA.

Table 2.2.7.1: 2022 RadNet Air Composite Results for Plutonium and Uranium

RadNet Air Composite Analysis for Plutonium and Uranium

	Y-12 East	Y-12 West	ORNL Bethel	ORNL Melton	ORR Average	ORR Maximum	Background Knoxville	Background Memphis	Background National Average*	CAA standard (amount above background)
Pu-238	-0.066	-0.097	0.034	-0.019	-0.037	0.034	0.154	-0.061	0.036	2100
Pu-239	-0.011	0	0.011	0.026	0.0065	0.026	0.033	-0.061	0.103	2000
U-234	14.9	32.3	10.3	3.7	15.3	32.3	6	18	17.2	7700
U-235				0.35			0.45	1.61	1.01	7100
U-238	12.6	15.1	7.9	4.0	9.9	15.1	5.44	15.8	15.6	8300

Units in ***aCi/m³*** *Plutonium (Pu) Uranium (U)* * includes RadNet sites with 2022 data. Highest Results

The 2022 composite gamma analysis for ORR RadNet sites were available for comparison. All Tennessee locations with data (Oak Ridge, Knoxville, Memphis) had results for:

1) beryllium-7 (naturally occurring)
2) potassium-40
3) sodium-22
4) radium-228 (for most)
5) cesium-137
6) cobalt-60

All results were below MDCs. One result for naturally occurring aluminum-26 at the ORNL Bethel Valley station and was over the MDC at 3.2 aCi/m^3. However, this concentration is much lower than the compliance limit of 4,800 aCi/m^3 over background.

2.2.8 Conclusions

The gross beta results for each of the four (4) RadNet Air monitoring stations exhibited similar trends and concentration levels for the period of July 2022 through June 2023 (FY23). All the data during this period was well below the levels which would warrant further analysis and none of the results indicated that activities on the ORR posed a significant impact on the environment or public health.

2.2.9 Recommendations

The project team recommends the continuation of ORR monitoring for airborne radiological contaminants. Currently, three (3) DoR-OR projects focus on the detection of these contaminated particulates. The combined efforts will help to ensure that air quality is protective of human health and the environment.

Monitoring is especially important because of the upcoming demolition of contaminated buildings, movement of contaminated soils, ongoing operations, and other remedial and construction activities on the ORR. All these activities have the potential to impact air quality. In the event of a radiological release on or around the ORR, the *RadNet Air Monitoring Project* could provide valuable information on the extent of airborne radiological contamination before, during, and after the release.

The *RadNet Air Monitoring Project* is a valuable addition to DOE air monitoring for three (3) main reasons. First, the annual RadNet Air sampling collects and analyzes more samples than the yearly DOE air monitoring. This project's monitoring includes twice weekly sampling with approximately 100 samples analyzed yearly for the four (4) ORR stations.

Second, gross beta analysis can also be used to detect much lower levels with low, sample specific MDCs. The lower MDCs levels can be very effective in detecting elevated gross beta levels and other variation. Third, gross beta analysis is an effective screening tool since few isotopes of interest are pure gamma or pure beta emitters. If a release occurred on the ORR, beta radiation would likely be emitted either directly or from daughter products. Results would be delayed due to NAREL analysis; however, this project's data would detect an increase in radiological levels in the air. This data would better pinpoint the time of release through comparison of DoR-OR twice weekly samples versus the DOE quarterly composites of weekly air filters.

2.2.10 References

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2.3 RadNet Precipitation

2.3.1 Background

Nationwide, the RadNet Precipitation Monitoring Program measures radioactive contaminants that are carried to the earth's surface by precipitation. On the ORR, the *RadNet Precipitation Monitoring Project* provides radiochemical analysis of precipitation samples taken from three (3) monitoring locations. Samples are collected by DoR-OR project staff based on EPA protocols. The gamma spectrometry analysis is performed on monthly composite samples at EPA's NAREL in Montgomery, Alabama. While there are no regulatory standards that apply directly to contaminants in precipitation, the data from this project could potentially provide an indication of the presence of radioactive materials that may not be evident in the particulate air samples.

2.3.2 Problem Statements

The two (2) campuses on the ORR with the greatest potential for releasing airborne radioactive contaminants are ORNL and Y-12. Contaminants released from previous and current operations are a concern. Airborne legacy contaminants could potentially be released from the deterioration of contaminated buildings and the D&D of these facilities.

2.3.3 GOALS

The goal of the *RadNet Precipitation Monitoring Project* is to measure radioactive contaminants that are washed out of the atmosphere and reach the earth's surface through precipitation. This is an additional methodology to possibly capture and measure radioactive contaminants in the environment. It compares sampling results to drinking water limits used by EPA (as conservative reference values only) to assure the public that human health and the environment are being protected.

The results from the project can also be used to identify anomalies in radiological contaminant levels, to assess the significance of precipitation in contaminant pathways, to evaluate associated control measures, to appraise conditions on the ORR compared to other locations in the nationwide EPA RadNet Program, and to determine levels of local contamination in the case of a local or distant nuclear disaster.

2.3.4 SCOPE

Four (4) precipitation samplers are used to monitor the precipitation for radiological contamination. Each sampler is co-located with a RadNet Air Station, at three (3) locations on the ORR. The first sampler is located at the east end of the Y-12 plant. This station is positioned to potentially provide an indication of radioisotopes traveling toward the City of Oak Ridge from the ORR. The second sampler is at ORNL in Bethel Valley, east of the main plant area. The third sampler is located at ORNL in Melton Valley, in the vicinity of the High Flux Isotope Reactor (HFIR) and the Solid Waste Storage Area (SWSA) burial grounds. Samples were measured and collected on Mondays and Thursdays, except when skipped due to a holiday. Station locations are shown in Figure 2.3.4.1. The precipitation samples were composited monthly at the EPA laboratory and analyzed for gamma radionuclides. Additional analysis on individual samples would likely be conducted in the event of elevated findings or for a nuclear release.

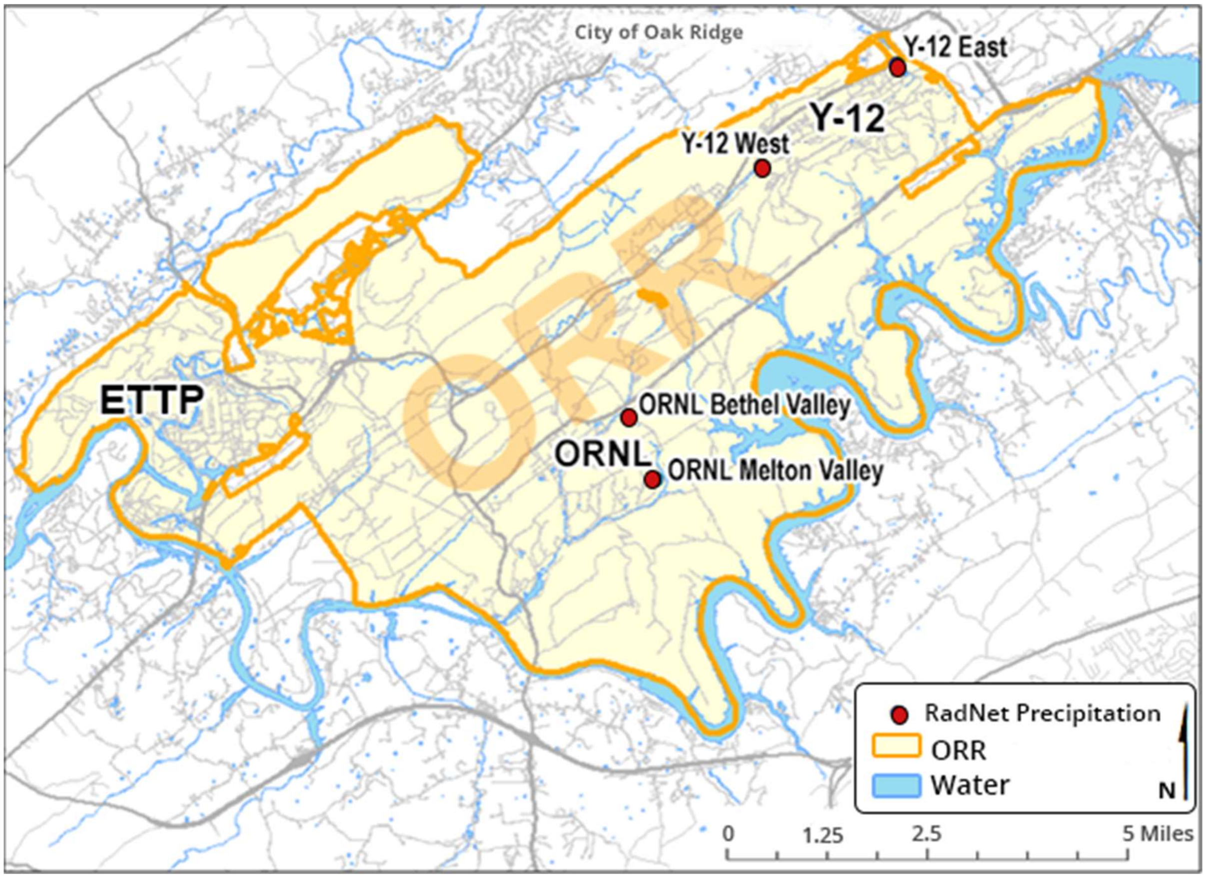

Figure 2.3.4.1: ORR RadNet Precipitation Samplers

2.3.5 Methods, Materials, Metrics

The four (4) precipitation samplers provided by the *EPA RadNet Program* were used to collect samples on the ORR. Samples were measured and collected on Mondays and Thursdays. On occasion, a holiday fell on a sampling day and the sample was rescheduled for a later date.

Each RadNet Precipitation sampler drains precipitation that falls on a 0.5 square meter fiberglass collector into a five-gallon collection bucket. Each sample was measured, then collected from the bucket into a four-liter container. Once a minimum of two liters of precipitation has accumulated or when the final sample of the month is collected, the sample is ready to ship. Each sample is processed as specified by EPA (EPA, 1988; EPA, 2017) and then shipped to NAREL for analysis.

NAREL composites monthly samples for each station and analyzes the samples for gamma emitting radionuclides. Additional analysis may be conducted if there is a known radiological release or in the event of elevated findings in the monthly gamma analysis results. The gamma analysis functions as a screening tool because few isotopes of interest are pure beta or pure gamma emitters, so if there were a release on the ORR, it is likely there would be some gamma radiation emitted either directly or from daughter products. Alpha and beta radiation could also be emitted but would not be directly measured by gamma analysis.

As mentioned, no regulatory limits for radiological contaminants in precipitation exist, so the results of the TDEC DoR-OR ORR sampling gamma analyses are compared to drinking water limits established by the EPA as conservative reference values. In general, EPA's Radionuclides Rule (EPA, 2000) for drinking water allows gross alpha levels of up to 15 picocuries per liter (pCi/L), while beta and gamma emitters are limited to 4 mrem per year and are radionuclide specific (EPA, 2015). Table 2.3.5.1 shows the maximum contaminant levels (MCLs) of beta and gamma emitters that EPA uses as drinking water limits, for select isotopes. Not all gamma producing isotopes have EPA drinking water limits, for example Potassium-40 and Thorium-228 do not. Results from RadNet Precipitation Monitoring stations on the ORR can also be compared to other sites in the EPA RadNet program. However, while the stations located on the ORR are in areas near nuclear sources, most of the other stations in the RadNet Precipitation Monitoring Project are located near major population centers, with no major sources of radiological contaminants nearby.

Table 2.3.5.1: EPA Drinking Water Limits (MCLs) for Select Isotopes

Isotope		**EPA Limit** ***(pCi/L)***
Beryllium-7	Be-7	6,000
Cobalt-60	Co-60	100
Cesium-137	Cs-137	200
Iodine-131	I-131	3
Note: Beta and Photon Emitters in Drinking Water table (EPA, 2015)		

2.3.6 Deviations from the Plan

The results in this report would normally cover FY23 (July 2022 through June 2023) however, the results were only available through December 2021 for the Fiscal Year 2022 report because analysis was still delayed due to COVID. Also, results are currently only available through April 2023, not June. Hence, the 2022 results as well as the results through April 2023 are discussed (monthly composite results from January 2022 through April 2023).

2.3.7 Results and Analysis

Nationwide RadNet Precipitation sampling results are available via the [RadNet Search] webpage (EPA, 2023).The gamma isotopes identified for sampling results from the ORR precipitation stations for 2022 and the first four months of 2023 include beryllium-7, cesium-137, cobalt-60, potassium-40, radium-226, radium-228, and thorium-228. For all isotopes except beryllium-7 (Be-7), results were less than EPA MDCs. As stated in the RadNet user guide, the MDCs reflect,

> "*…the ability of the analytical process to detect the analyte for a given sample. The MDC is the activity concentration for which the analytical process detects the radioactive material in a given sample that provides a 95% chance that the radioactive material will be detected.*"

While the majority of Be-7 results were higher than MDCs, Be-7 results were not present all months at any ORR location. In addition, Be-7 is a naturally occurring cosmogenic radionuclide produced in the upper atmosphere and has a drinking water limit of 6,000 pCi/L. The highest ORR RadNet Be-7 result during this time period was 108 pCi/L, with an average value of 45 pCi/L, well below the conservative drinking water limit.

2.3.8 Conclusions

In the absence of regulatory limits for radionuclides in precipitation, EPA's drinking water limits provide conservative reference values for data comparison. Overall, the highest values seen in the composited monthly precipitation samples for all three (3) ORR stations were well below the EPA Drinking Water MCLs. Only Be-7, had any results above the associated MDCs, and is naturally occurring. RadNet Precipitation results for the ORR stations were below detection limits or below the regulatory limits used for drinking water and did not indicate a significant impact on the environment or public health from ORR emissions.

2.3.9 Recommendations

Continued monitoring of the ORR precipitation for airborne radiological contamination via the ORR RadNet Precipitation project is recommended by DoR-OR. Precipitation monitoring will help ensure that contamination on the ORR does not present risk to human health or the environment. This is especially important as the demolition of older buildings continues across the ORR. Ongoing operations also have the potential to impact precipitation contaminant levels. In the event of an emergency either on or off the ORR, this program could provide valuable data relating to the extent of radiological contamination in the air and precipitation before, during, and after an event.

2.3.10 References

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3.0 BIOLOGICAL MONITORING

3.1 BENTHIC ECOLOGICAL COMMUNITY HEALTH

3.1.1 BACKGROUND

The *Benthic Macroinvertebrate Monitoring Project* monitors the current condition and changing conditions of benthic communities (i.e. organisms that live on or in the bottom of a waterbody) in streams on the ORR. These streams have been impacted by historical Manhattan Project activities as well as current DOE operational activities. The purpose of this project is to document the macroinvertebrate taxa present in streams, assign Tennessee Macroinvertebrate Index (TMI) scores for stream sites, and note any changes from previous sampling years over time. Additionally, changes that coincide with ongoing CERCLA remedial activities are documented.

Aquatic macroinvertebrate species serve as both quantitative and qualitative indicators to assess biotic responses to environmental stressors (Holt, 2010). Macroinvertebrates are tied to the stream bottom and generally do not move or migrate very far. These animals are continuously exposed to any adverse conditions caused by direct or indirect discharges to these waters. In addition, the longest life stage for macroinvertebrate species is usually aquatic or semi-aquatic. Remaining in the same stream portion during a long life-stage allows these animals to be a good index of environmental changes over time.

The biodiversity of macroinvertebrates was evaluated for the four (4) main watersheds on the ORR and unimpacted reference streams were used to determine the typical composition of a healthy benthic community in this region. The benthic taxa from each impacted stream were compared with those found in the associated reference stream.

Four (4) main watersheds were studied at the three (3) ORR campuses:

1) ORNL: White Oak Creek Watershed
2) ETTP: Mitchell Branch Watershed
3) Y-12: East Fork Poplar Creek Watershed and 4) Bear Creek Watershed

Related DOE Project

ORNL conducts benthic macroinvertebrate sampling for DOE across the ORR. After completion of the taxonomy and relevant calculations, ORNL reports their findings in both the *Remediation Effectiveness Report (RER)* and the *Annual Site Environmental Report (ASER)* each year.

ORNL's Aquatic Ecology Group conducts benthic macroinvertebrate monitoring on some of the same streams as DoR-OR. The number of specific stream sites differs between the two agencies, but some sampling sites are shared. At these sites, TDEC sampling serves as an independent check on ORNL's monitoring results.

3.1.2 Problems Statements

Past studies have indicated that most of the benthic community sampling sites located in ORR streams have been negatively impacted when compared to healthy communities in unimpacted reference streams (TDEC 2021, DOE 2021). Many of the impacts affecting these streams result from both the historical Manhattan Project activities on the ORR and the current operational activities. When a benthic assemblage changes, the project team attempts to determine whether the migration of legacy waste, current operations, and/or another variable is responsible for this change. Below are the resulting, specific problem statements.

1) Determining the contaminants impacting each sampled benthic community.
    1. Disturbance and migration of legacy contaminants (the Manhattan Project)
    2. Current operational effluents and/or spills.
    3. Both legacy contaminants and current operation effluents.

2) Channelization inhibits the establishment of diverse, healthy stream bottom communities:
    1. Alters *riffle, run, pool* sequence reducing number of preferred habitats.
    2. Straightening a stream eliminates its natural sinuosity (i.e. curvature), which slows stormwater and reduces flooding. Sinuosity in turn also allows for in-stream areas of refuge.

3) Controlling inherent, environmental variability as much as possible and moderating data through long-term sampling
    1. Seasonal changes (e.g. spring is the most biodiverse season).
    2. Year-to-year fluctuations in weather patterns.

4) Controlling for the knowledge and experience of the sampler, which has been alleviated by ongoing long-term sampling.

5) Necessary sample site location changes. Necessity for changes could be due to:
    1. Remove site due to changes in habitat.
    2. Severe weather events exacerbated by climate change can lead to flash flooding.

3. Human and animal activities can also cause habitat change or habitat loss in streams.

4. Working around beaver activity, which is especially high on the ORR, may also lead to changes in sample sites.

6) DoR-OR *spring* sampling is quantitative benthic data as compared to ORNL's *fall* semi-quantitative benthic data. Due to this difference DoR-OR must evaluate for qualitative similarities as opposed to direct, quantitative comparisons.

3.1.3 Goals

1) Assess the benthic macroinvertebrate population health of the four (4) main ORR watersheds.
2) Maintain continuous sampling at impacted sites to compare current stream health with previous sample years and to find any changes in biodiversity that may be due to contaminant migration and/or potential releases.
3) Maintain continuous sampling at reference sites for yearly comparisons to the ORR stream samples.
4) Provide a yearly quality check on DOE's ORR macroinvertebrate data.
5) Draft monitoring recommendations, and COC impact concerns based on the analysis of macroinvertebrate assemblages, on methods to improve the overall health of each watershed.

3.1.4 Scope

The four (4) main watersheds on the ORR were sampled in FY23; one (1) upstream sample and one (1) downstream sample. During the spring, nine (9) benthic macroinvertebrate samples were collected from DOE impacted streams and four (4) samples were collected from reference streams (Table 3.1.4.1).

Table 3.1.4.1: Benthic Macroinvertebrate Sampling Sites

Facility	Watershed	Site	Reference Station
Y-12	Bear Creek	BCK 12.3	MBK 1.6 & CCK 1.6
		BCK 3.3	
	East Fork Poplar Creek	EFK 23.4	
		EFK 13.8	
		EFK 6.3	
		EFK 2.2	
ORNL	White Oak Creek	WCK 3.9	WCK 6.8
		WCK 2.3	
ETTP	Mitchell Branch	MIK 0.45	MIK 1.43

To support the *East Fork Poplar Creek Assessment Project (EFPCAP)*, an additional site along EFPC (EFK 2.2) was included in the project for FY23. Results from this site were shared with the EFPCAP team.

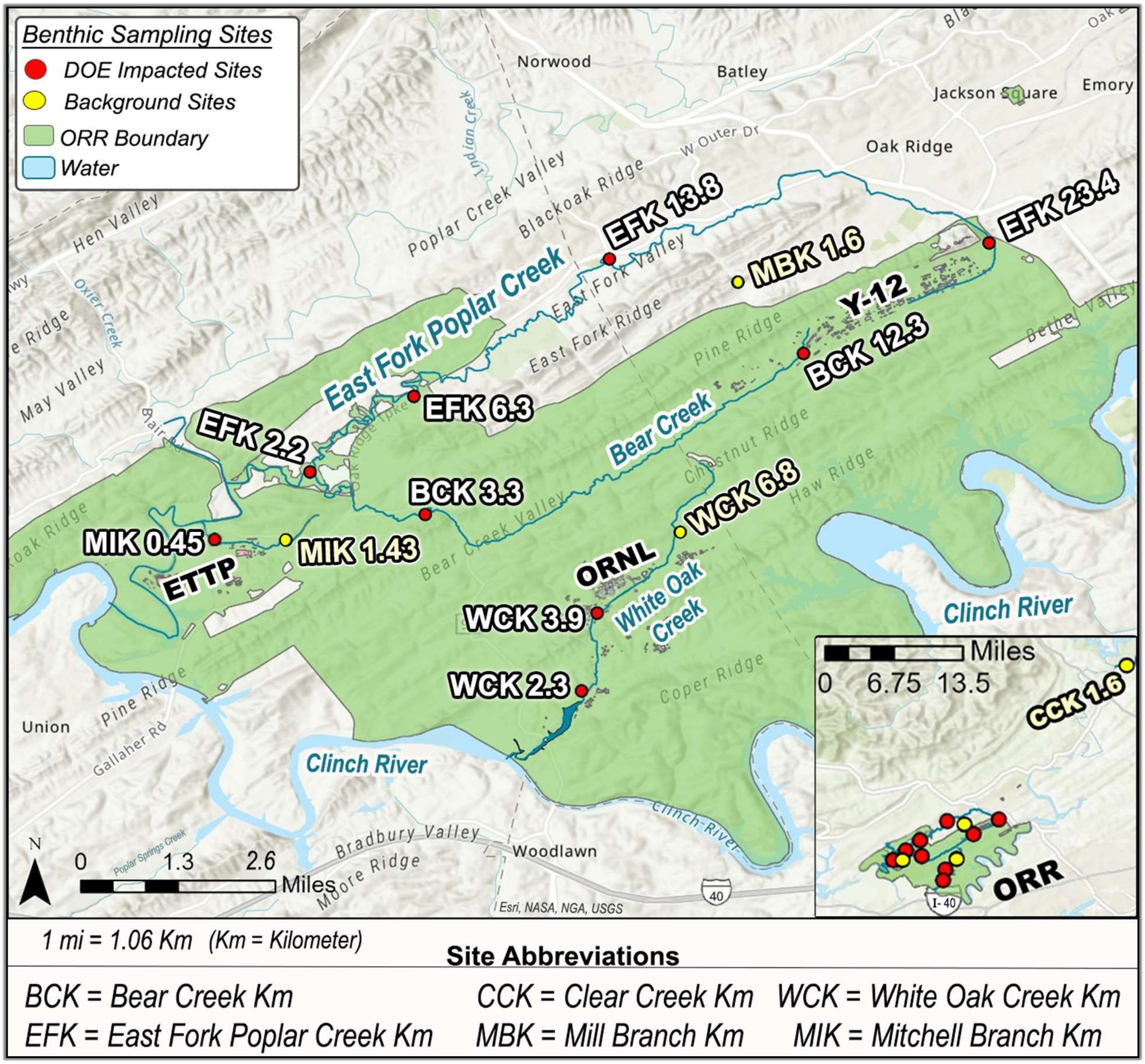


Figure 3.1.4.1: Benthic Community Health Sampling Locations

3.1.5 Methods, Materials, Metrics

Macroinvertebrate Collection:

Sampling for this project required two people at a minimum. One person set a one-square-meter kick net with a 500-micron mesh across a predetermined riffle downstream. The other person, using their feet, disturbed approximately 1 square meter (m^2) area of the stream substrate directly upstream of that net. The organisms, sediment, and detritus flowed into the net. The net was then carefully lifted out of the water and carried horizontally to the streambank. The bottom of the net was positioned in a 500-micron sieve bucket. The net was thoroughly rinsed into the sieve bucket. Organisms still clinging to the net after rinsing were collected and placed into the bucket using forceps. This process was repeated using a second riffle upstream of the previous kick. The two square kicks were then composited, placed in a plastic container, and preserved with 95% ethanol.

PROCESSING SAMPLES:

The processing of benthic samples occurred at the DoR-OR Laboratory and consisted of two (2) major steps. The first step was sample sorting, where benthic organisms were removed from almost all the detrital material collected. The benthic organisms and any remaining detrital material were transferred into a numbered tray and evenly distributed. Four (4) random numbers were selected using a random number generator. The corresponding numbers in the tray were then selected as subsamples.

The four (4) subsamples were processed using a binocular dissecting microscope to remove benthic macroinvertebrates from the remaining detrital material. During sorting of the subsamples, macroinvertebrates were placed into a separate vial with 95% ethanol and a running count of collected organisms was maintained. If more than 300 macroinvertebrates were collected after processing all four (4) subsamples, then another subsampling was performed. During a second subsample, organisms and ethanol were transferred to a petri dish with a grid. Four (4) grids were selected using a random number generator and macroinvertebrates were sorted and again counted. If the second sorting produces less than ~300 individuals, additional grid numbers were randomly selected and counted. Grid numbers were selected until the required number of macroinvertebrates were collected. Typically, more than four (4) grids were needed to achieve the desired number of organisms.

Once sorting and subsampling of all samples was completed, macroinvertebrates were sent to Third Rock Consultants to be identified. Macroinvertebrates were identified to species when possible. However, due to processing time, the FY22 results were received in fall of FY23 and published in this FY23 EMR.

A taxonomic enumeration efficiency and precision quality control count was performed by two taxonomists on the EFK 13.8 sample. The two taxonomists had zero discrepancies in the number of macroinvertebrates in the sample and a taxonomic disagreement of 0.6%, passing the QA/QC process.

DATA ANALYSIS:

After receiving the identification results, the data was transcribed into the Division of Water Resources (DWR) macroinvertebrate template. Data was sent to DWR where various biometrics were calculated and scored to produce final TMI scores for each site. A description of the biometrics calculated and the expected response to environmental stressors is listed in Table 3.1.5.2.

A numerical score is calculated for each individual biometric. Those scores were used to determine the TMI score. A TMI score of 32 meets all bio-criteria for a healthy benthic macroinvertebrate community with no impairment to the system. A TMI score below 32 falls below bio-criteria guidelines and indicates stream impairment. TMI scores for impacted sites are then compared to the unimpacted reference sites. Further information about sampling procedures and biometric calculations can be found in the *Quality System SOP for Macroinvertebrate Stream Surveys* published by DWR.

Table 3.1.5.2: TMI Score Components

Description of Biometrics and Expected Responses to Stressors			
Category	Metric	Description	Response to Stress
Richness	Taxa Richness	Measures overall diversity of the macroinvertebrate assemblage	Number Decreases
	EPT Richness	Number of taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera	Number Decreases
Composition	% EPT-Cheum	% of EPT abundance excluding Cheumatopsyche taxa	% Decreases
	% OC	% of Oligochaetes and Chironomids present	% Increases
Tolerance	North Carolina Biota Index (NCBI)	Incorporates richness and abundance with a numerical rating of tolerance	Number Increases
	% TNUTOL	% of Nutrient Tolerant organisms, those with NCBI scores > 3.0	% Increases
Habitat	% Clingers	% of organisms with fixed retreats or attach themselves to substrate	% Decreases

3.1.6 Deviations from the Plan

Samples were identified by an outsourced laboratory instead of being identified in the DoR-OR Laboratory. In the past, DoR-OR staff has identified macroinvertebrates, but after an analysis of the budget for this project it was determined outsourcing for identification was more cost effective.

Due to staffing changes, DoR-OR staff were unable to provide oversight to DOE's sampling efforts in fall 2022.

3.1.7 Results and Analysis

1) East Fork Poplar Creek (EFPC) Watershed

The headwaters of EFPC originate from tributaries that flow through the main industrialized portion of Y-12. At its headwaters, EFPC receives inputs of contaminants such as mercury, uranium, volatile organic compounds (VOCs), and other metals and organics. Once offsite, EFPC receives further contaminant loading from municipal Oak Ridge as it flows downstream through urbanized and suburbanized areas. Additionally, site EFK 13.8 is located just upstream of a sewage treatment facility. Downstream portions of EFPC after site EFK 6.3 are relatively undisturbed before reaching its confluence with Poplar Creek.

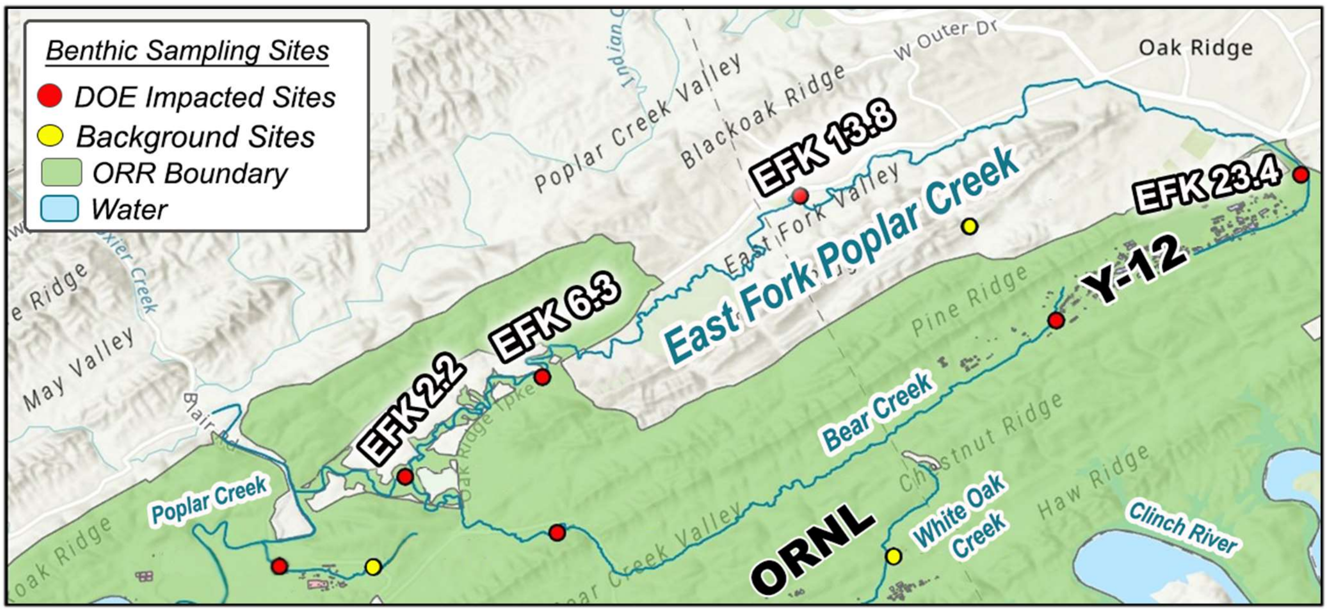
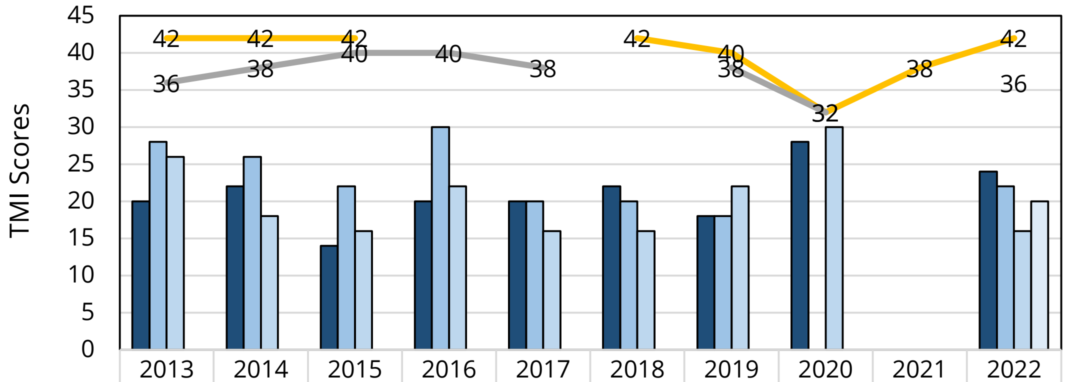


Figure 3.1.7.1: East Fork Poplar Creek Sample Sites



	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
EFK 23.4	20	22	14	20	20	22	18	28		24
EFK 13.8	28	26	22	30	20	20	18			22
EFK 6.3	26	18	16	22	16	16	22	30		16
EFK 2.2										20
MBK 1.6	42	42	42			42	40	32	38	42
CCK 1.6	36	38	40	40	38		38	32		36

EFK 23.4 EFK 13.8 EFK 6.3 EFK 2.2 MBK 1.6 CCK 1.6

Figure 3.1.7.2: EFPC Historical and Current TMI Scores (2013-2022)

TMI scores for all EFPC sites have been below the biocriteria guideline of 32 for the past ten (10) years (Figure 3.1.7.2). Additionally, all EFPC sites have lower TMI scores than their reference sites (MBK 1.6 and CCK 1.6). In 2022, EFK 23.3 had the highest TMI score of all the EFPC sites. On the other hand, EFK 6.3 had the lowest score and, in fact, had the biggest decrease overall when compared to the 2020 data indices. The reason for this substantial decrease is currently unknown, but a TMI score of 16 has been the average score for this site in previous years. EFK 2.2 was hypothesized to have a high TMI score due to its distance from Y-12 inputs, but results did not support this hypothesis.

Small year-to-year variations in TMI scores can be attributed to a multitude of factors including, but not limited to, the following:

1) Recent DoR-OR staff changes
2) Climate fluctuations with increased extremes in temperatures
3) Extreme weather events, especially heavy rains and flooding on days prior to sampling events

EFPC sites have scored substantially lower than reference sites consistently over the years. Lower scores are potentially the result of human alterations.

1) Channelization at the headwaters of EFPC reduced ideal stream habitats.

2) Water temperatures are typically higher at EFPC sites than at reference sites.
3) EFPC receives substantial inputs of mercury from Y-12 facilities.

The individual calculated biometrics for each EFPC site in 2022 can be found in Table 3.1.7.1. Each of these metrics were given a score and were composited to yield the TMI score.

Table 3.1.7.1: EFPC Macroinvertebrate Biometrics in 2022

East Fork Poplar Creek Macroinvertebrate Metrics						
	EFK 23.4	EFK 13.8	EFK 6.3	EFK 2.2	MBK 1.6	CCK 1.6
Taxa Richness	26	21	20	27	31.5	33.5
EPT Richness	5	6	5	4	14	14
%EPT-Cheum	15.3	12.3	6.4	2.9	66.1	42.3
%OC	47.3	19.7	9	71	5.35	29.85
NCBI	5.85	5.53	6.07	6.44	3.035	4.075
%Clingers-Cheum	59.9	35.9	25.4	31.6	59.75	33.4
%TNutol	49.4	60.5	82.9	27.4	12.45	13.4

2) Bear Creek Watershed

Bear Creek is a small to moderate-sized stream whose headwaters originate at the west end of Y-12 National Security Complex. Historically, pollutants from industrial activities, as well as waste disposal activities at Y-12, were released into Bear Creek. Former waste disposal sites, such as the S3 ponds (at its headwaters), continue to negatively impact the water quality of the stream. Downstream from Y-12, Bear Creek continues to be impacted by inputs from legacy and active waste disposal sites, like the EMWMF Landfill and Bear Creek Burial Grounds. Bear Creek is also a stream where shallow groundwater and surface waters mingle freely throughout its length to its confluence with EFPC.

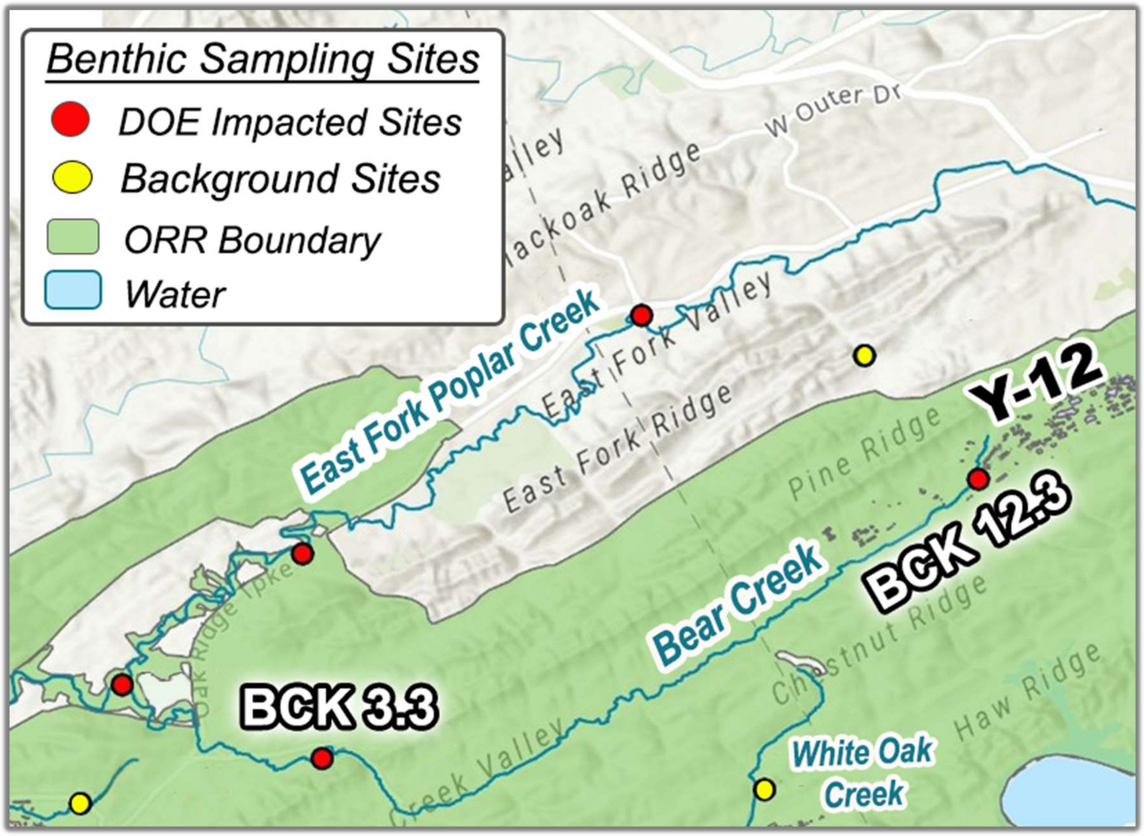
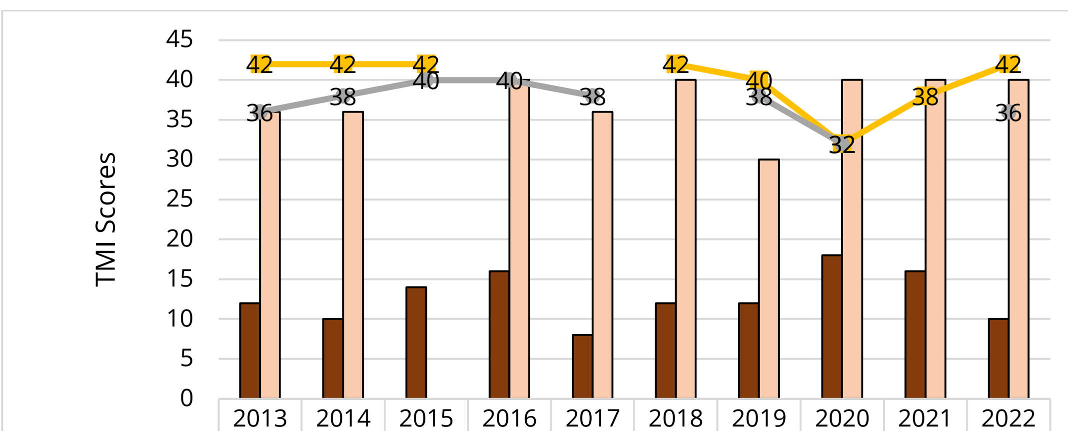


Figure 3.1.7.3: Bear Creek Sample Sites



	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
BCK 12.3	12	10	14	16	8	12	12	18	16	10
BCK 3.3	36	36		40	36	40	30	40	40	40
MBK 1.6	42	42	42			42	40	32	38	42
CCK 1.6	36	38	40	40	38		38	32		36

Figure 3.1.7.4: Bear Creek Historical and Current TMI Scores (2013-2022)

In 2022, BCK 12.3 had the lowest TMI score of any Bear Creek site (Figure 3.1.7.4). This site is located near Y-12. Stormwater runoff and effluent releases cause the stream to have at least small amounts of water year-round increasing the potential for contamination inputs and mobility of those contaminants downstream.

These variables are all contributing factors to the low TMI scores observed at this site in 2022 and for the past ten (10) years. Further downstream at BCK 3.3, the TMI scores have been consistently above bio-criteria guidelines (TMI ≥32). This site benefits from being farther away from Y-12, which results in a greater flow of water. As water travels downstream in Bear Creek, the farther away from Y-12, the more diluted contaminants become. This dilution helps reduce the stress on macroinvertebrate populations.

In addition to scoring well below bio-criteria guidelines, BCK 12.3 TMI scores are decidedly below those of both reference sites (MBK 1.6 and CCK 1.6). The ten (10) year average for BCK 12.3 is only a 13. Additionally, the ten (10) year average for both reference sites is 40 (MBK 1.6) and 37 (CCK 1.6) respectively. BCK 3.3 has a ten (10) year average of 38, which better aligns with the reference site TMI scores.

The individually calculated biometrics for each Bear Creek site in 2022 can be found in Table 3.1.7.2. Each of these metrics were given a score and were composited to yield the TMI score.

Table 3.1.7.2: Bear Creek Macroinvertebrate Biometrics 2022

Bear Creek Macroinvertebrate Metrics				
	BCK 12.3	BCK 3.3	MBK 1.6	CCK 1.6
Taxa Richness	12	27	31.5	33.5
EPT Richness	3	15	14	14
%EPT-Cheum	5	44.7	66.1	42.3
%OC	4.3	10.2	5.35	29.85
NCBI	6.74	3.73	3.035	4.075
%Clingers-Cheum	15.1	52.8	59.75	33.4
%TNutol	89	20.5	12.45	13.4

3) White Oak Creek (WOC) in Bethel Valley and Melton Valley Watersheds

WOC is the main drainage for the majority of ORNL's contaminated areas. The stream flows near the Spallation Neutron Source, then through the main plant area in Bethel Valley, and finally into the Melton Valley Watershed. WOC flows through the SWSA and then empties into White Oak Lake (WOL). Next, water from WOL exits the reservation through White Oak Embayment into the Clinch River. WCK 3.9 is located on the south side of ORNL and downstream of Fifth Creek. This tributary receives inputs from a large portion of ORNL's main campus. WCK 3.9 is downstream of a radiological wastewater treatment facility. WCK 2.9 is located near the mouth of WOL and just after SWSAs. The main COCs of WOC and WOL are radioactive materials.

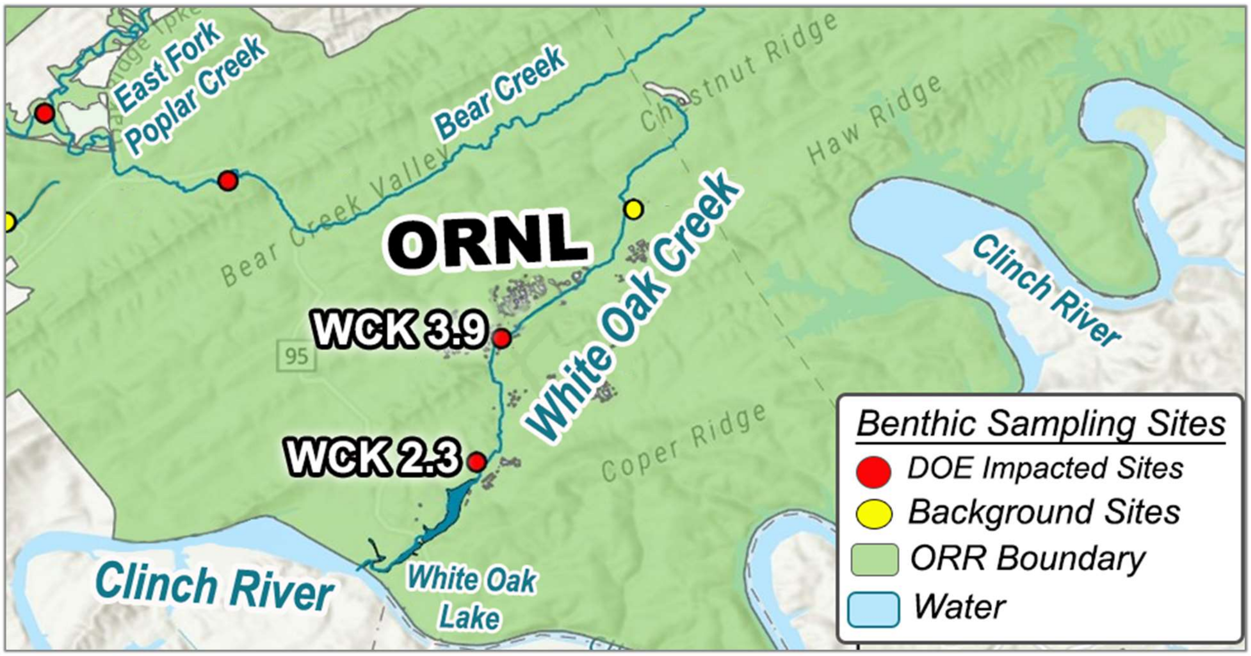


Figure 3.1.7.5: White Oak Creek Sites

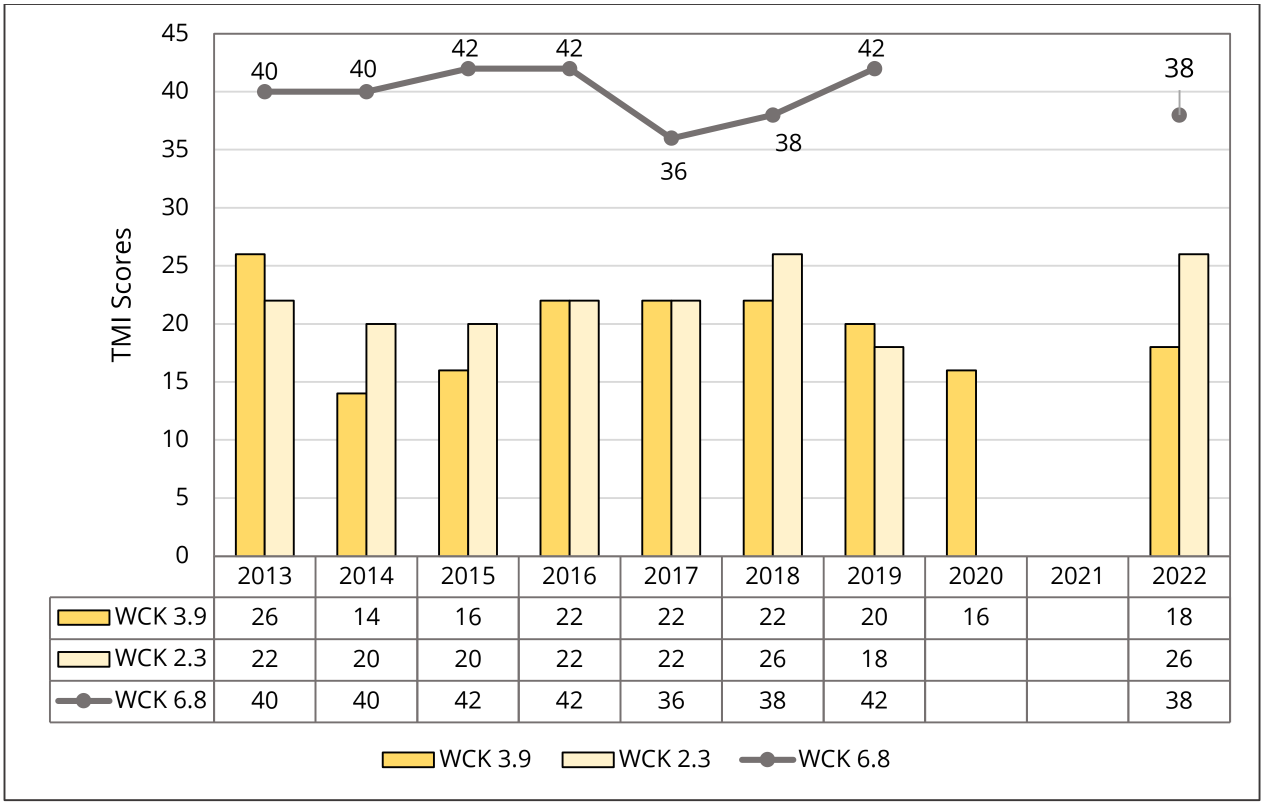


Figure 3.1.7.6: WOC Historical and Current TMI Scores (2013-2022)

In 2022, WCK 3.9 scored similarly to previous years, showing some improvement in score from the 2020 results (Figure 3.1.7.6). When compared to the reference site WCK 6.8, located upstream of contaminant inputs, WCK 3.9 consistently scores much lower. The ten (10) year average TMI score for WCK 3.9 is 20, whereas the ten (10) year average for WCK 6.8 is 40.

Additionally, WCK 3.9 remains well below the bio-criteria guideline (32). A little further downstream, WCK 2.3 had a TMI score of 26 which is an improvement from 2019. Even though there has been improvement at WCK 2.3, the ten (10) year average for the site is 22 which is much lower than the reference site's ten (10) year score and bio-criteria guidelines.

Both WOC impacted sites score well below bio-criteria guidelines and their corresponding reference site in the same watershed (WCK 6.8). ORNL activities continue to impact this watershed causing lower TMI scores. WCK 2.3 tends to score higher than WCK 3.9, possibly because it is located further downstream from ORNL's main campus.

The individual calculated biometrics for each WOC site in 2022 can be found in Table 3.1.7.3. Each of these metrics were given a score and were composited to yield the TMI score.

Table 3.1.7.3: 2022 WOC Macroinvertebrate Biometrics

White Oak Creek Macroinvertebrate Metrics			
	WCK 3.9	WCK 2.3	WCK 6.8
Taxa Richness	22	21	23
EPT Richness	2	5	11
%EPT-Cheum	19	35.5	63.6
%OC	17.9	19.8	6.1
NCBI	5.81	5.32	2.54
%Clingers-Cheum	11	32.1	82
%TNutol	56.6	32.1	6.8

4) Mitchell Branch

Mitchell Branch is a small headwater tributary to Poplar Creek at the ETTP. The highest upstream station, which serves as the reference station (MIK 1.43), does not meet the criteria for rating, according to the bioregion concept, due to the size of the watershed above it (less than two square miles). Because of the small upstream watershed and variable flow conditions depending on annual rainfall, MIK 1.43 does not always provide a clear picture of the impacted condition of the downstream station (MIK 0.45). Historically, MIK 1.43 has been relatively unimpacted by the presence of ETTP. The lower station, MIK 0.45, has been impacted not only from former industrial activities at ETTP and waste areas but has also been channelized with much of the channel being replaced with unnatural substrate.

Over time, the substrate (stream bottom) is becoming more natural, allowing a more diverse community to inhabit those stations. Further improvements in substrate as well as water quality improvements due to remediation activities will allow Mitchell Branch to continue to improve.

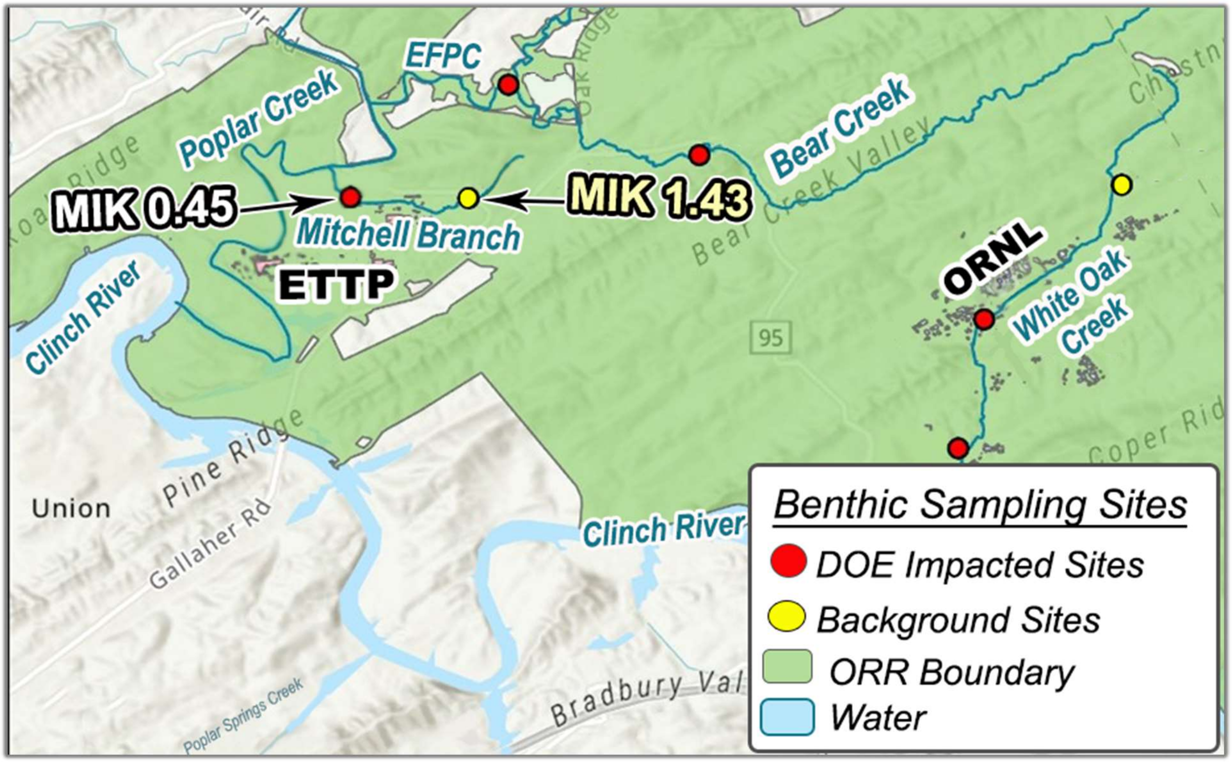
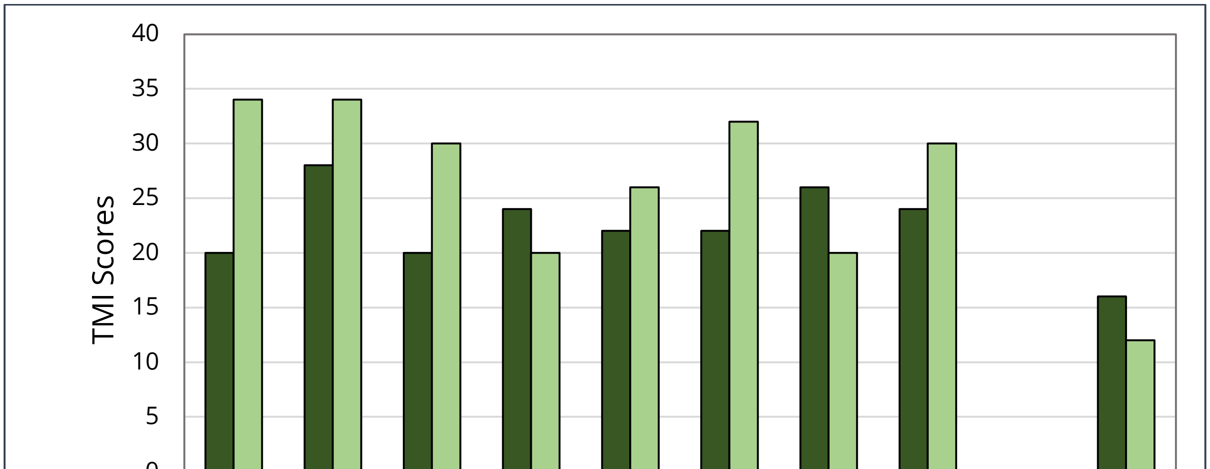


Figure 3.1.7.7: Mitchell Branch Reference Sites



	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
MIK 0.45	20	28	20	24	22	22	26	24		16
MIK 1.43	34	34	30	20	26	32	20	30		12

Figure: 3.1.7.8 Mitchell Branch Historical and Current TMI Scores

In 2022, there was a sharp decrease in the TMI score for MIK 1.43, the reference site, from 30 to 12 in only two (2) years. The impacted site, MIK 0.45, outscored the reference site in

2022 with a TMI of 16. The reason for this sharp decline has not been ascertained. MIK 1.43 is used as a reference site because it is located above typical inputs that impact Mitchell Branch. Given its location, MIK 1.43 should provide valuable insight into the impacts of DOE contamination and/or clean-up activities. The ten (10) year average TMI score for MIK 1.43 is 26 and the ten (10) year average for MIK 0.45 is 22. Furthermore, MIK 1.43 only met bio-criteria guidelines three (3) out of nine (9) sampling years. While both the averages and 2022 TMI scores were below bio-criteria guidelines, the similarities in average TMI scores between MIK 0.45 and MIK 1.43 suggests minimal impacts from downstream inputs. However, the recent significant decrease in TMI scores suggests a potential need to re-evaluate an appropriate reference site for MIK.

The individual calculated biometrics for each MIK site in 2022 can be found in Table 3.1.7.4. Each of these metrics were given a score and were composited to yield the TMI score.

Table 3.1.7.4: 2022 MIK Macroinvertebrate Biometrics

Mitchell Branch Macroinvertebrate Metrics		
	MIK 0.45	MIK 1.43
Taxa Richness	20	24
EPT Richness	4	7
%EPT-Cheum	2.3	6.5
%OC	36.3	80.2
NCBI	5.66	6.09
%Clingers-Cheum	25.4	9.6
%TNutol	51.9	73.7

3.1.8 Conclusions

The health of the benthic macroinvertebrate communities in ORR streams has improved since the 1980's. The improvement has plateaued for the past few years. In 2022, many impacted sites saw a decrease in TMI scores from previous sampling years, but there were a few that were comparable to previous years or improved. The two (2) Y-12 watersheds continue to show impairment at their headwaters, which are located near DOE facilities and industrial activities. In the Bear Creek Watershed, BCK 12.3 had the lowest TMI score out of all the ORR sites sampled in 2022. On the other hand, BCK 3.3 continues to express TMI scores above bio-criteria guidelines and comparable to scores seen at reference sites.

In the second watershed, East Fork Poplar Creek Watershed, EFK 6.3 had the lowest TMI score of all the EFPC sites. In previous years, EFPC macroinvertebrate communities tended to improve downstream. The farther the site was from the source of contamination, the higher the TMI. Unfortunately, EFK 6.3 did not show this trend in 2022.

The ORNL watershed, White Oak Creek Watershed, has been relatively static over the past decade, with only slight variations from year-to-year. WCK 3.9 and WCK 2.3 scored comparable to previous years, with a slight increase in TMI scores. This score does not represent a statistically significant change from historical trends.

The ETTP watershed, Mitchell Branch, expressed a sharp decrease in its TMI scores for both the reference site and impacted site. This may be due to the stream's small size and its susceptibility to natural and anthropomorphic stressors. However, exact cause is unknown and additional sampling may elucidate the change in TMI scores.

3.1.9 Recommendations

Benthic macroinvertebrate communities should continue to be monitored yearly. This ongoing long-term sampling will help to adjust for differences in the sampler experience and additional environmental variables like temperature increases and flooding events. TMI scores that are higher than previous years serve to verify that DOE remedial efforts are having a positive effect on those communities. Other areas, with lower TMI scores, are possibly more impacted and may take more time to be effectively remediated.

A frisbee golf course was expanded above the Mill Branch reference stream. Riprap was put in at the stream crossing for vehicles. The gravel road was widened, and more gravel put down. The pools were very deep and had sediment deposits which suggests flooding, bank erosion, and changes in the riparian zone. Mill Branch scores will need continued monitoring to discern its quality as a reference stream.

With regards to the Mitchell Branch reference site, MIK 1.43, this stream appears to have been affected by new stressors in the past two (2) years. Sampling should continue; however, a different reference stream may need to be used in future comparisons. Every effort should be made to protect the quality of streams that meet bio-criteria guidelines and improve those that fall below.

3.1.10 References

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3.2 ORR Roving Creel Survey

3.2.1 Background

The Roving Creel Survey (RCS) is an ongoing project that measures angling effort at three (3) key locations along the Clinch River and Poplar Creek. The three (3) survey zones are located just outside the ORR boundaries and occur where impaired ORR watersheds drain into publicly accessible waters. Angler interviews were conducted at these confluences; White Oak Lake (WOL) with the Clinch River (CR), Poplar Creek (PC) with the CR, EFPC with PC (Figure 3.2.4.1). Both catch-and-release fishing and fishing for consumption were documented at the confluence points. These confluence areas are a concern. These streams have been negatively impacted by releases from historical ORR activities as well as current operations.

During FY23, the scope of this project was extended to measure fishing and recreational activities along the North Boundary Greenway (NBG). The lower reaches of Bear Creek (BC) and EFPC flow near the trails of the NBG and feed into PC. The NBG is a popular recreation attraction for Oak Ridge residents and these recreators have been observed there year-round. In FY23, DoR-OR personnel interviewed recreators along the NBG to determine how they spend their time at the greenway. Both paper and digital surveys were collected at project survey stations placed along the NBG.

BC and EFPC originate within the confines of Y-12 and are fed by springs and numerous outfalls from various plant facilities. During weapons production at Y-12 in the 1950s and 1960s, large amounts of mercury, chemical contaminants, and radiological materials like uranium were released in a wide range of concentrations to surface waters, sediments, and floodplain soils (Brooks et al, 2017; Pant et al, 2010).

Mercury in streams and wetlands often undergoes methylation and is transformed into toxic methylmercury (MeHg) in conjunction with the activity of microorganisms (Kalisinska et al, 2013). Methylmercury is particularly bioavailable to wildlife (and humans) and, if ingested, may cause serious neurological, reproductive, and other physical damage (Standish, 2016). Fish are especially vulnerable to mercury bioaccumulation due to their habitat and diet (Murphy, 2004).

Another stream assessed, WOC, originates just north of ORNL and eventually empties into the CR via WOL. Radionuclides released from ORNL to WOC are a result of leaks from ponds and waste disposal areas and include contaminants such as Sr-90 and cesium-137 (Cs-137), as well as other byproducts from nuclear and industrial activities (DOE, 1988). These are significant because of their radiotoxicity, their mobility in the environment, and the quantities released. Other radionuclides of significance include tritium and transuranics (DOE, 1988). The availability of Cs-137 for biological uptake is a major public health concern, as it can be transferred to humans through food webs. Even in the most mobile aquatic habitats (i.e., flowing rivers), Cs-137 may persist in a biologically available form for several years after release (Rowan DJ, 1994; Sakai MT et al, 2016).

3.2.2 Problem Statements

1) Fish have been shown to bioaccumulate mercury and other contaminants (Murphy, 2004). If contaminated, ingestion of these fish could harm people and other species eating fish.
2) Fish consumption warning signs and postings are either not visible due to weathering or they are missing. In addition, residents who have fished these waters for many years may disregard warnings.
3) Little is known about the extent of human engagement with natural areas on and near the ORR.

3.2.3 Goals

1) Quantify the angling effort in the five (5) key locations just outside ORR boundaries (EFPC and BC along the NBG, confluence points of EFPC-PC, PC-CR, and WOL-CR).
2) Determine if recreational fishing is a significant pathway for human exposure to contaminants.
3) Provide data that is pertinent to CERCLA requirements and future ORR decisions regarding human health and environmental protection.
4) Document the amount of human recreational activity in the lower reaches of BC and EFPC within the North Boundary Greenway.

3.2.4 Scope

RCSs were conducted along the CR and PC. Attempts to interview every angler observed along the entire route (in between zones) were made; however, fishing effort was only calculated for the survey zones of interest. These survey zones are the confluence areas; (1) WOL-CR, (2) PC-CR, and (3) EFPC-PC. Additionally, a survey box was installed at the Gallaher boat ramp to passively collect digital and paper surveys (Figure 3.2.4.1).

NBG recreator interviews were conducted at the same time as the RCSs. During these surveys DoR-OR personnel would stop recreators along the NBG and ask them questions about their visit. The same path was walked each survey and survey boxes along the greenway were checked for submitted paper surveys (Figure 3.2.4.1).

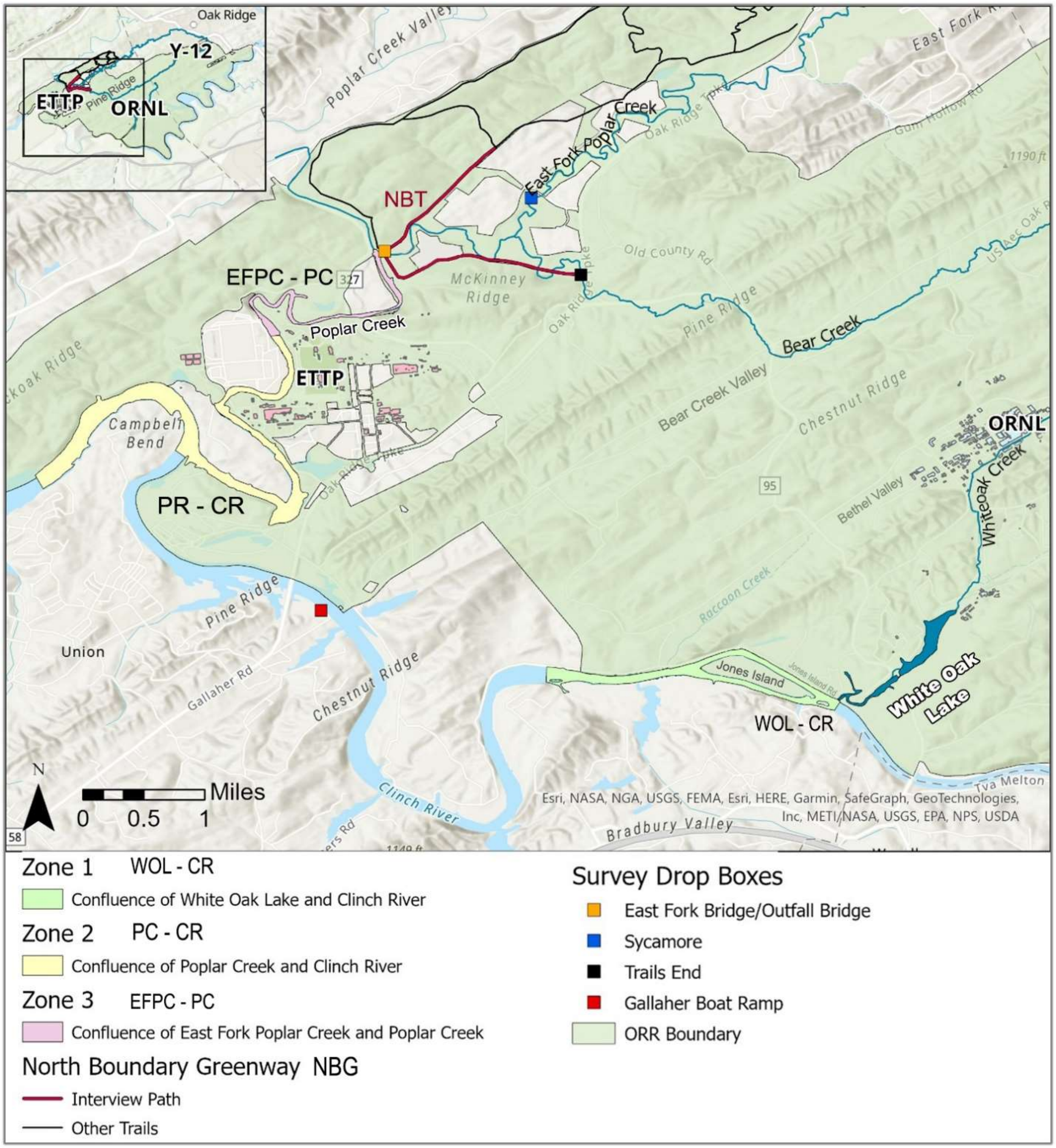

Figure 3.2.4.1: Angler Survey Zones and NBG Interview Path

3.2.5 Methods, Materials, Metrics

A randomized sampling schedule was created prior to the beginning of the survey year. Dates selected for sampling events used non-uniform probability, stratified random sampling to maximize sampling efficiency and minimize bias. A total of twenty (20) dates were selected to conduct RCSs and NBG surveys simultaneously. RCSs were typically conducted from 8:00 AM to noon and NBG surveys from 8:00 AM to 11:00 AM, with few deviations.

Roving Creel Survey – Angler Interviews

DoR-OR personnel conducted angler interviews between 8/21/2022 and 6/24/2023 along the CR and PC. Anglers were interviewed either before, during, or immediately following fishing trips. All waterbodies were sampled using roving creel survey methods, outlined in the TWRA 2007 Fisheries Report (TWRA, 2007).

RCSs were conducted by boat for a half-day sampling period. DoR-OR interviewed all anglers spotted either on the water or on the shore. There were no efforts to stop vessels underway to conduct interviews according to safety standards. Anglers that declined to be interviewed were thanked for their time and DoR-OR personnel immediately left the area.

Both observable and angler reported survey information collected are listed below.
<u>Observable data collected includes:</u>

1. Date/Time
2. Type – boat/bank fishing, private/commercial
3. Location – Latitude/Longitude
4. Number of people in party

<u>Angler reported data includes:</u>

1. Local (living within 50 miles of the area) or visiting (living further than 50 miles)
2. County and state residence
3. Total hours spent fishing for that trip
4. An estimate of days spent fishing per month
5. Target species of fish
6. Consumption of fish harvested from the study zones
7. Provision of fish to sensitive populations (i.e., pregnant women, nursing mothers, or children) for consumption
8. Knowledge of posted signage for the study area

Digital surveys were downloaded, and voluntary paper surveys were collected from the survey box posted at the Gallaher boat ramp (Figure 3.2.3.1).

North Boundary Greenway – Recreator Interviews

DoR-OR personnel conducted interviews of recreators along the NBG between 8/21/2022 and 6/24/2023. Recreators were interviewed as they were encountered along the greenway. Some bike riders and runners were not stopped by DoR-OR personnel unless they stopped on their own. Interviews were conducted in the morning while the RCSs were taking place. Interview questions were equivalent to RCS questions. If recreators were not fishing that day, then the questions about fishing were skipped.

Both observable and recreator reported survey information collected are listed below.
<u>Observable data collected includes:</u>

1. Date/Time
2. Location – Latitude/Longitude
3. Number of people in party

<u>Recreator reported data includes:</u>

1. Total hours spent recreating
2. An estimate of days spent recreating per month
3. Local (living within 50 miles of the area) or visiting (living further than 50 miles)
4. County and state residence

If fishing, recreators were also asked the following:

5. Type of fishing (wading, kayaking, bank)
6. An estimate of days spent fishing from the NBG per month
7. Target species of fish
8. Consumption of fish harvested from the area
9. Provision of fish to sensitive populations (i.e., pregnant women, nursing mothers, or children) for consumption
10. Knowledge of posted signage for the study area

Again, digital surveys were downloaded, and voluntary paper surveys were collected from three (3) survey boxes posted at different locations along the NBG (Figure 3.2.3.1).

Fishing Effort for Roving Creel Surveys

Estimates of fishing efforts for a given fiscal year quarter were calculated using TWRA's method (John, 1992):

$$e = c(h)$$

fishing effort or total hours = total party size (number of hours reported)

where fishing effort or total hours per interview (e) was calculated as the product of the total party size (c) and the number of hours reported (h). Each interview's total hours (e) were then added together for each quarter in each zone.

For this RCS, all surveys were performed during the morning half of the day. Each survey event encompassed the same three 100-acre sections (zones). Following TWRA's methodologies to calculate full-day angler hours, DoR-OR personnel assumed that morning and evening angler counts are roughly equal and provide an adequate approximation of fishing activity over the course of a whole day. Thus, total hours (e) were multiplied by two to give full-day angler hours per day (f):

$$f = e(2)$$

*full day = total hours (*2)* **for morning and evening*

To estimate the fishing effort per quarter (T), full-day angler hours (f) were divided by the number of RCSs performed during each quarter (RCS per quarter) then multiplied by the number of days in each quarter (d):

$$T = \left(\frac{f}{RCS\ per\ quarter}\right) x\ d$$

total fishing effort of the quarter = (full day in hours / # RCS for the quarter) x # days in the quarter

TDEC's fiscal year runs July 1st – June 30th with the number of days per quarter (d) listed below.

- Quarter 1 = **92** days (July – September)
- Quarter 2 = **92** days (October – December)
- Quarter 3 = **90** days (January – March)
- Quarter 4 = **91** days (April – June)

Using the methods listed above, fishing effort was also calculated from survey responses collected digitally or via paper submission from the Gallaher Boat Ramp. Digital or paper surveys collected at the other three (3) survey boxes on the NBG were used to calculate recreator activity.

3.2.6 Deviations from the Plan

DoR-OR personnel made every effort to conduct five (5) RCSs and five (5) NBG surveys per quarter for a goal of forty (40) surveys in FY23. Due to issues with the boat engine, two (2) RCSs were started but not completed. Only one (1) RCS and NBG survey was cancelled due to inclement weather.

Since the sampling events were predetermined, there were instances where inclement weather could not be avoided. DoR-OR did not operate the boat during unsafe weather conditions. Every effort was made to reschedule sampling events to the following week during a similar timeslot to avoid influencing the random nature of the sample schedule.

There were seven (7) out of twenty (20) surveys rescheduled. Surveys that were rescheduled occurred on the same day of the week either a week prior or a week after the original survey day.

3.2.7 Results and Analysis

Notable Angler Observations from RCS Results:

1) 33 fishing vessels were encountered in FY23
2) 58 individuals were observed fishing.
3)

40 individuals	69%	described themselves as "locals"
18 individuals	31%	described themselves as "visiting"
50 individuals	86%	were on private fishing vessels
8 individuals	14%	were on commercial fishing charters
18 individuals	31%	reported "Yes" to consuming fish from the area
58 individuals	100%	reported "Yes" to awareness of signage in the area warning against consumption of fish

Notable Angler Comments from RCS Results:

- A pair of anglers were camping on Jones Island for four days and reported they would be eating fish that they caught from the area for those days (Interview Q2-12).
- A party of three anglers reported using fish from the area for fish fries stated, "If it hasn't killed the old timers, we figure we'll be ok." (Interview Q4-20).

Maps of Interview Points and Results by Zone:

The following maps contain angler interview points that are listed by the fiscal year quarter in which the survey took place. The format is *Q# - X*, where X is the sample event number. GPS locations were attached to surveys via the Survey123 App.

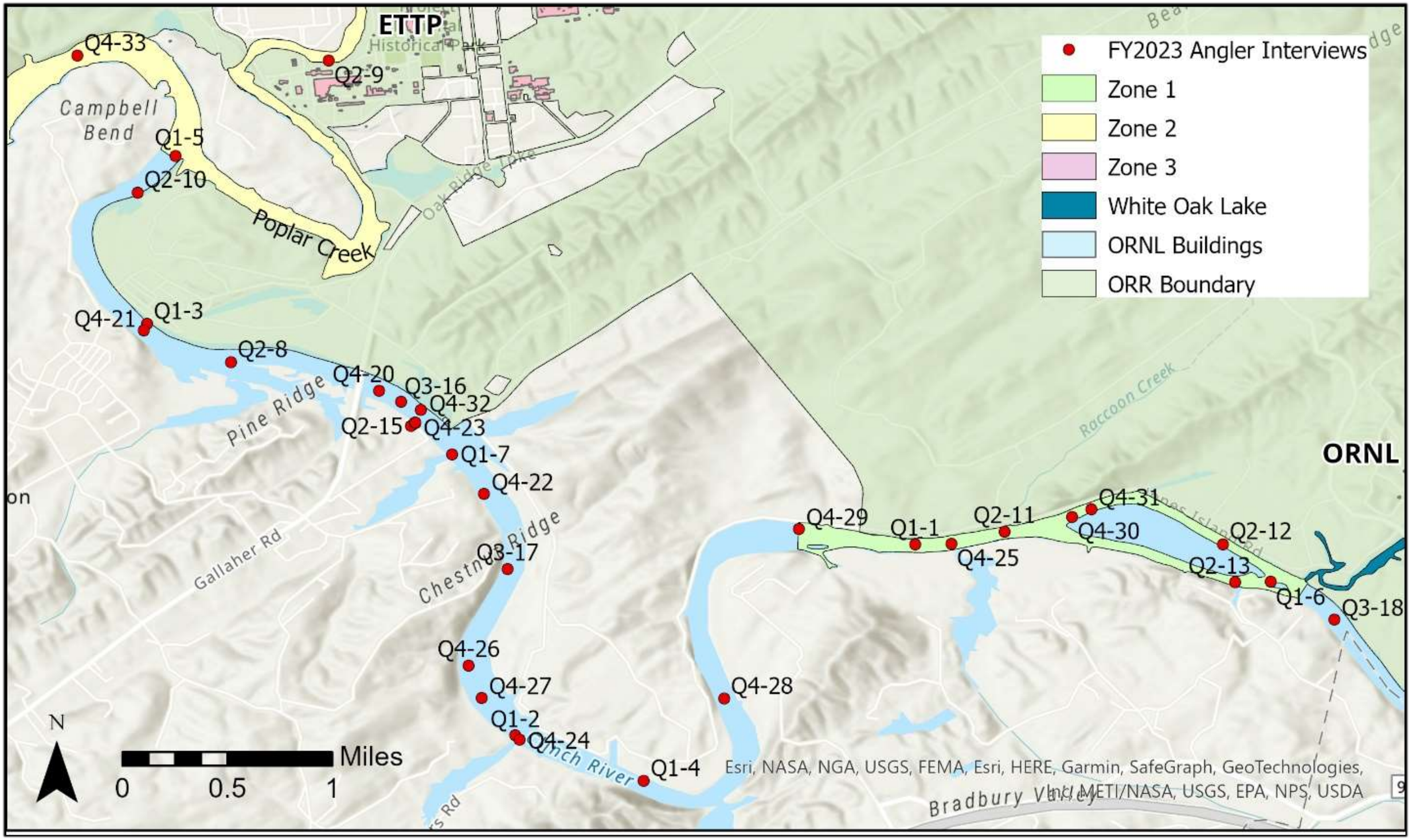

Figure 3.2.7.1: RCS Interview Locations

1) RCS *Zone 1: WOL-CR* Confluence *(White Oak Lake and the Clinch River Region)*

The *Zone 1* region receives inputs from WOL and WOC both containing discharges originating within the footprint of ORNL. The primary contaminants of concern (COC) in this area are byproducts from historical or legacy radionuclides as well as COCs from ongoing industrial activities. These radionuclides include Cs-137, Sr-90, and other fission daughter products. Due to potential release of legacy contaminants, signage is required to dissuade anglers from fishing directly in front of the White Oak Creek Embayment. The signage should read:

***"Warning, no fishing, no water contact area, contaminated, keep out"*.**

DoR-OR personnel documented the current condition of the signage, as visible from the boat (see Figure 3.2.7.3 – Figure 3.2.7.5).

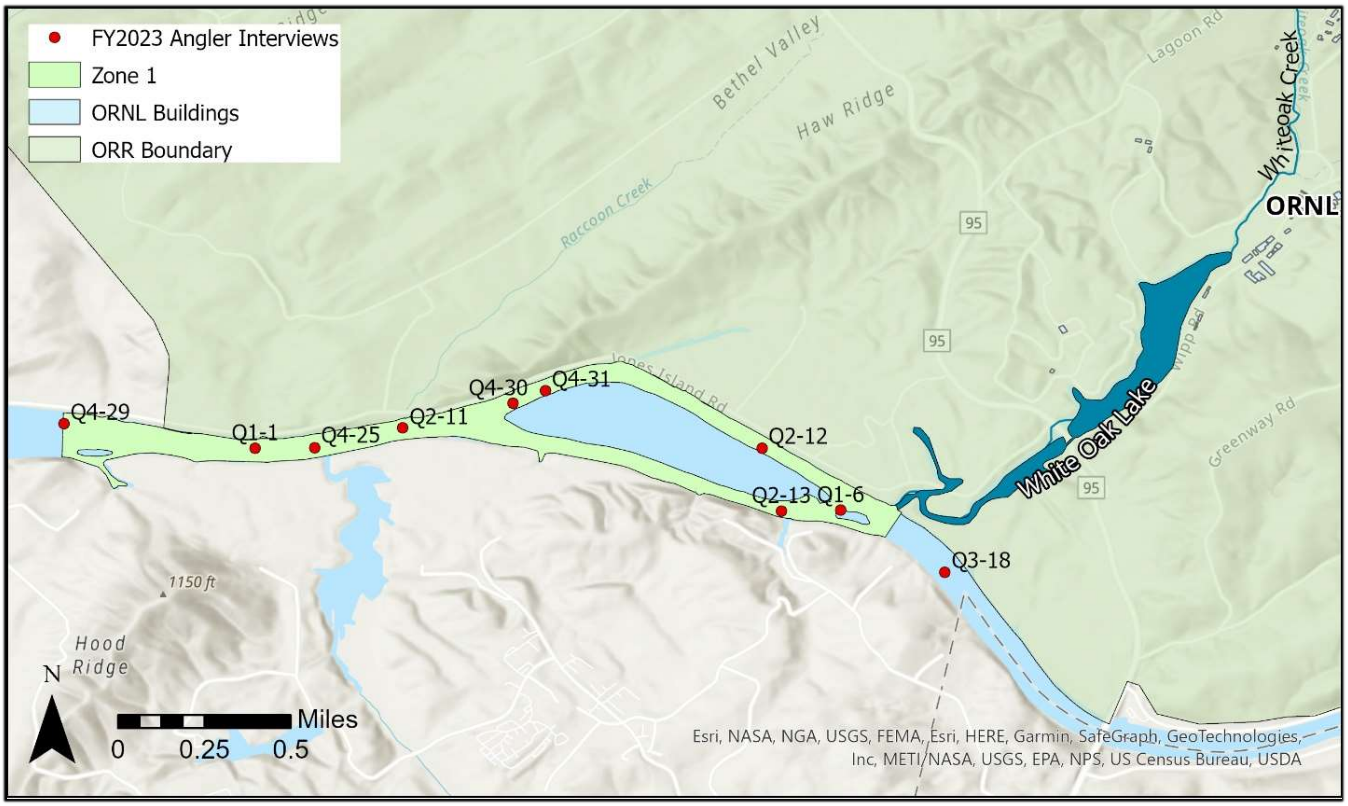

Figure 3.2.7.2: *Zone 1* RCS Interview Locations

Table 3.2.7.1: RCS *Zone 1* Angler Counts and Reported Hours

Zone 1 Interviews						
Quarter-Interview	Date	Party Size (c)	Reported (h)	Total Hours (e)	Lat (DM)	Long (DM)
Q1-1	8/21/2022	2	2.0	4.0	35.8990009	-84.3597328
Q1-6	9/7/2022	1	10.0	10.0	35.8964117	-84.3352489
Q2-11	10/18/2022	2	7.0	14.0	35.8998588	-84.3535785
Q2-12	11/7/2022	1	1.5	1.5	35.8989966	-84.3385362
Q2-13	11/7/2022	3	6.0	18.0	35.8963746	-84.3377241
Q4-25	5/3/2023	2	12.0	24.0	35.8990254	-84.3572434
Q4-29	6/24/2023	2	5.0	10.0	35.9000281	-84.3677357
Q4-30	6/24/2023	2	2.0	4.0	35.9008757	-84.3489464
Q4-31	6/24/2023	1	4.0	4.0	35.9014089	-84.3476073
Total		16	49.5	89.5		

Table 3.2.7.2: RCS *Zone 1* Fishing Effort

Zone 1		
	Hours/Day (f)	Hours/Quarter (T)
Quarter 1	28	515.2
Quarter 2	67	1232.8
Quarter 3	0	0.0
Quarter 4	84	1911.0
Yearly	179	3659.0

Nine (9) unique vessels were approached in Zone 1 between 8/21/2022 and 6/24/2023, at the locations shown in Figure 3.2.7.2. Anglers interviewed reported the hours they spent fishing during their trips, listed as “Reported (h)” column (Table 3.2.7.1). Anglers in Zone 1 reported fishing between 1.5 and 12 hours on the day that they were interviewed. The average time reported fishing in this area was 5.5 hours. The median reported fishing time was 5 hours. DoR-OR personnel estimated that fishing effort (amount of time spent fishing) in Zone 1 was approximately 3659 hours during FY23 (Table 3.2.7.2).

Figure 3.2.7.3: Left Side WOC Embayment Signage

Figure 3.2.7.4: Central WOC Embayment Signage

Figure 3.2.7.5: Right Side WOC Embayment Signage

2) ***RCS Zone 2: PC-CR Confluence*** *(Poplar Creek and the Clinch River Region)*

Zone 2 includes portions of PC located near the former K-25 Gaseous Diffusion Processing Building that has since been demolished. This zone also includes the confluence point of PC with the CR and downstream from the confluence around Campbell Bend. The overall site is now known as the ETTP and has been repurposed as an industrial park. The contaminated buildings at ETTP have been removed and remediation of contaminated areas is ongoing. RCSs take place along this portion of the creek and river to monitor the ongoing impacts of historical DOE activities and the resulting legacy contaminants.

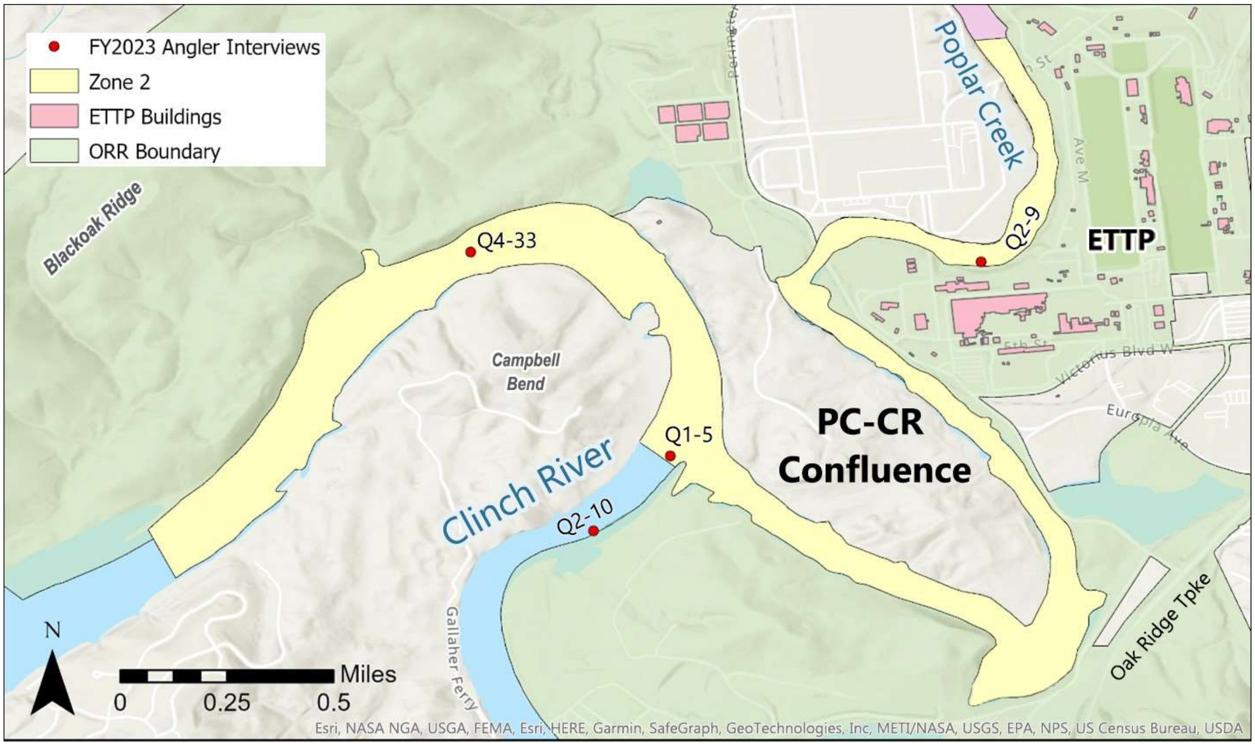

Figure 3.2.7.6: *Zone 2* RCS Interview Locations

Table 3.2.7.4: *Zone 2* Angler Counts and Reported Hours

Zone 2 Interviews						
Quarter-Interview	Date	Party Size (c)	Reported (h)	Total Hours (e)	Lat (DM)	Long (DM)
Q1-5	9/2/2022	4	8.0	32.0	35.9257244	-84.4106482
Q2-9	10/8/2022	2	5.0	10.0	35.9322944	-84.4001153
Q4-33	6/24/2023	2	5.0	10.0	35.9326237	-84.4173982
Total		8	18.0	52.0		

Table 3.2.7.5: *Zone 2* Fishing Effort

Zone 2		
	Hours/Day (f)	Hours/Quarter (T)
Quarter 1	64	1177.6
Quarter 2	20	368.0
Quarter 3	0	0.0
Quarter 4	20	455.0
Yearly	104	2000.6

Three (3) unique vessels were approached in Zone 2 between 9/2/2022 and 6/24/2023 (Figure 3.2.7.6). Anglers interviewed reported the hours they spent fishing during their trips, listed as “Reported (h)” column (Table 3.2.7.4). Anglers in Zone 2 reported fishing between 5 and 8 hours on the day that they were interviewed. The average time reported fishing in this area was 6 hours. The median reported fishing time was 5 hours. DoR-OR personnel estimated that fishing effort (amount of time spent fishing) in Zone 2 was approximately 2,000.6 hours during FY23 (Table 3.2.7.5).

3) **<u>RCS *Zone 3:* EFPC – PC Confluence</u>** *<u>(East Fork Poplar Creek and Poplar Creek Region)</u>*

Surveys conducted in previous fiscal years suggest that the *Zone 3* region is typically utilized by locals. These locals regard PC as a “prime fishing spot” during the spring and fall fishing seasons, when the CR shows an increase in anglers.

Recent survey efforts show that *Zone 3* is typically accessed by foot from East Fork Bridge located at the EFPC-PC confluence, or adjacent to Blair Road. There is litter scattering the banks of the area across from the bridge and a small trail leading to PC. This indicates the potential for significant fishing activity.

While there were no interviews conducted via boat during the RCSs, anglers were either interviewed during NBG walks or reported fishing on the NBG surveys (see NBG results section).

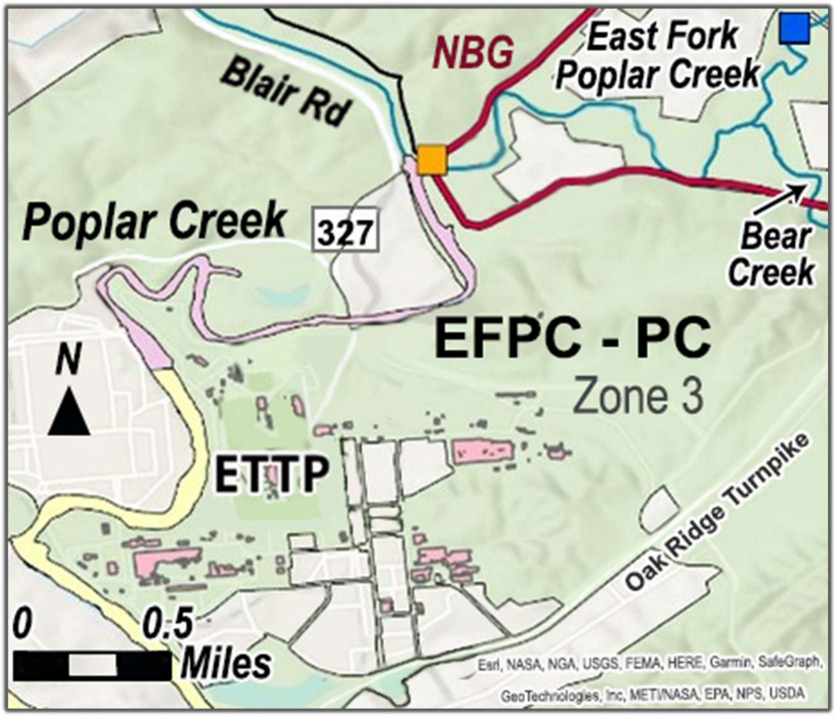

Figure 3.2.7.7: ***Zone 3:*** **EFPC-PC Confluence**

Survey Box at Gallaher Boat Ramp

During FY23 a survey box was placed at the Gallaher Boat Ramp to passively collect surveys from anglers (Red Box, Figure 3.2.4.1). Gallaher Boat Ramp is utilized by DoR-OR to launch the boat for RCSs. Many anglers planning to fish in the defined study zones use this boat ramp to launch their own boats. Additionally, many anglers utilize the banks and boat dock at the ramp to fish.

A total of eight (8) surveys were collected from the survey box. Four (4) reported fishing within the study zones; therefore, fishing effort was calculated based on the results of those four (4) surveys.

Table 3.2.7.6: Gallaher Boat Ramp Angler Counts and Reported Hours

Gallaher Boat Ramp				
Quarter-Survey #	Date	Party Size (c)	Reported (h)	Total Hours (e)
Q2-1	11/22/2022	12	3	36.0
Q2-2	11/24/2022	1	3	3.0
Q4-6	4/8/2023	4	5.5	22.0
Q4-8	6/11/2023	2	4	8.0
Total		19	15.5	69.0

Table 3.2.7.7: Gallaher Boat Ramp Fishing Effort

Gallaher Boat Ramp		
	Hours/Day (f)	Hours/Quarter (T)
Quarter 1	0	0.0
Quarter 2	78	1435.2
Quarter 3	0	0.0
Quarter 4	60	1365.0
Yearly	138	2800.2

Four (4) surveys submitted between 11/22/2022 and 6/11/2023 reported fishing in the study areas. Since the exact location of where fishing occurred cannot be determined these results are only an estimate of additional fishing hours for study Zones 1 through 3. The Q2-1 submitted survey listed other activities (boating, hunting access, swimming, kayaking, birding) in addition to fishing. The same survey reported "Yes" to consuming fish from the area. DoR-OR personnel estimated that fishing effort (amount of time spent fishing) based on the submitted surveys was approximately 2,800.2 hours during FY23 (Table 3.2.7.7).

Notable Observations from NBG Interviews:

1) 75 individuals were observed recreating along the greenway.
2) 101.25 total hours of reported recreator use.
3) 2 individuals 3% described themselves as "visiting"
   73 individuals 97% described themselves as "locals"
4) 1 individual that was observed fishing reported "No" to fish consumption from the area and "Yes" to awareness of signage.
5) Types of reported recreation – running, hiking, swimming, biking, walking, bird watching, and fishing

Notable Comments from NBG Recreator Interviews:

1) One recreator reported swimming in the quarry near the NBG.
2) An angler was spotted fishing from the banks of EFPC at the confluence of EFPC and PC. The angler reported regularly wading barefoot and fishing in EFPC and BC.

Notable Comments from NBG Recreator Surveys:

1) An angler reported wading and fishing in BC. Reported, "It's a good clean creek with great fish, and no one knows!" Angler also reported "No" to fish consumption and "Yes" to signage awareness.

2) One person hiking reported sometimes travelling via boat up EFPC as far as they could to fish for sunfish. Angler reported "Yes" to fish consumption and "Yes" to signage awareness.

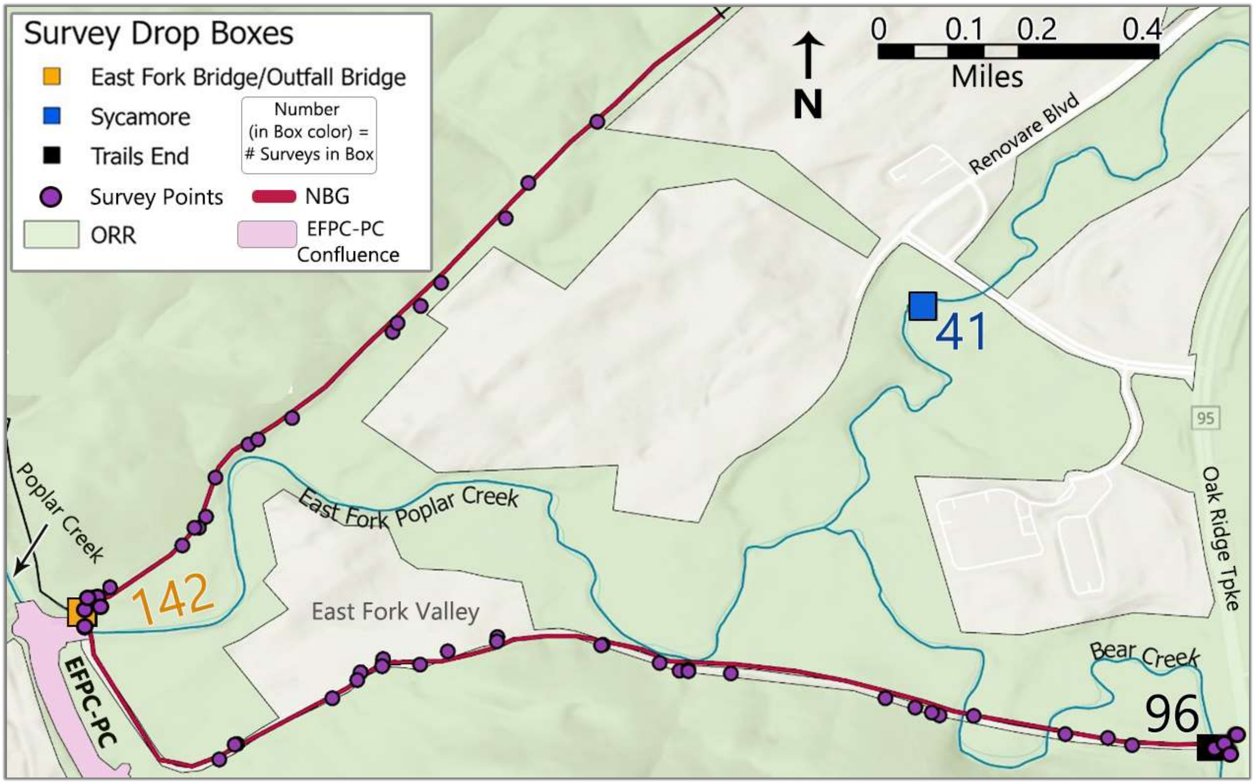

Figure 3.2.7.8: NBG Interviews and Survey Drop Box Locations

Table 3.2.7.8: NBG Interview and Paper/Digital Survey Statistics

	Number of Surveys	Recreators	Hours	Average Hours	Days/Month	Anglers	Fishing Hours
East Fork Bridge	142	252	303.25	2.2	1402	8	12
Trails End	96	199	184	1.9	859	1	2
Sycamore	41	107	96	2.5	214	19	49
NBG Interviews	58	75	101.25	2.025	550	1	5
TOTAL	337	633	684.5	8.625	3025	29	68

Between 5/16/2022 and 6/25/2023 surveys were collected at three (3) survey drop boxes along the NBG (Figure 3.2.7.8). Additionally, DoR-OR personnel conducted walking surveys along the NBG and completed fifty-eight (58) interviews. Recreators reported spending a total of 684.5 hours of activity on the greenway. The average hours spent each day along the greenway were 8.625 hours (Table 3.2.7.8). Recreators reported spending between one and thirty (1-30) days per month along the greenway. A total of twenty nine (29) anglers were observed or reported fishing along or just off the greenway. Anglers reported a total of 68 hours of fishing use along the greenway.

Some of the main types of recreation and the reported number of people participating in these activities are as follows:

1) Running (62)
2) Biking (185)
3) Walking (220)
4) Hiking (265)

Other activities included but are not limited to:

5) Bird Watching
6) Fishing
7) Dog Walking
8) Kayaking
9) Swimming
10) Photography

3.2.8 Conclusions

RCS in FY23 indicate that the WOC-CR confluence was the most popular among anglers with an estimated 3,659 total Angler Hours. The PC-CR confluence had an estimated 2,000.6 total Angler Hours. However, there were no RCS angler interviews conducted from the boat in the EFPC-PC confluence. NBG surveys and interviews did record 17 total hours of reported fishing activity from paper surveys and one (1) interview.

Sixty-nine percent (69%) of the individuals who participated in the RCS portion of this study described themselves as locals. Ninety-seven percent (97%) of those that were interviewed along the NBG described themselves as locals. Many locals reported that they fish frequently and often angle in this area, with some reporting that they also consume fish caught in this area. These results suggest that there is potential for human exposure to contaminants through the consumption of fish, especially amongst locals.

3.2.9 Recommendations

DoR-OR is aware that concentrations of contaminants in the water are higher than background levels at ORR watershed exit points. DoR-OR suggests that a more precise study be conducted to evaluate the potential human exposure risk of fishing in these publicly accessible waters. At minimum, the RCS project should continue.

In addition, signage along the outskirts of the ORR needs more regular maintenance, with clearer warnings. The level of risk to anglers consuming fish they catch around the ORR is largely unknown. Better signage will allow anglers to weigh the risks and pursue fishing in these areas with proper caution.

3.2.10 References

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3.3 Radiological Uptake in Food Crops

3.3.1 Background

DOE has conducted sampling on locally grown vegetables, including root crops (turnips), fruiting crops (tomatoes), and leaf crops (turnip greens, lettuce), as well as on cow milk and hay. The purpose of this sampling is to determine if there is evidence of environmental contamination by accumulation of radionuclides in foods grown and consumed by local residents.

DOE requested that TDEC DoR-OR conduct similar sampling for comparison to DOE's results. The purpose of the DoR-OR Radiological Uptake in Food Crops project is to support evaluation whether radionuclide contamination extends beyond the bounds of the ORR and is taken up into local vegetables, grasses (potential animal fodder), and animal products, like milk.

DOE initially conducted vegetable sampling at their perimeter monitoring stations on the ORR from 1992 to 1996. The focus then shifted to sampling at farms and gardens near the ORR. Their hay sampling later shifted from multiple locations on and near the ORR to only having one (1) location at the far eastern edge of the ORR that is also harvested for hay by an offsite operation.

Prior to 2017, cow milk was sampled from a dairy in Claxton, near the ORR, and at a few other local dairies as reference sites. There has not been any milk sampled since 2016 because the Claxton Dairy shut down and there have been no other dairy options found near the ORR by DOE staff, although they check each year. DOE's sampling results for vegetables, hay, milk (when available), and other media are documented in the annual DOE EMP and ASER (DOE, 2022a; DOE, 2022b).

3.3.2 Problem Statements

- Members of the public may have the potential to be exposed to doses of radiological contaminants through the consumption of locally grown food crops and animal products (i.e., milk) if releases were to occur.
- Radionuclide deposition from current operations, as well as past DOE activities, may occur, especially with ongoing D&D and remedial activities, which may cause the transportation of contaminants beyond the boundaries of the ORR.

3.3.3 GOALS

To obtain food crops data to determine if there is any indication of radionuclide contamination in the local food crops due to DOE activities on the ORR, and to evaluate DOE's comparable data to assess any indications of radiological contamination off the ORR.

3.3.4 SCOPE

The scope of this project was to sample food crops from gardens, farms, dairies, and other sources within a five (5)mile radius of the ORR and use radiological analysis to determine whether radionuclide contamination extended beyond the boundary of the ORR and had impacted local food crops, animal fodder, and animal products. Reference locations beyond this five (5) mile area were also sampled for comparison.

3.3.5 METHODS, MATERIALS, METRICS

Vegetable, hay, and milk samples were collected within five (5) miles of the ORR (Figure 3.3.5.1). Reference samples from locations greater than five (5) miles from the ORR were used to establish background levels. Results from this project were also compared to similar sampling by DOE, as published in their ASER.

Vegetable and hay samples were collected by DoR-OR staff in June through November in the 2022 growing season, with milk samples collected in May 2023. Vegetable and hay samples were shipped to the TDH-NEL for radiological analysis. Vegetation samples (vegetables and hay) were analyzed for gross alpha, gross beta, and gamma isotopes. Additional analyses (e.g. isotopic uranium or specific beta isotopes) were only conducted if alpha or beta levels were elevated.

Prior to July 2021, all vegetation samples were analyzed for isotopic uranium and strontium-90 initially, even though most gross alpha and gross beta levels ended up being low. Starting with FY22 sampling, the project team decided to screen samples for gross alpha and beta before requesting further analysis. This way doesn't result in analysis shown to be unnecessary by low gross alpha or gross beta results and is more cost-effective.

Milk samples continue to be analyzed for gamma isotopes as well as tritium, isotopic uranium, and strontium-90, as gross alpha-beta analysis is not able to be completed effectively for milk samples. Because of this, gross alpha-beta analysis can't be used to determine if additional analysis is needed for milk samples. Eberline Analytical performed the analyses for the May 2023 milk samples.

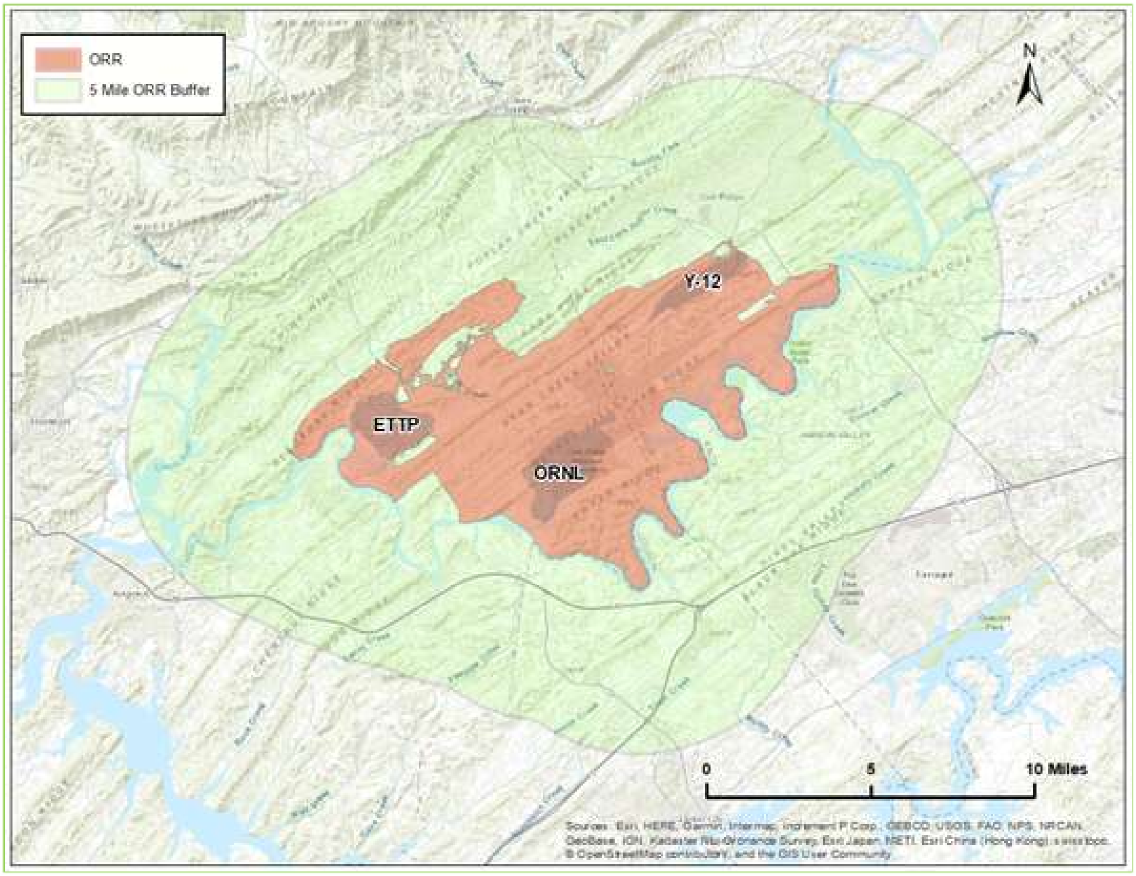

Figure 3.3.5.1: Map of the five-mile radius around the ORR

3.3.6 DEVIATIONS FROM THE PLAN

Nine (9) samples were collected and analyzed in June 2022 and would normally have been included in the FY22 EMR. However, the full data were not yet available, so the results from June 2022 sampling are shown below along with the July to November 2022 data. The June data is from the same growing season and is best compared here regardless.

Two (2) milk samples were collected and analyzed in May 2023. One (1) was a cow milk sample. There were two (2) small goat milk samples that were composited into one (1) sample due to the low volume of each. This composite sample was from two (2) locations within five (5) miles of the ORR. Even with combining the goat milk samples, there was not enough sample volume to run all the planned analyses.

The 2021 food crop results from the DOE ASER published in September 2022 are used for a comparison to DoR-OR data as the most recent DOE ASER data when this report was written (DOE, 2022).

3.3.7 Results and Analysis

The results of the June 2022 and FY23 food crops sampling are shown in Table 3.3.7.1 (vegetables and hay) and Table 3.3.2 (milk). There were forty-four (44) samples analyzed, with forty-two (42) vegetation samples (16 hay, 26 vegetable) and two (2) milk samples analyzed.

Vegetation: Vegetables and Hay

The 2022 vegetable and hay sampling results are shown in Table 3.3.7.1. Results shown in gray text rather than black did not qualify as detects as they had an analytical uncertainty (error) more than a third of the result. Locations with green shaded cells were background or reference locations from than five (5) miles from the ORR. The results of the gamma analyses with no values and the entire cell shaded gray, had no reported results for that analyte.

Table 3.3.7.1: DoR-OR 2022 Vegetable & Hay Sampling Results (units in pCi/g)

Location	crop type	gross alpha	gross beta	gamma K-40	Be-7	Bi-214	Pb-214	Pb-212	Ac-228	Tl-208
Clinton home garden	greens- lettuce	0.10	6.7	9.7		0.103				
West Knox Co home garden 1	greens- lettuce	0.93	16.8	19.5	3.3	0.25				
Karns home garden	greens- kale	0.58	20.8	30.1		0.38			0.67	
West Knox Co home garden 1	greens- rocket	0.62	22.3	23.8						
Oak Ridge Scarboro community garden	greens- mustard	0.05	4.6	5.9				0.048		
Mid Oak Ridge community garden	greens- collard	0.57	17.5	24.6		0.4				
Farragut home garden	greens- mint	0.32	17.0	22.1	4.7			0.39		
West Knox Co home garden 2	greens- mint	1.20	16.5	27.3	3.7					
Mid Oak Ridge garden	greens- mint	0.85	17.2	18.3	4.3					
Fort Loudoun Dam Access	hay- grasses	1.24	16.9	29.6	4.8	0.52	0.31			
Karns home garden	hay- grasses	0.79	13.2	13.8	6.0	0.25	0.21			
ETTP west end hay field	hay- grasses	4.30	10.6	11.0	2.6					
Public boat ramp near ETTP	hay- grasses	0.73	10.8	11.7	5.5			0.094		
Below Melton Hill Dam, along Clinch	hay- grasses	0.28	24.4	33.7	11.4					
Hickory Creek W. Knox Park	hay- grasses	0.90	14.4	20.2	8.4					
West Knox park field	hay- grasses	1.67	14.6	15.9	3.0	0.29				0.071
Guinn Rd Park	hay- grasses	0.96	14.0	26.7						
Near ORNL east end hay	hay- grasses	0.38	35.9	51.3						
East end Oak Ridge field	hay- grasses	1.01	10.4	11.5	3.8					
Mid Oak Ridge field	hay- grasses	0.55	11.7	10.2	6.7					
Scarboro field	hay- grasses	0.63	17.4	17.2	8.5		0.18			
Big Turtle Park Access	hay- grasses	0.65	20.0	35.2	7.9		0.25			
East Quarry Trail Access	hay- grasses	0.33	15.7	27.3						
North Boundary Trail access	hay- grasses	0.28	13.8	22.7	6.4	0.30	0.22			
Dyllis Orchard Trail access east	hay- grasses	0.42	19.6	32.8	7.4	0.49				
Claxton garden	root- potato	0.25	2.9	4.09						
West Knox Co home garden 2	root- sweet potato	0.17	4.8	5.44		0.144	0.140			
South Knox home garden	root- garlic	0.48	3.0			0.168			0.126	
Grocery garlic	root- garlic	0.09	4.2	5.07						
Mid Oak Ridge community garden	root- garlic	0.19	2.0	3.45						
Karns home garden 2	root- onion	0.04	1.5	2.01						
Grocery onion	root- onion	0.02	1.1	1.31		0.078				
Mid Oak Ridge community garden	root- onion	0.12	1.3	2.29		0.138	0.094			
Solway garden	root- onion	0.10	1.2	2.19		0.063				
Karns home garden	vegetable- cucumber	0.04	1.2	1.62						
Mid Oak Ridge community garden	vegetable- cucumber	0.1	1.1	1.8						
Home Garden SW of ORNL	vegetable- cucumber	0.09	0.88	1.58						
Karns home garden	vegetable- squash	0.02	1.2	1.3						
Oak Ridge east home garden	vegetable- squash	0.12	1.4	2.46		0.028	0.028			
West Knox Co home garden 2	vegetable- squash	0.11	0.9	1.4						
Mid Oak Ridge community garden	vegetable- squash	0.11	1	1.55			0.041			
Oak Ridge Scarboro garden	vegetable- squash	0.08	0.7	1.2						

Gray text = non-detect (uncertainty > 1/3 result) *Orange Text = estimated value*

Green Cell = background site (> 5 miles from ORR) *Filled Gray Cells = gamma analysis yielded no results for that isotope*

Vegetable and hay samples were analyzed for gross alpha, gross beta, and gamma isotopes with additional analysis (isotopic uranium or specific beta isotopes) only completed if indicated by elevated gross alpha or gross beta results. Consequently, only one (1) hay sample (from the ETTP west end field location) had a higher gross alpha result (4.3 pCi/g) suggesting that isotopic uranium analysis be run. However, the analytical error was too high for that result and hence was not an official detect. The isotopic uranium results for that sample were similar to that of a background hay sample from June 2021, and not considered elevated. The June 2021 result was used for comparison as isotopic uranium was not run on all samples in 2022.

The gross alpha and gross beta results with numbers in gray (Table 3.3.7.1) were not considered detects as the associated analytical errors were considered too high. The one (1) gross alpha result that was considered as a detect was greater than twice background for the other lettuce sample, but not for the background kale or mint samples. Regardless, all the gross alpha results were relatively low, with the TDH-NEL not considering anything below 3.0 pCi/g for gross alpha to be detectable.

The 2022 gross beta levels were quite variable, but most gross beta results were lower for fruiting vegetables (cucumber and squash) and root vegetables. However, most gross beta results were higher for samples of greens and grasses. These elevated levels are likely due to higher levels of potassium-40 (K-40), which is naturally occurring and is both a beta and a gamma emitter. The higher gross beta results did correspond to higher K-40 results, so K-40 was likely the largest beta constituent.

The highest gross beta result (35.9 pCi/g) was collected near where DOE has been collecting their hay samples on the eastern edge of the ORR (DOE, 2022). The result was a little over twice the highest background gross beta value. Some of the lushest green grass (hay) samples had higher levels of K-40 and hence higher gross beta levels. Some of the gross beta could have been due to fertilizer, although greens and grasses do appear to be especially good at bioaccumulating K-40. Samples grasses or dryer greens that were not weighed by the lab before drying (as the lab considered them mostly dry already) could show a slightly higher activity result than they would have if the original wet weight were accounted for in the calculations. However, most of the root and fruiting vegetable samples had gross beta results that were relatively low, with the TDH-NEL verbally not considering anything below 4.0 pCi/g for gross beta in vegetation to be detectable.

Some amount of isotopic uranium and thorium, as well as gamma emitting daughter products (lead, bismuth, and potassium), are naturally occurring in soils and thus not unexpected in sample results. Beryllium-7 is a naturally occurring cosmogenic radionuclide and is also not unusual. The amount of isotopic uranium in the one (1) 2022 vegetation sample tested due to a higher gross alpha value was negligible when compared to the international food products standard of 2.7 pCi/g (100 Bq/kg) for U-235 (FAO, 2006). In addition, the amounts of U-235 were similar to the 2021 background hay sample results. The international foos products standard was used for comparison since there are no known US Food and Drug Administartion isotopic uranium limits for food products.

If higher levels of isotopic uranium are seen at locations with higher levels of gross alpha, such as in previous years, this may be due to fertilizer use. This correlates with the higher levels of K-40 (a beta and gamma emitter) seen at these locations, as higher levels of K-40 can be seen with increased amounts of potassium in NPK (nitrogen, phosphorus, and potassium) fertilizer. Uranium levels in soils can also be increased with fertilizer use, as uranium and thorium are often concentrated during the manufacture of fertilizers from the levels normally found in the phosphate rocks used to make fertilizer. This can lead to higher gross alpha levels, levels of isotopic uranium, and levels of uranium daughter products emitting gamma radiation (World Nuclear Association, 2020; ORAU 2021). It appears that hay (grasses) and leafy greens may naturally bioaccumulate K-40, as it is seen in higher levels in those samples, even when no fertilizer was likely to have been applied. However, no additional analysis was needed (as indicated by no elevated gross alpha or gross beta results) at any of the home garden locations for 2022 samples, and the low-level concentrations that were detected were comparable to background locations outside a five (5) mile radius of potential impact from the ORR.

Milk

As stated in the DOE ASER, "Milk is a potentially significant exposure pathway to humans for some radionuclides deposited from airborne emissions because of the relatively large surface area on which a cow can graze daily, the rapid transfer of milk from producer to consumer, and the importance of milk in the diet." The milk data for the DoR-OR FY23 sampling is shown in Table 3.3.2. The background (i.e. reference) cow milk sample was from a small commercial dairy outside the five (5) mile radius around the ORR. No sampling locations within the five (5) mile radius or the ORR were found with active dairies in FY23; however, there was an opportunity to collect a goat milk sample composited from samples at two (2) locations within the five (5) mile radius around the ORR. The sample was a composite of both goat milk samples, in an effort to increase the sample volume. However, the sample still was not large enough to run all the planned analyses of tritium (H-3) and isotopic uranium.

Table 3.3.7.2: DoR-OR FY23 Goat Milk Sampling Results (results in pCi/L)

		gamma			beta		isotopic uranium		
location	sample	K-40	Cs-137	Co-60	Sr-90	H-3	U-234	U-235	U-238
Small Knox Co Dairy	milk- cow	896.7	2.1	-0.33	0.20	644.423	0.544	0.173	0.279
Near ORR (composite)	milk- goat	1348.6	13.8	14.52	1.37	*	*	*	*

Gray text = non-detect (< MDA, or uncertainty > 1/3 result) * = low volume, not analyzed

Results shown in gray text rather than black were below detection limits, meaning below the minimum detectable activity and/or with the uncertainty (error) being more than a third of the result. Locations with green shaded cells were background or reference locations, greater than five (5) miles from the ORR. While there were varied levels of K-40, the results were within range of levels seen from prior DoR-OR milk sampling and similar to or lower than levels seen in 2016, when milk was last sampled by DOE. Tritium (H-3) was detected in the cow milk sample from the background location. However, when compared to the 20,000 pCi/L drinking water limit for tritium (EPA, 2002), this is a very low result.

All DoR-OR milk sample Sr-90 results were well below the FDA derived intervention limit of 4400 pCi/L for Sr-90 in milk, and even below detection limits. Analysis from more milk samples and especially goat milk samples would be helpful for more meaningful comparisons. DOE did not sample milk in 2022 or any year since 2017. The only results from DOE's 2016 milk sampling program that were above detection limits were for K-40 (Potassium-40) and are shown in Table 3.3.7.3. The 2016 ASER stated that analysis was done for gamma emitters and strontium, but there were no gamma or strontium detections.

2021 DOE ASER Comparisons

Vegetables

The most recent DOE ORR ASER data was from 2021 in the *ORR Environmental Monitoring Program* section (DOE, 2022). The similar DOE sampling from the 2021 ASER was limited to vegetables, and included tomatoes (6 samples), turnip greens (2 samples), and turnip roots (2 samples), with no hay sampled in 2021.

The DOE vegetable results were converted to the same units (pCi/g) used for the DoR-OR data. Only data with results above detection limits were shown in the 2021 ASER, with non-detects listed as "n", as opposed to included but shown in gray in DoR-OR data. Detection limits are likely not the same between DOE and DoR-OR sampling projects as different laboratories were used.

Table 3.3.7.3: 2021 DOE Vegetable Radionuclide Results (results in pCi/g)

Location	gross alpha	gross beta	gamma		uranium isotopes		
			Be-7	K-40	U-234	U-235	U-238
tomatoes (fruiting vegetables)							
North of Y-12	*n*	2.06	*n*	2.26	*n*	*n*	*n*
North of Y-12	*n*	1.79	*n*	2.31	*n*	*n*	*n*
South of ORNL	*n*	2.35	*n*	3.08	*n*	*n*	*n*
East of ORNL	*n*	1.95	*n*	2.33	*n*	*n*	*n*
West of ETTP	0.061	1.25	n	1.63	n	n	n
Reference site	*n*	1.93	*n*	2.07	*n*	*n*	*n*
turnips (roots)							
North of Y-12	*n*	2.91	*n*	3.42	*n*	*n*	*n*
Reference site	*n*	3.00	*n*	3.29	*n*	*n*	*n*
turnips (greens)							
North of Y-12	0.118	6.41	*n*	6.58	*n*	*n*	*n*
Reference site	*n*	5.32	0.349	5.77	*n*	*n*	*n*

n = non-detect, value < MDA (minimum detectable activity)

DOE vegetable samples were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. The 2021 DOE vegetable gross alpha results were similar to the amounts seen by the 2022 DoR-OR sampling, with most less than the minimum detectable activity. Gross beta and K-40 results were similar for root and fruiting vegetables between the two projects, although DoR-OR greens results were higher than those listed above for DOE's analyses. DOE's 2021 greens' results, and 2020 ASER hay results also showed higher concentrations of the measured activities, indicating greens and hay as efficient bioaccumulators. The same is shown in the 2022 DoR-OR data.

Hay

Hay is a potential radiation exposure pathway to humans if meat, milk, or other animal products are consumed. However, DOE did not collect any hay samples for analysis in 2021 (DOE, 2022), although recent samples from prior years have been collected near the DoR-OR site 'Field East of ORNL'.

Milk

DOE did not collect any milk samples for analysis in 2021 (DOE, 2022); however, DOE checks each year for dairies that could potentially be affected by the ORR. The last milk analysis was done for 2016 samples, when a near dairy was found. The results of this analysis can be seen in Table 3.3.7.4 (DOE, 2017).

Table 3.3.7.4: DOE's 2016 milk sampling results (pCi/L)

	Claxton		Maryville (reference)	
	Mean	Maximum	Mean	Maximum
Potassium-40	1330	1350	1325	1360

Analysis was also done for gamma isotopes, strontium, and tritium for the above samples, but only samples with results above their detection limits were shown in the ASER and are listed here.

3.3.8 Conclusions

The DoR-OR *Radionuclide Uptake in Food Crops Project* in 2023 collected vegetable, hay, and milk samples within a five (5) mile radius of the ORR, as well as at reference locations outside this area. The samples were analyzed for radiological contaminants and compared to levels seen at reference locations. In addition, samples were also compared with the results from DOE's most recent similar sampling with 2016 milk, 2021 vegetables, and 2020 hay (DOE, 2017; DOE, 2022b; DOE, 2021). In general, for the vegetation samples (hay, vegetables) collected in 2022 and the milk samples collected in May 2023, the low-level concentrations that were detected were comparable to background locations outside a radius of potential impact from the ORR. Overall, the TDEC DoR-OR FY23 vegetable, hay, and milk sampling results did not indicate that DOE ORR activities are significantly impacting radionuclide concentrations in food crops in the areas surrounding the ORR, nor did the DOE data from the current ASER.

3.3.9 Recommendations

DoR-OR recommends that additional vegetable, hay, and animal product (e.g. – cow milk, goat milk, egg) sampling be conducted in order to generate a larger dataset to identify any trends in radionuclide uptake that may be present in the vicinity of the ORR and for comparison to DOE data and contaminant limits.

3.3.10 References

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3.4 Mercury Uptake in Biota

3.4.1 Background

Mercury is found in elevated levels throughout the ORR resulting from processes and spills dating back to Manhattan Project and Cold War era activities. Mercury in streams and wetlands often undergoes methylation and is transformed into toxic methylmercury (MeHg) in conjunction with the activity of microorganisms (Kalisinska et al, 2013). Methylmercury is particularly bioavailable to wildlife (and humans) and, if ingested, may cause serious neurological, reproductive, and other physiological damage (Standish, 2016). Decreases in reproductive success of 35–50% have been observed in birds with high dietary methylmercury uptake including reduced hatching and fledging success (USDI, 1998; Hallinger et al, 2011).

The headwaters of Bear Creek and EFPC Watersheds are fed, in part, by Y-12 runoff. Stormwater flows from the main plant facilities and parking lots into these two (2) ORR streams. Additionally, groundwater also receives surface water from Y-12. These inputs represent a potential exposure risk that could impact human health, the environment, and both terrestrial and aquatic wildlife.

More specifically, Y-12 runoff is potentially contaminated with legacy contamination like mercury and its byproduct, methylmercury. Methylmercury biomagnifies through food chains. Organisms at higher trophic-levels (i.e., secondary and tertiary consumers), such as songbirds and ducks, acquire increasingly larger body burdens of methylmercury through consumption of lower trophic-level prey items. Small invertebrates like benthic larval-stage biota, terrestrial spiders, and emergent flying insects (Scheuhammer et al 2007) are consumed regularly by these insectivores. Emergent adults of some aquatic macroinvertebrates are often eaten by terrestrial insectivores thereby creating a key link for bioaccumulation between aquatic to terrestrial environments (Henderson et al. 2012).

It is important that TDEC DoR-OR monitor key species from multiple trophic strata to assess the movement of contaminants through the food web. Sampling songbirds, adult flying insects, and spiders provide a clearer picture of the bioaccumulative transfer of mercury.

3.4.2 Problem Statements

1) Migratory birds are highly mobile and, therefore, have the capability to travel great distances and potentially disperse contaminants.
2) Potential cross-over of contaminants from aquatic to terrestrial environments is a major concern. Emergent aquatic insect adults developed as larvae in contaminated aquatic environments. These adult insects are often eaten by terrestrial insectivores such as songbirds, waterfowl, bats, and spiders. This food web is a key link for mercury and/or MeHg transfer and bioaccumulation from water to land.

3.4.3 Goals

1) Determine the extent to which biota have bioaccumulated mercury and methylmercury within the impacted areas of Bear Creek Valley (BCV) floodplain and the project's aquatic monitoring sites.
2) Determine contaminant migration paths from aquatic to terrestrial environments in the BCV and draft suggestions for DOE to control migration.
3) Evaluate bioaccumulation of mercury and methylmercury in biota samples collected from the impacted BCV.

3.4.4 Scope

This project consists of collection and laboratory analysis of mercury and methylmercury in songbird eggs, adult flying insects, and wolf spiders throughout the BCV watershed. These samples were analyzed for mercury and methylmercury, as well as additional contaminants to support the Bear Creek Assessment Project (BCAP); namely, arsenic, cadmium, and uranium metals, and PCBs.

Biotic specimen(s) were captured on the ORR by the project team from three (3) main study zones in the BCV Watershed and one (1) reference zone in the spring and summer months of FY23.

- Zone 1 (BCAP001) – the downstream region of Bear Creek, including some publicly-accessible and recreational areas.
- Zone 2 (BCAP002) – the middle region of Bear Creek that represents a buffer zone between the relatively unimpacted downstream areas and the industrial impacted areas of Bear Creek. The future Environmental Management Disposal Facility (EMDF) landfill will be located within Zone 2.
- Zone 3 (BCAP003) – the upper reaches and headwaters of Bear Creek where discharges from burial grounds and industrial areas create significant impacts to the watershed. This area receives discharges from the Bear Creek Burial Grounds via North Tributary 8 (NT-8), the S-3 ponds, and other sources of contamination.
- Reference Zones (REF001 and REF002) – the Freel's Bend area of Melton Hill Lake for songbird eggs, and Mill Branch for spiders and adult flying insects.

Specific site locations for the different sampling activities are shown on the maps and table below (Fig. 3.4.4.1, Fig. 3.4.4.2, Table 3.4.4.1).

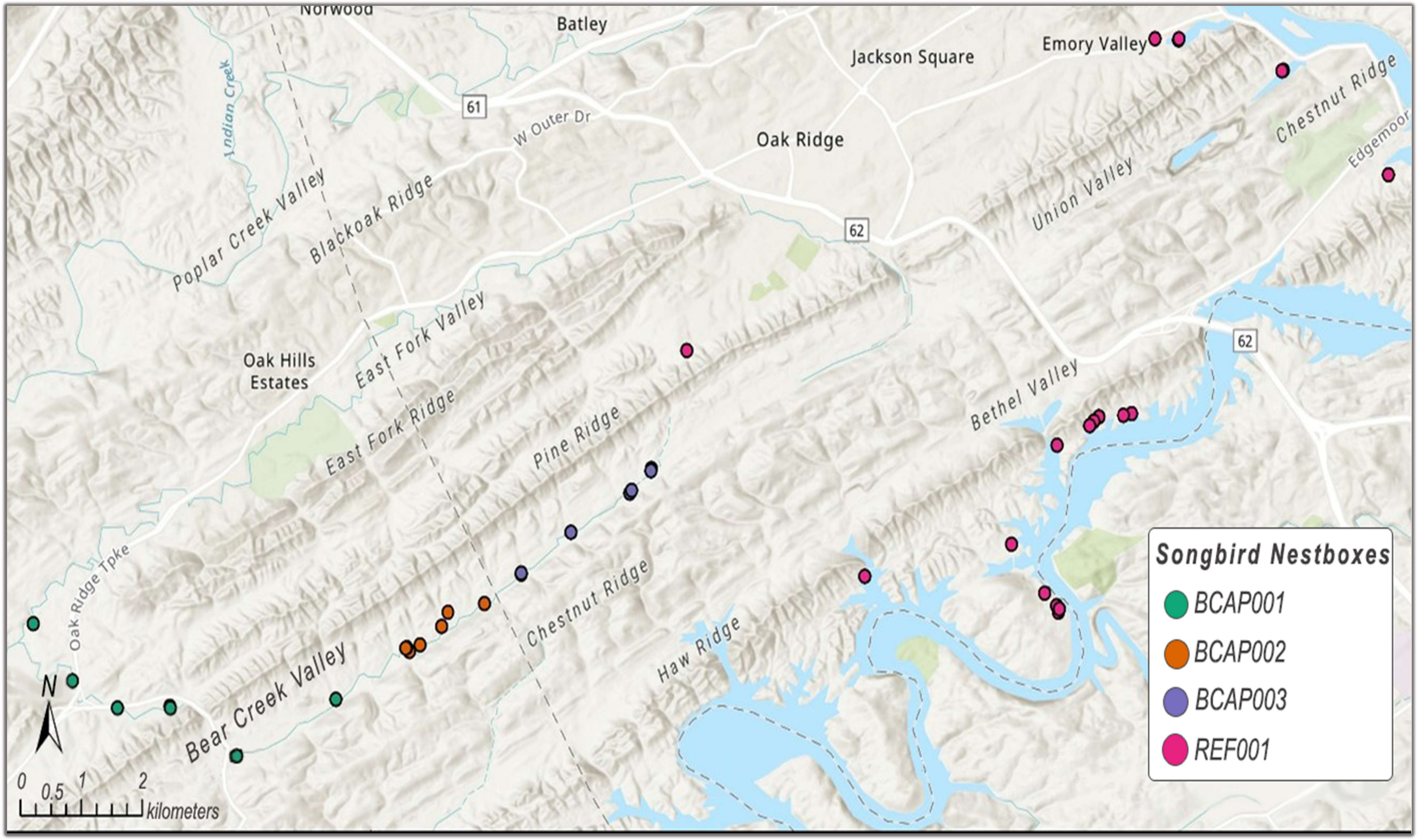

Figure 3.4.4.1a. Songbird Nestbox Sampling

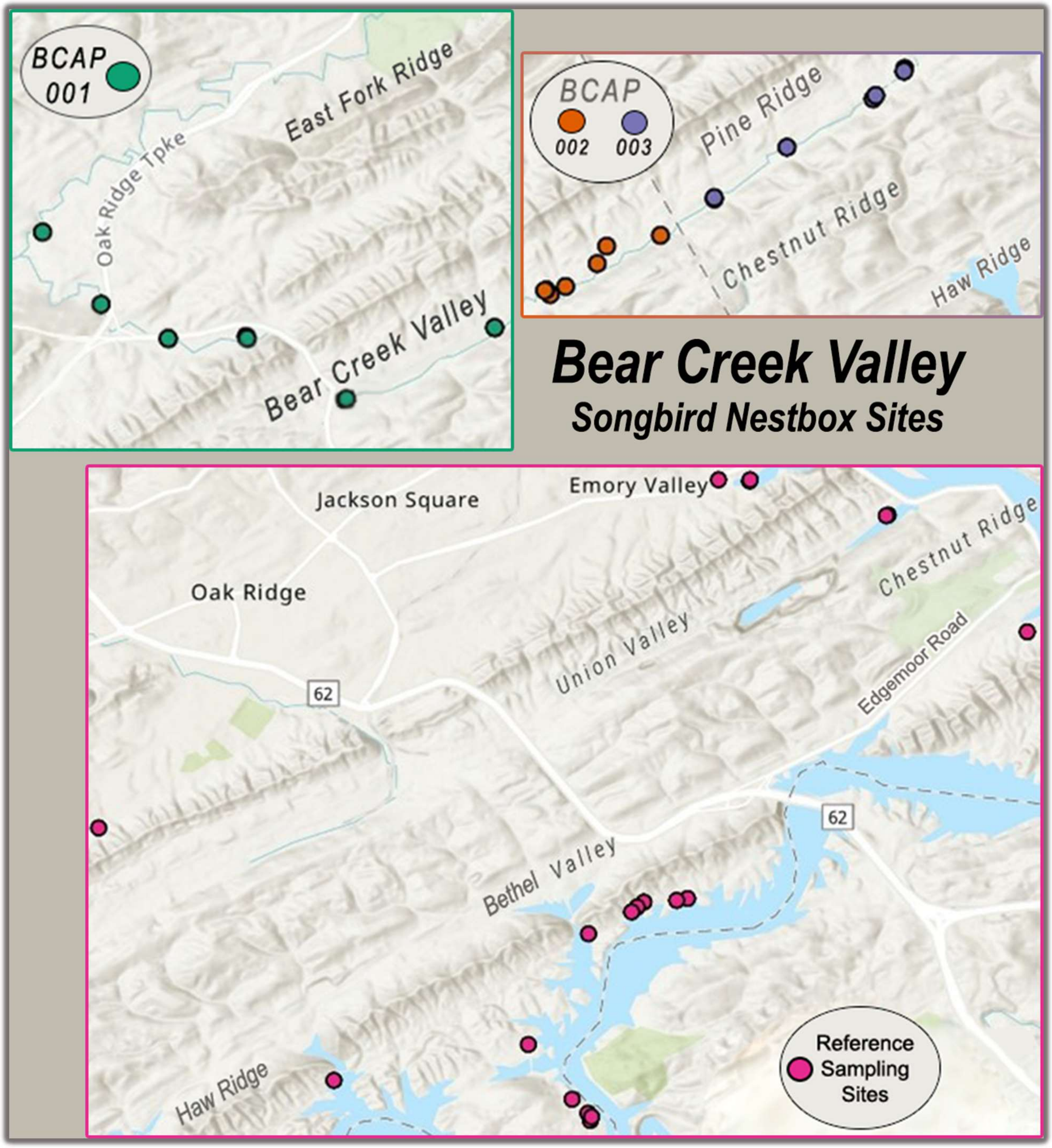

Figure 3.4.4.1b. Enlarged Excerpts of BCV Songbird Nestbox Sites

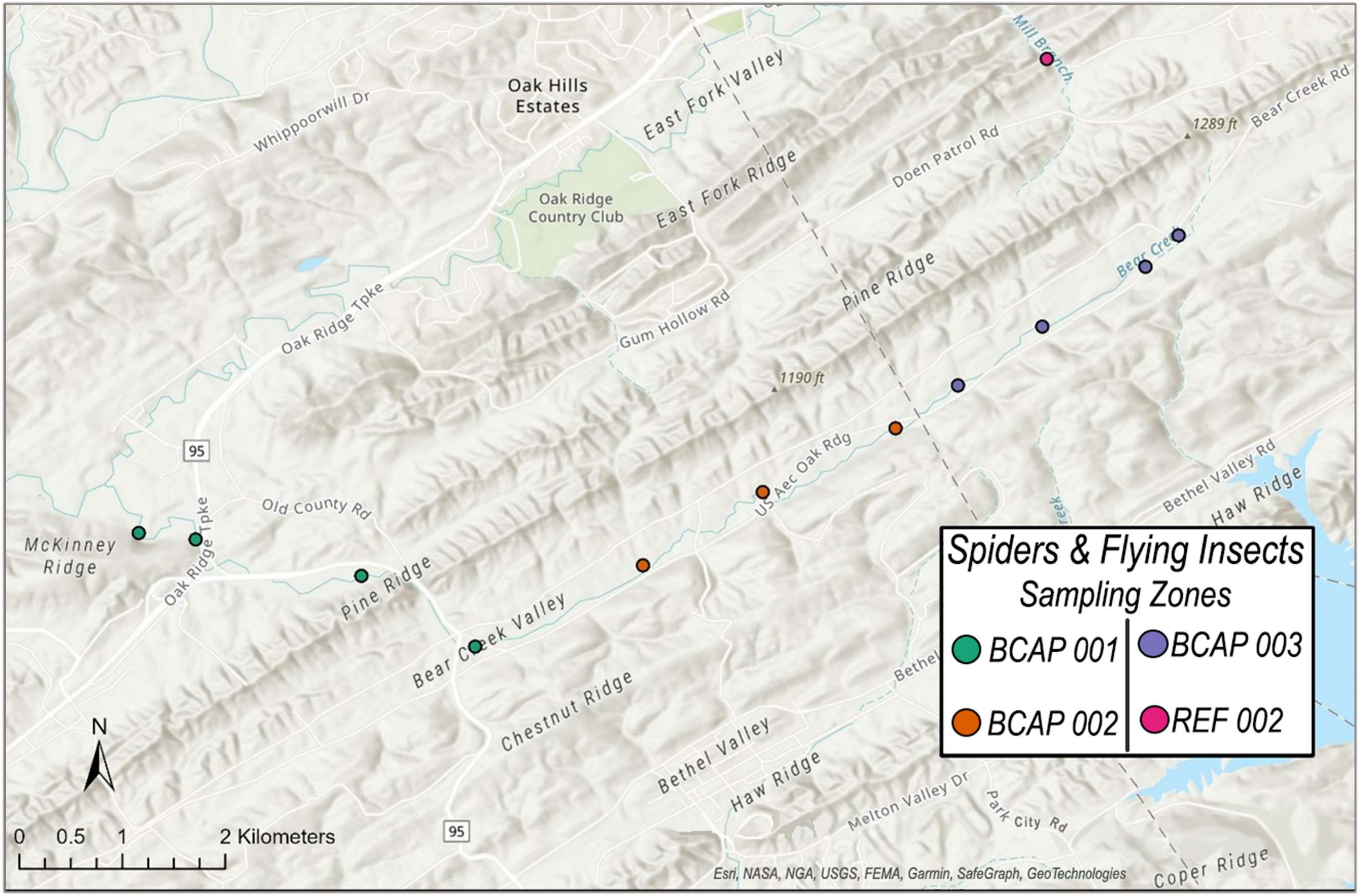

Figure 3.4.4.2a. Map of Spider and Adult Flying Insect Sampling Sites

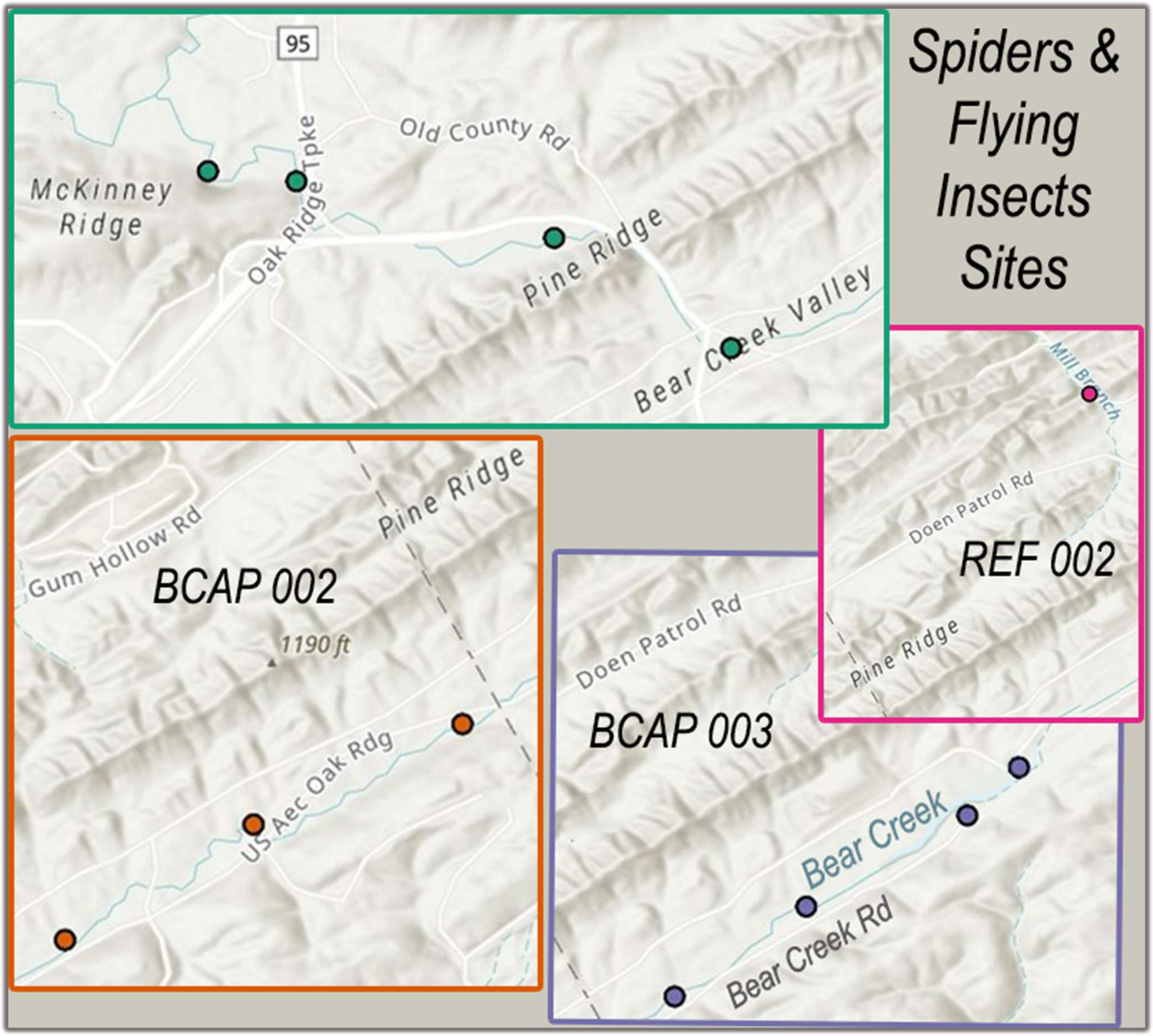

Figure 3.4.4.2b. Enlarged Excerpts - BCV Spiders & Flying Insect Sites

Table 3.4.4.1 TDEC DoR-OR Bear Creek Biota Sampling Sites

Zone	Site	KM / #	Latitude	Longitude	SB Eggs	Spiders & FI
BCAP 001	BCK	0.0	35.94974	-84.383688		x
		0.0	35.95409742	-84.36932059	x	
		0.6	35.94747	-84.36855		x
		1.8	35.94692549	-84.36356071	x	x
		2.2	35.94359079	-84.35686282	x	
		3.3	35.94374812	-84.34914744	x	x
		4.5	35.93758348	-84.33921305	x	x
		6.0	35.94466669	-84.32454279	x	x
BCAP 002		7.6	35.95107512	-84.31409173	x	x
		7.8	35.95059789	-84.31362486	x	
		8.0	35.95143826	-84.31208175	x	
		8.3	35.953787	-84.30889637	x	
		8.6	35.95552042	-84.30792273	x	
		9.2	35.95663483	-84.30253476	x	x
BCAP 003		9.6	35.9603836	-84.29707998	x	x
		10.6	35.96550217	-84.28974993	x	x
		11.7	35.97039595	-84.28100358	x	
		11.8	35.97072263	-84.28074282	x	x
		12.3	35.9734817	-84.27785735	x	x
REF 001	BBR SBB	45	35.96000805	-84.24624852	x	
	DPR SBB	53	35.98823	-84.27249	x	
	EVR DB	51	36.0270393	-84.19973625	x	
	EVR SBB	48	36.02720094	-84.1996355	x	
	EVR SBB	49	36.02715011	-84.20317182	x	
	FBR SBB	40	35.95791328	-84.219582	x	
		41	35.95631536	-84.21782666	x	
		42	35.95592053	-84.21737454	x	
		43	35.95552683	-84.21754226	x	
		44	35.96402625	-84.22445515	x	
	HRP SBB	46	36.01016992	-84.16865154	x	
	PHR DB	15	35.98014846	-84.2078641	x	
	PHR DB	17	35.98030797	-84.20666783	x	
	PHR SBB	37	35.97941022	-84.21231086	x	
		38	35.97884763	-84.21293867	x	
		39	35.97636261	-84.21770822	x	
		47	35.97992097	-84.21156747	x	
	UVR DB	52	36.02319662	-84.1841926	x	
	UVR SBB	50	36.02318396	-84.18440298	x	
REF 002	MBK	1.6	35.98886	-84.28935		x

BCK = Bear Creek	*BBR = Bull Bluff Rd*	*EVR = Emory Valley Rd*
FBR = Freels Bend Rd	*HRP = Haw Ridge Park*	*PHR = Pumphouse Rd*
UVR = Union Valley Rd	*MBK = Mill Branch Creek*	

3.4.5 Methods, Materials, Metrics

Songbird Eggs:

Songbird nest boxes were installed along Bear Creek (BCK) and at reference locations. Songbird nest boxes were checked routinely in the spring to determine occupancy. Once a nest box was confirmed to have an occupant, the box was checked twice per week to collect the initial clutch of eggs for analysis.

The breeding season for songbirds typically runs from March through June and each breeding pair may have one to two broods. When the first brood is taken from a nest box for analysis, there is a good chance that the female will have a second brood. All eggs collected from the same zone were composited into one (1) sample. There were three (3) total songbird egg samples sent to an external laboratory for analysis.

Spiders:

Wolf Spiders were sampled by project members at BCK sites and at the reference sites. Sampling activities occurred in June 2022. During night hours, flashlights held at eye level were used to locate the reflective spider eyes near the stream shoreline or adjacent floodplain area. Then, the spider was retrieved using long forceps or tongs. During collection, spider specimens were placed into plastic cups with lids. Spiders collected from the same zone were composited into one (1) sample. There were four (4) total spider samples sent to an external laboratory for analysis.

Adult Insects:

In June 2022, insects were co-sampled with spiders by project staff at BCK sites and at reference sites. Nocturnal insects were attracted to a black light which provided a maximum insect response from as far away as 500 meters. The adult insect trap was comprised of a device with a white mesh globe (no-see-um material). Inside the trap, a black light attracts the insects after dark. After numerous insects landed on the globe, they were hand collected using an aspirator-vacuum tool. This device sucks the bugs off the white no-see-um mesh globe and secures them in replaceable sample vials. Insect samples collected from the same zone were composited into one (1) sample. There were four (4) insect samples sent to an external laboratory for analysis.

Sample Preparation and Handling at the DoR-OR Laboratory (all biota samples):

1) In the laboratory, all biota samples were weighed to the nearest 0.01 gram (g) and recorded on the laboratory sample log.
2) Egg samples were weighed (nearest 0.01 g) and recorded on the laboratory sample log.
3) All composited biota samples were placed into Level 2 pre-cleaned glass jars (with labels and screw-top plastic lids). These sample jars were stored at -18degrees Celsius (ºC) in the DoR-OR laboratory freezer until shipment to the laboratory for processing.

3.4.6 Deviations from the Plan

Originally, the FY23 sampling plan included collecting biota samples from lower EFPC; however, in FY22, BCAP sampling did not produce enough biomass. More specifically, the sample was depleted after initial analyses and testing for heavy metals and PCB was not possible. The project team decided that for FY23 sampling, a follow-up evaluation of the Bear Creek Watershed would be conducted. The focus was to obtain new sampling data to fill in data gaps left from the Phase 2 investigation. More data was used to better determine the overall health of the Bear Creek Watershed.

The next project year will address the health of the lower EFPC Watershed. Sampling will be postponed until FY24, and the subsequent data reported in the FY24 EMR.

3.4.7 Results and Analysis

Sufficient songbird egg biomass was collected from two (2) out of the three (3) impacted BCK zones (i.e. BCAP001, BCAP002). A different reference zone, REF001, was utilized to collect sufficient egg biomass. In contrast, sampling in BCAP003, which is the farthest site upstream. produced insufficient egg biomass; therefore, no analysis was completed.

Nocturnal spiders and flying insects were collected from all three (3) impacted Bear Creek (BCK) zones. Reference samples for these animals were collected from reference site 002 (REF002) located at Mill Branch kilometer 1.6 (MBK 1.6).

Table 3.4.7.2. contains a summary of the detected results for heavy metals and PCBs across all biota media. The table includes minimum and maximum detection results. Additionally, the table indicates how many samples (songbird egg, spider, or flying insects) resulted in either detections, estimates (J), or non-detections (U) of specific analytes. All non-detect results were excluded from the figures below for simplicity. Most of the non-detect (U) results are attributed to PCBs.

__Mercury and Methylmercury__

All mercury (Hg) and methylmercury (MeHg) sample values were below the EPA recommended limits for fish tissue, which are used here for reference. The actionable concentration for mercury in fish is 0.3 milligram per kilogram (mg/kg). Hg concentrations ranged from 0.028-0.16 mg/kg, while MeHg ranged from 0.011-0.179 mg/kg (Table 3.4.7.2).

Concentrations of MeHg were highest in spiders. Songbird eggs contained the lowest concentrations of both Hg and MeHg. Spiders and adult flying insects had opposite trends, where spiders contained the higher MeHg concentrations and adult flying insects contained higher concentrations of Hg. For spiders, general spatial trends followed those of previous studies, where MeHg concentrations are higher downstream than upstream. For adult flying insects, the middle zone (BCAP002) had the highest concentrations of both Hg and MeHg.

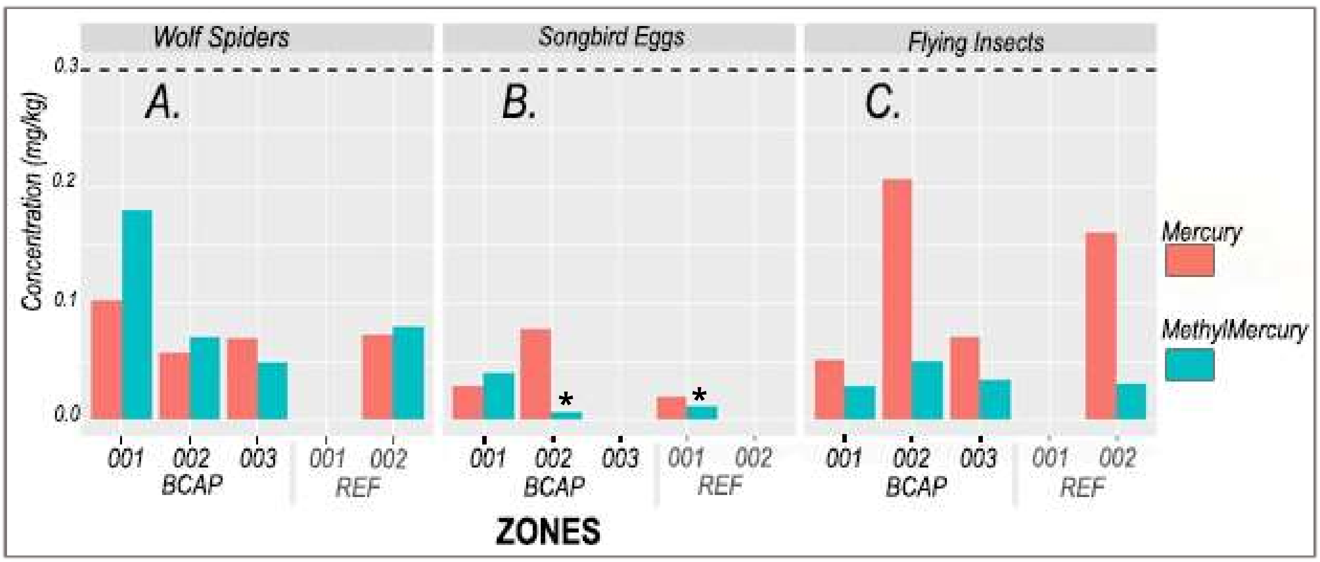

Figure 3.4.7.1 Mercury and Methylmercury Concentrations in Biota

** = estimated values. Dashed line represents EPA recommended actions limit for Hg in fish (0.3 mg/kg).*

In Figure 3.4.7.1, mercury and methylmercury results for (a) spiders, (b) songbird eggs, and (c) adult nocturnal flying insects are shown. Results for each zone and organism are represented, with BCAP zones arranged from downstream to upstream Bear Creek.

__Other metals:__

Arsenic, cadmium, and uranium metals were detected in nearly all the insect and spider samples (Figure 3.4.7.2). While arsenic was detected in the songbird eggs, concentrations were very low and returned as estimated values; cadmium and uranium concentrations were not detected in songbird eggs. All uranium concentrations returned for flying insects and spiders are relatively low and returned as estimated values. Arsenic and cadmium were the main metals detected in the flying insect and spider samples. Flying insects and spiders have opposing trends between those two metals. Flying insects have higher concentrations of arsenic (0.14 – 1.3 mg/kg), while spiders have higher concentrations of cadmium (0.7 – 2.9 mg/kg).

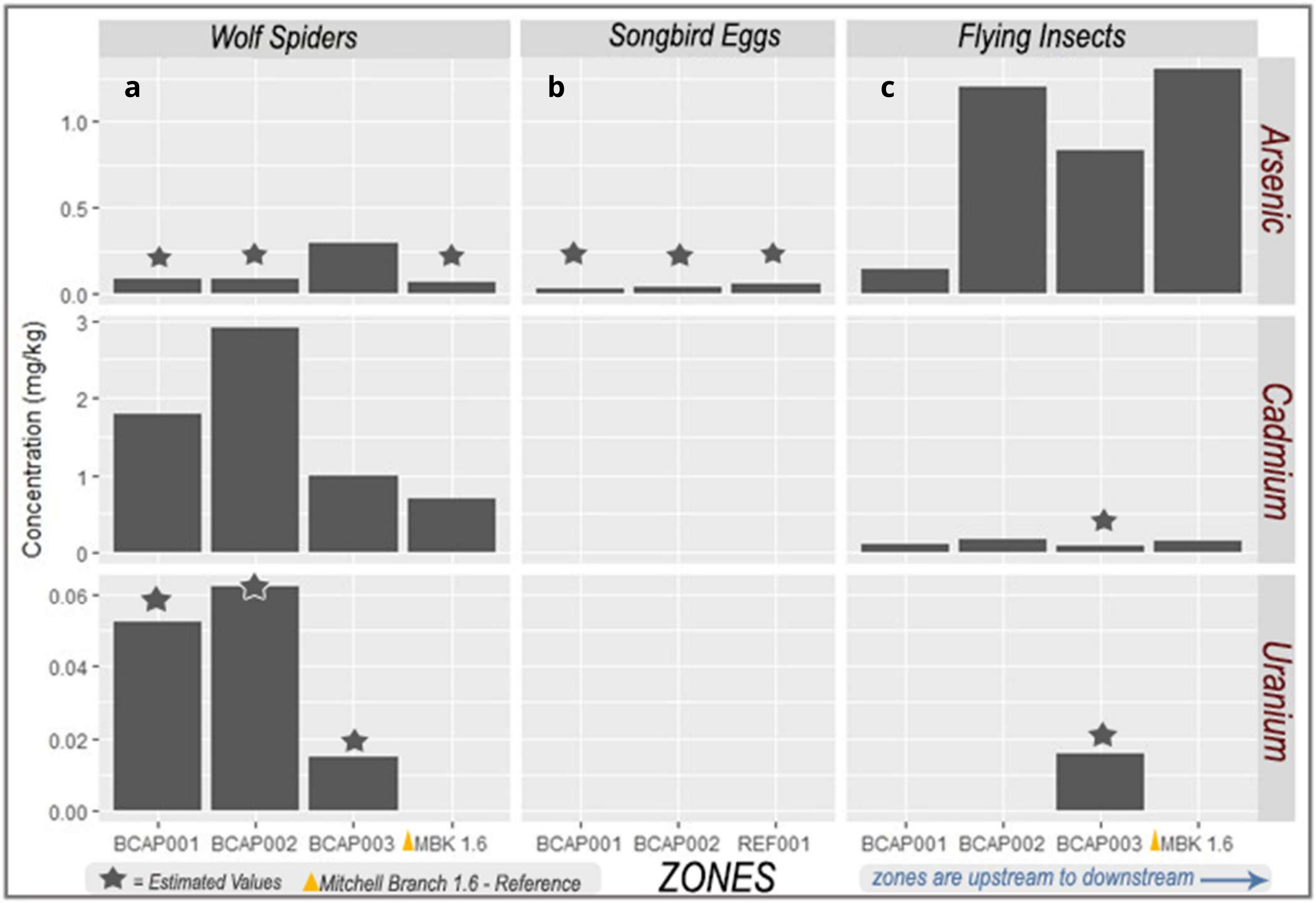

Figure 3.4.7.2 Heavy metals Concentrations in Biota - arsenic, cadmium, uranium

PCBs:

Of the seven (7) PCBs tested, the Total PCB concentration was mainly comprised of two (2) Aroclors (PCB-1254 and PCB-1260). Spider samples only returned concentrations for PCB-1260, while songbird eggs and flying insects both contained PCB-1254 and PCB-1260 (Figure 3.4.7.3, Table 3.4.7.1). Generally, spiders (0.011 – 0.57 mg/kg) and flying insects (0.04 – 0.32 mg/kg) carried higher concentrations of PCBs than songbird eggs (0.015 – 0.18 mg/kg). Spatially, Zone 2 (BCAP002, midstream) had higher concentrations of PCBs than other zones, followed by BCAP001 (downstream) and BCAP003 (upstream). All organisms and zones have higher concentrations than the reference zones, though some zones just marginally so (e.g., BCAP003 zone for spiders).

Table 3.4.7.1 PCB Range in Biota Samples

Biota	Ranges of 2 Main PCBs - Aroclors (mg/kg)	
	***BOTH* PCB-1254 & 1260**	***ONLY* PCB-1260**
Spiders		0.011-0.57
Songbird Eggs	*0.015-0.18	
Flying Insects	0.04-0.32	
** lowest concentration PCBs Total*		***Zone 2** midstream = highest PCBs*

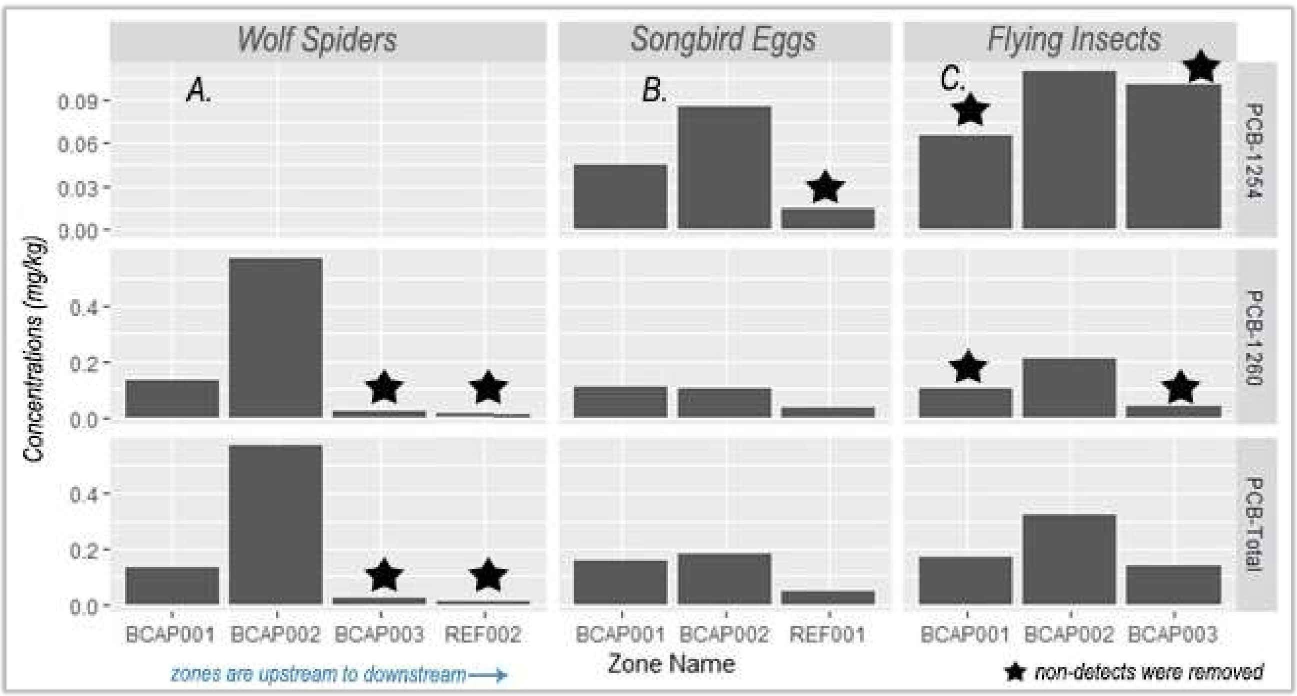

Figure 3.4.7.3 PCBs Total concentrations per Taxonomic Group per Site

Table 3.4.7.2 All Biota Metals and PCB Summary Table

Analyte	Zone	Minimum (mg/kg)	Maximum (mg/kg)	Result Qualification (U)	Result Qualification (J)	Result Qualification (Detected)	Total Samples
Arsenic	BCAP001	0.035	0.14	-	2	1	3
	BCAP002	0.04	1.2	-	2	1	3
	BCAP003	0.29	0.83	-	-	2	2
	REF001	0.059	0.059	-	1	-	1
	REF002	0.072	1.3	-	1	1	2
Cadmium	BCAP001	0.11	1.8	1	-	2	3
	BCAP002	0.18	2.9	1	-	2	3
	BCAP003	0.097	1	-	1	1	2
	REF001	-	-	1	-	-	1
	REF002	0.15	0.7	-	-	2	2
Mercury	BCAP001	0.028	0.102	-	-	3	3
	BCAP002	0.0572	0.206	-	-	3	3
	BCAP003	0.069	0.0702	-	-	2	2
	REF001	0.0196	0.0196	-	-	1	1
	REF002	0.072	0.16	-	-	2	2
Methyl-mercury	BCAP001	0.0282	0.179	-	-	3	3
	BCAP002	0.0498	0.0705	-	1	2	3
	BCAP003	0.0335	0.0483	-	-	2	2
	REF001	0.0111	0.0111	-	1	-	1
	REF002	0.0304	0.0789	-	-	2	2
PCB-1016	BCAP001	-	-	3	-	-	3
	BCAP002	-	-	3	-	-	3
	BCAP003	-	-	2	-	-	2
	REF001	-	-	1	-	-	1
	REF002	-	-	2	-	-	2
PCB-1221	BCAP001	-	-	3	-	-	3
	BCAP002	-	-	3	-	-	3
	BCAP003	-	-	2	-	-	2
	REF001	-	-	1	-	-	1
	REF002	-	-	2	-	-	2
PCB-1232	BCAP001	-	-	3	-	-	3
	BCAP002	-	-	3	-	-	3
	BCAP003	-	-	2	-	-	2
	REF001	-	-	1	-	-	1
	REF002	-	-	2	-	-	2
PCB-	BCAP001	-	-	3	-	-	3

1242	BCAP002	-	-	3	-	-	3
	BCAP003	-	-	2	-	-	2
	REF001	-	-	1	-	-	1
	REF002	-	-	2	-	-	2
PCB-1248	BCAP001	-	-	3	-	-	3
	BCAP002	-	-	3	-	-	3
	BCAP003	-	-	2	-	-	2
	REF001	-	-	1	-	-	1
	REF002	-	-	2	-	-	2
PCB-1254	BCAP001	0.045	0.065	1	1	1	3
	BCAP002	0.085	0.11	1	-	2	3
	BCAP003	0.1	0.1	1	1	-	2
	REF001	0.015	0.015	-	1	-	1
	REF002	-	-	2	-	-	2
PCB-1260	BCAP001	0.1	0.13	-	1	2	3
	BCAP002	0.099	0.57	-	-	3	3
	BCAP003	0.024	0.04	-	2	-	2
	REF001	0.036	0.036	-	-	1	1
	REF002	0.011	0.011	-	1	-	2
PCB Total	BCAP001	0.13	0.17	-	-	2	2
	BCAP002	0.32	0.57	-	-	2	2
	BCAP003	0.024	0.14	-	1	1	2
	REF001	-	-	-	-	-	0
	REF002	0.011	0.011	1	1	-	2
Uranium	BCAP001	0.052	0.052	2	1	-	3
	BCAP002	0.062	0.062	2	1	-	3
	BCAP003	0.015	0.016	-	2	-	2
	REF001	-	-	1	-	-	1
	REF002	-	-	2	-	-	2
REF 002 = MIK 1.6; U = non-detect J = estimated value; mg/kg = milligram/gram							

Heavy metals and PCBs were detected in nearly all submitted biota samples. Only one (1) heavy metal within one (1) of the zones was at a level of concern at the time of the sampling. The COC cadmium (2.9 mg/kg) appeared in spider samples from BCAP002 (midstream). Several samples had elevated PCB concentrations at levels of potential concern.

For comparison, the *EPA Fish Consumption Limits* listed below, are given as the concentration allowable for consumption for one (1) fish meal per month (EPA, 2000):

Heavy Metals:

1) Cadmium limit is 1.4 – 2.8 mg/kg.
    1. BCAP002 Spiders (2.9 mg/kg) exceeded the limit.
2) Arsenic limit is 1.4 – 2.8 mg/kg; stream advisory remains in place.
    1. BCAP002 flying insect samples were 1.2 mg/kg and approached the limit.
    2. REF002 zone (MBK 1.6) samples were 1.3 mg/kg and approached the limit.

PCBs:

1) PCBs *Non-Cancer Health End Point* is 0.094-0.19 mg/kg.
    1. Four (4) samples consisting of flying insect and spiders from BCAP 002 exceeded this limit (0.21-0.57 mg/kg).
2) PCBs *Cancer Health End Point* is 0.023-0.047 mg/kg.
    1. 18 of 26 biota samples exceeded this limit of 0.05-0.57 mg/kg, consisting of flying insect and songbird egg samples from zones BCAP001, 002, and 003 as well as a songbird egg sample from REF001 and spider samples from BCAP 001 and 002.

An additional comparison for this biota sample data was DOE's fish tissue sampling data at shared BCK sites. DOE collected data at three (3) comparable Bear Creek sites (Table 3.4.7.3). While DOE samples were taken from fish tissue, these samples are representative of the concentrations of contaminants within biotic communities of the Bear Creek watershed. These data provide some additional insight into the concentration of contaminants tied up in the aquatic community versus the concentrations represented in the more terrestrial communities adjacent to the stream.

DOE fish tissue samples contained a similar spread of metal contaminants, except that there were no detections of arsenic; however, there were novel detections of PCB-1248 in addition to PCB-1254 and PCB-1260. All DOE samples resulted in lower concentrations of metal and PCB contaminants than TDEC samples.

Table 3.4.7.3 Fish Tissue Summary - Metals and PCBs (DOE RER 2022)

Analyte	Site	Minimum (mg/kg)	Maximum (mg/kg)	Average	Result Qualification (U)	Result Qualification (J)	Result Qualification (Detected)	Total Samples
Arsenic	BCK 3.3	-	-	-	6	-	-	6
	BCK 9.9	-	-	-	6	-	-	6
	BCK 12.4	-	-	-	6	-	-	6
Cadmium	BCK 3.3	0.0372	0.0897	0.0703	-	6	-	6
	BCK 9.9	0.129	0.2	0.160333333	-	4	2	6
	BCK 12.4	0.388	1.77	0.848285714	-	-	7	7
Mercury	BCK 3.3	0.034	0.72	0.2604375	-	6	10	16
	BCK 9.9	0.035	0.37	0.21535	-	7	13	20
	BCK 12.4	0.045	0.1	0.066857143	-	-	7	7
Methyl-mercury	BCK 3.3	0.033	1.2	0.352	-	-	16	16
	BCK 9.9	0.038	0.53	0.2723	-	-	20	20
	BCK 12.4	0.029	0.13	0.073	-	-	7	7
PCB-1016	BCK 3.3	-	-	-	16	-	-	16
	BCK 9.9	-	-	-	20	-	-	20
PCB-1221	BCK 3.3	-	-	-	16	-	-	16
	BCK 9.9	-	-	-	20	-	-	20
PCB-1232	BCK 3.3	-	-	-	16	-	-	16
	BCK 9.9	-	-	-	20	-	-	20
PCB-1242	BCK 3.3	-	-	-	16	-	-	16
	BCK 9.9	-	-	-	20	-	-	20
PCB-1248	BCK 3.3	0.205	0.28	0.247	13	-	3	16
	BCK 9.9	0.231	0.706	0.511666667	17	3	-	20
PCB-1254	BCK 3.3	0.0132	0.705	0.2245	5	4	7	16
	BCK 9.9	0.0334	2.28	0.377975	-	2	18	20
PCB-1260	BCK 3.3	0.0128	0.701	0.222272727	5	3	8	16
	BCK 9.9	0.031	2.47	0.38317	-	1	18	19
PCB-1262	BCK 3.3	-	-	-	16	-	-	16
	BCK 9.9	-	-	-	20	-	-	20
PCB-1268	BCK 3.3	-	-	-	16	-	-	16
	BCK 9.9	-	-	-	20	-	-	20
Uranium	BCK 3.3	0.141	0.284	0.201833333	-	3	3	6
	BCK 9.9	0.236	0.505	0.401333333	-	3	3	6
	BCK 12.4	0.127	0.839	0.504714286	-	4	3	7
U = non-detect J = estimated value; mg/kg = milligram/gram								

3.4.8 Conclusions

Streams comprise one of the main contaminant transport systems to the environment. Contaminant transfer from streams to terrestrial systems occurs through bioaccumulation and biomagnification up food chains. Adult flying insects and spiders can be primary sources of bioaccumulation due to their direct contact with sediments and stream-side soils. Based on these biotic samples, when compared to EPA limits, biota that are more closely tied to the sediments and soils in the food web showed a higher concentration of contaminants, especially at BCAP 002 in midstream samples.

These comparative results possibly suggest that heavy metals, except for mercury and methylmercury, and PCBs may be more mobile through the stream banks than the surface water, affecting the terrestrial biotic communities.

Songbird eggs, spiders, and adult flying insects are representative of ecological impacts within the BCV watershed. Cadmium and PCB concentrations within the biota samples exceed EPA advisory limits for fish and are cause for concern.

3.4.9 Recommendations

Based on the presence of cadmium and PCBs, the project team suggests a continuation of monitoring biota within the Bear Creek watershed. It is important that TDEC DoR-OR monitor key species from multiple trophic strata to assess the movement of contaminants through the food web. Sampling songbirds, adult flying insects, and spiders will provide a clearer picture of the bioaccumulative transfer of contaminants. A frequency of around every three (3) years is suggested. This is the recommended timeframe for Bear Creek soil sampling due to slow changes in soil characteristics, which is likely a key source of exposure for biota.

3.4.10 References

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4.0 Groundwater Monitoring

4.1 Groundwater Monitoring Offsite

4.1.1 Background

Offsite groundwater downgradient of the DOE ORR has been monitored by both the TDEC DoR-OR and the DOE. The purpose of TDEC's DoR-OR *Offsite Groundwater Monitoring Project* is to protect human health and the environment through monitoring offsite groundwater for possible migration of ORR legacy contamination into the adjacent surrounding area. The location of sampling efforts during FY23 were private residential water wells and springs located downgradient, to the southwest and along strike, of the ETTP. Several other locations were also sampled to the north of the ETTP. This general area will be referred to herein as the ETTP Offsite Subarea whose boundary is defined by DOE (DOE, 2017) and is illustrated on Figure 4.1.1.1.

The ETTP encompasses approximately 5,000 acres of the ORR, of which approximately 2,200 acres were heavily industrialized, and where the Oak Ridge Gaseous Diffusion Plant was sited. Between 1942 and 1964, the ETTP's primary mission was to supply enriched uranium material for nuclear weapons. After 1964, the mission shifted towards the supply of low-enriched uranium for fabricating fuel elements for commercial and research reactors and recycling of uranium recovered from spent fuel. Subsequently, the Oak Ridge Gaseous Diffusion Plant was permanently shut down in 1987 (DOE, 2021). Documented historical contaminant releases from the numerous facilities at the ETTP included uranium isotopes, technetium-99, and other fission and activation products. Some COCs were released during the processing of recycled uranium from spent nuclear reactor fuel. Other releases occurred from legacy operations, burial grounds, historical disposal, and waste storage and accidental releases from various facilities following decades of operations.

Currently, the demolition of historical facilities and associated soil assessment/cleanup is nearing completion at the ETTP, and portions of the ETTP are being transferred for industrial or public use. For this reason, TDEC-DoR-OR elected to focus on the ETTP Offsite Subarea for the FY23 Project.

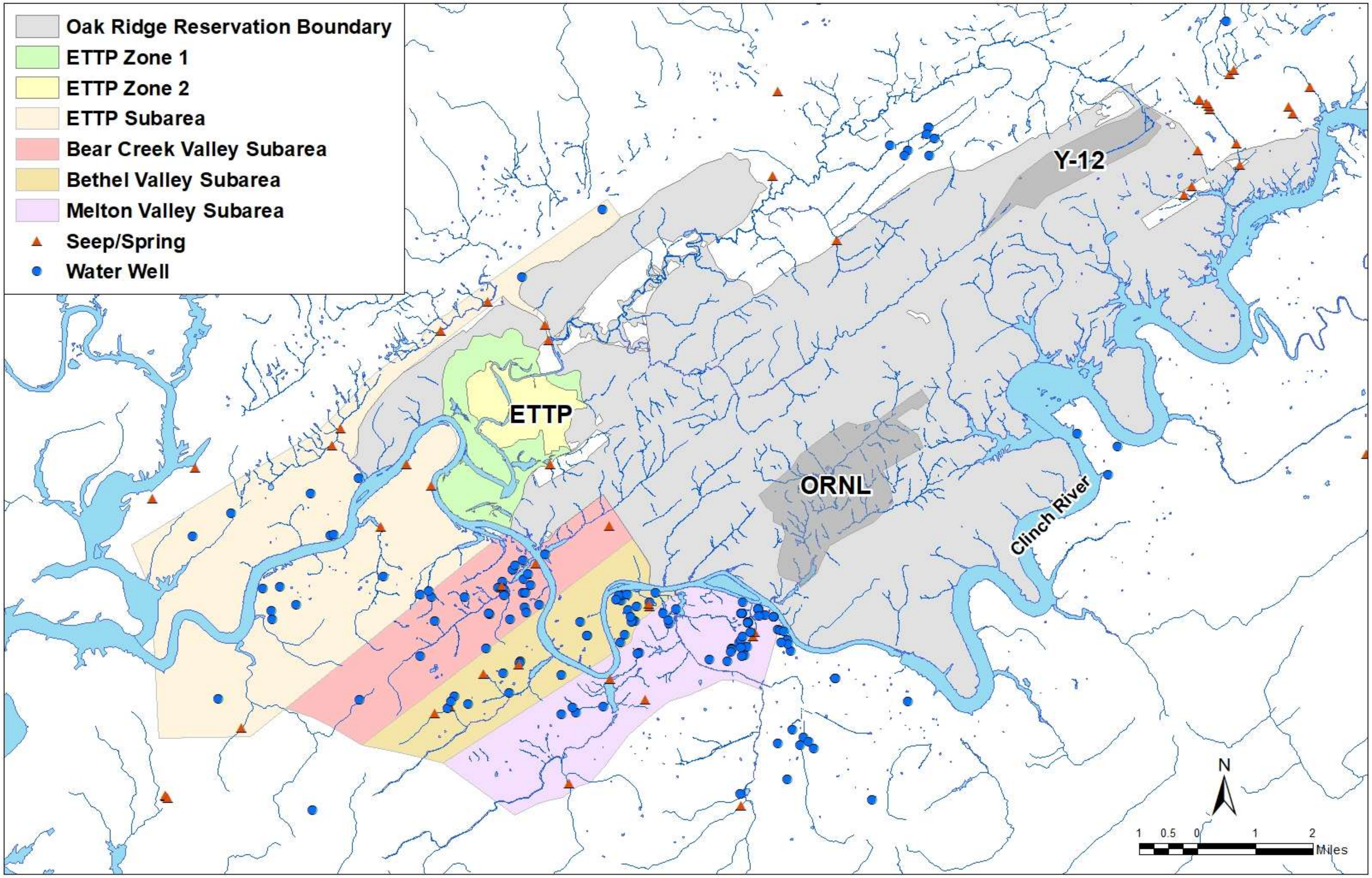

Figure 4.1.1.1: Oak Ridge Reservation Offsite Groundwater Subareas Map

4.1.2 Problem Statements

Delineation of the nature and extent of groundwater contamination is incomplete in many areas of the ORR (DOE, 2022). Figure 4.1.1.1 depicts the reservation boundary and the three (3) primary DOE campuses. Each of these facilities have numerous groundwater contaminant plumes due to past DOE mission activities. Many contaminant plumes are not well defined and require ongoing investigation to delineate their vertical and horizontal extent.

The ORR is an area with complex bedrock containing many faults and carbonates that exhibit a karst terrain with large sinkholes. Little is understood about the contaminant flow paths within the bedrock and further investigation is necessary to evaluate these flow paths. Research has shown that groundwater can move long distances rapidly in all fractured-rock settings (Worthington, 2001) and in channels and conduits.

4.1.3 Goals

The primary goal of this project is to protect human health and the environment though monitoring groundwater offsite the ORR. The objectives of this Project include the following:

- Monitor water quality of private water wells and springs in the area surrounding the ORR to ensure there is no threat to human health.
- Provide additional offsite data to allow for comparison with DOE collected onsite and offsite groundwater data.

Collection of these data may help guide future groundwater cleanup decisions that support TDEC's mission.

4.1.4 Scope

The scope of this project was to collect groundwater samples during the dry season from seventeen (17) private water wells and eight (8) springs within the ETTP Offsite Subarea (Figure 4.1.4.1). Additionally, samples from nine (9) springs within Zone 1 of ETTP (Figure 4.1.4.2) were also collected. A second monitoring event for the eight (8) springs within the ETTP Offsite Subarea and nine (9) springs within Zone 1 of ETTP occurred during the wet season.

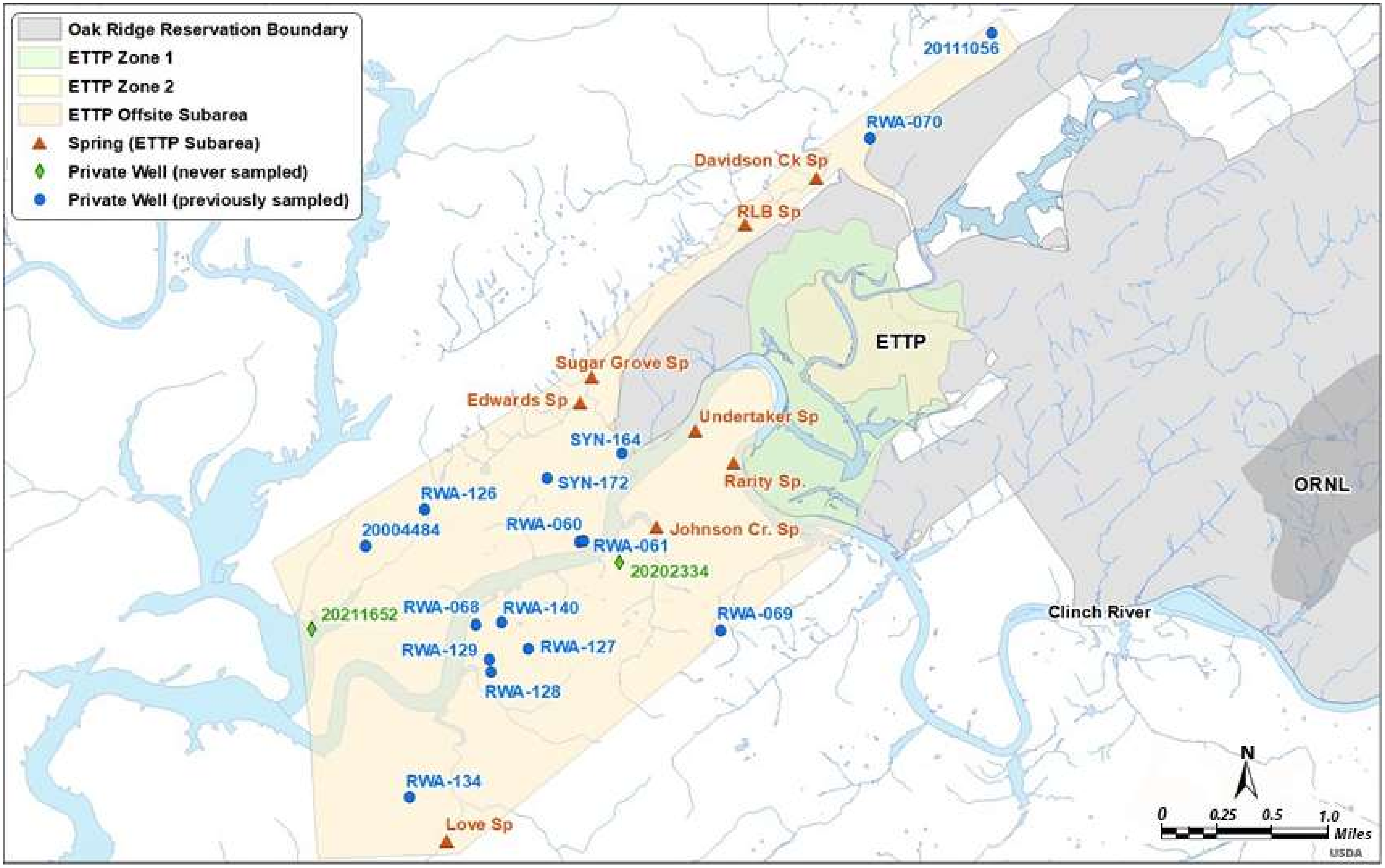

Figure 4.1.4.1: ETTP Offsite Subarea Sample Locations

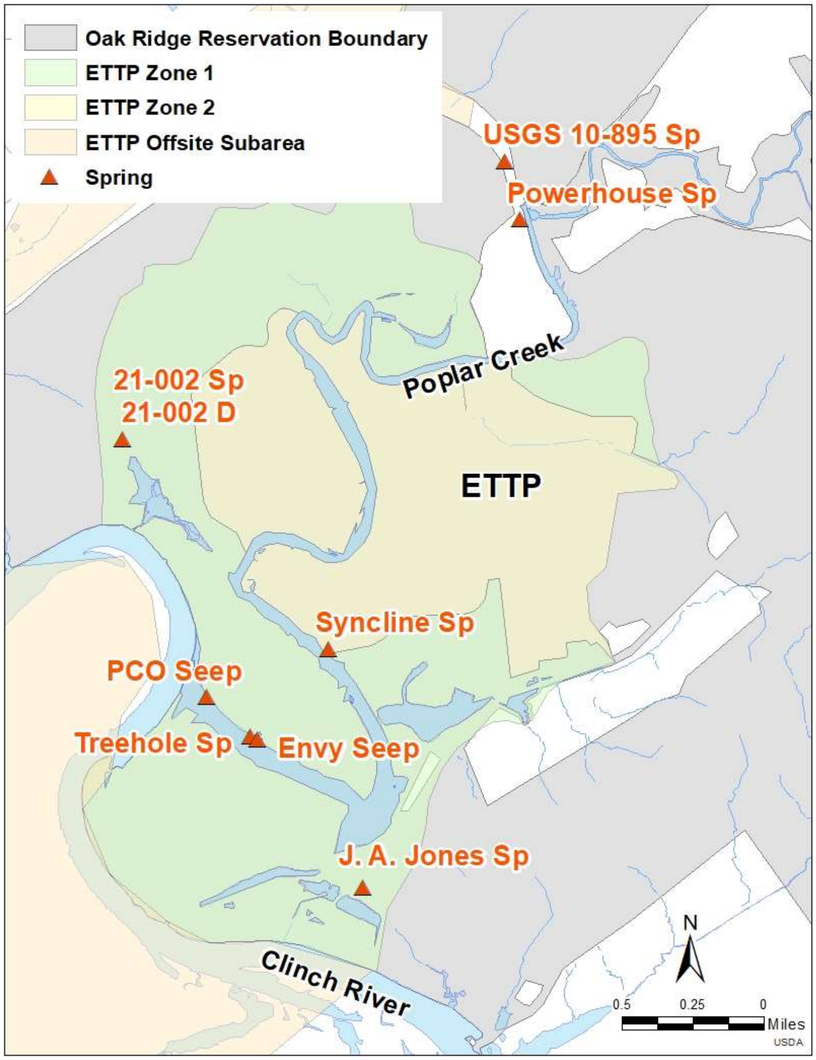

Figure 4.1.4.2: ETTP Zone 1 Spring Sample Locations

4.1.5 Methods, Materials, Metrics

Sample Collection

Due to extenuating circumstances, groundwater samples were only collected from eight (8) private water wells and fourteen (14) springs within the ETTP Offsite Subarea and ETTP Zone 1 (Table 4.1.5.1). The private water well samples were collected using each well's dedicated submersible pump from an outside tap located as close to the well as possible, prior to any filtration and/or water softener systems. Once the appropriate volume of water was purged, and water quality parameters stabilized, a groundwater sample was collected. Field water quality parameter measurements and laboratory samples were collected from the springs using a peristaltic pump.

The water samples collected from the private water wells and springs were analyzed for VOCs, gross alpha/beta, inorganics, and metals. For samples in which gross alpha activity was detected at a concentration greater than or equal to 5 pCi/L, isotopic uranium was also analyzed.

Table 4.1.5.1: ETTP Offsite Subarea Groundwater Sampling

Station Name	No. of Samples per Location
SYN-164, SYN-172, RWA-060, RWA-068, RWA-127, RWA-128, RWA-129, 20111056	1
RWA-061, RWA-069, RWA-070, RWA-126, RWA-134, RWA-140, 20004484, 20202334, 20211652	Not sampled; access not obtained
ETTP Offsite Subarea Springs	
Edwards Sp, Love Sp, Sugar Grove Sp	1
Johnson Cr. Sp and RLB Sp	2
Davidson Ck Sp	Not sampled; no flow
Rarity Sp and Undertaker Sp	Not sampled; could not locate
ETTP Zone 1 Springs	
21-002 D, Treehole Sp, Syncline Sp	1
USGS 10-895 Sp, PCO Seep, J.A. Jones Sp, 21-002 Sp, Powerhouse Sp, Envy Seep	2

All quality assurance/quality control (QA/QC) samples were collected as planned and samples were collected in accordance with internal TDEC DoR-OR SOPs.

4.1.6 Deviations from the Plan

Groundwater samples were planned to be collected from seventeen (17) private water wells; however, due to access issues, only eight (8) private water wells were sampled (Table 4.1.6.1). Additionally, of the eight (8) springs locations planned to be sampled within the ETTP subarea, only five (5) spring locations were sampled. Three (3) springs were not sampled, Rarity and Undertaker springs could not be located, and no flow was observed at Davidson Creek Spring. Several springs within the ETTP subarea or in ETTP Zone 1 were only sampled once either due to access issues or lack of flow.

4.1.7 Results and Analysis

For comparison purposes only, the resulting analytical data were evaluated and compared against numerical standards set forth in TDEC's *General Water Quality Criteria Chapter 0400-*

40-03-.03 and the EPA *National Priority Drinking Water Regulations*. A summary of the results for the private water wells, the ETTP Subarea springs, and the ETTP Zone 1 springs is presented below.

Private Water Wells

No significant results were noted in any of the analytical results for the eight (8) private water wells sampled. Alpha activity measured at wells RWA-128 (6.82 pCi/L) and RWA-129 (10.5 pCi/L) were greater than 5 pCi/L; therefore, isotopic uranium was analyzed at these two (2) locations. Notable levels of isotopic uranium were not observed. Additionally, two (2) locations had iron or fluoride concentrations detected above their corresponding *National Secondary Drinking Water Regulations*, which are guidelines for contaminants that may cause cosmetic or aesthetic effects in drinking water.

ETTP Subarea Springs

No significant results were noted in any of the analytical results for the five (5) ETTP Subarea springs sampled. Three (3) locations had either iron and/or manganese concentrations detected above their corresponding *National Secondary Drinking Water Regulations*, which are guidelines for contaminants that may cause cosmetic or aesthetic effects in drinking water.

ETTP Zone 1 Springs

Groundwater samples collected from numerous ETTP Zone 1 spring locations had VOCs detected, three (3) of which had VOCs detected at concentrations greater than the State and Federal maximum contaminant levels (MCLs) as shown in Table 4.1.7.1. Most notably, tetrachloroethene (PCE) was detected at J.A. Jones Sp at a concentration of 6.5 micrograms per liter (µg/L) and trichloroethene (TCE) was detected at 21-002 Sp and 21-002 D at concentrations of 8.2 µg/L and 9.0 µg/L, respectively. These PCE and TCE concentrations were greater than the 5 µg/L State and Federal MCLs for both PCE and TCE.

Sample Location	Sample Date	1,1-Dichloroethene	Carbon tetrachloride	cis-1,2-Dichloroethene	Tetrachloroethene	Toluene	Trichloroethene	Vinyl chloride
MCL		7	5	70	5	1000	5	2
Concentration		µg/L						
21-002 D	10/17/2022	**1.6**	**1.3**	0.47 U	0.41 U	0.29 U	**9.0**	0.17 U
21-002 Sp	12/8/2022	0.58 U	**0.43 J**	0.47 U	0.41 U	0.29 U	**3.4**	0.17 U
21-002 Sp	2/14/2023	**1.4**	1 U	1 U	1 U	2 U	**8.2**	1 U
Envy Seep	1/27/2023	1 U	1 U	1 U	1 U	2 U	1 U	1 U
Envy Seep	3/23/2023	1 U	1 U	1 U	1 U	2 U	1 U	1 U
J. A. Jones Sp	11/30/2022	0.58 U	0.37 U	**21**	**1.1**	0.29 U	**1.3**	**1.1**
J. A. Jones Sp	2/14/2023	1 U	1 U	**18**	**6.5**	2 U	**4.7**	**1.7**
PCO Seep	1/27/2023	1 U	1 U	1 U	1 U	2 U	**4.8**	1 U
PCO Seep	3/23/2023	1 U	1 U	1 U	1 U	2 U	**2.7**	1 U
Powerhouse Sp	1/27/2023	1 U	1 U	1 U	1 U	2 U	1 U	1 U
Powerhouse Sp	3/23/2023	1 U	1 U	1 U	1 U	2 U	1 U	1 U
Syncline Sp	11/30/2022	0.58 U	0.37 U	0.47 U	0.41 U	0.29 U	0.32 U	0.17 U
Treehole Sp	2/24/2023	1 U	1 U	1 U	1 U	2 U	1 U	1 U
USGS 10-895 Sp	10/18/2022	0.58 U	0.37 U	0.47 U	0.41 U	**2.7**	**0.53 J**	0.17 U
USGS 10-895 Sp	2/14/2023	1 U	1 U	1 U	1 U	2 U	**1.94**	1 U

Notes:
Bolded *Values indicate a detection.*
Bolded *values exceed the State and Federal MCLs*
µg/L = micrograms per liter
J = reported result is estimated
U = not detected

Table 4.1.7.1: ETTP Zone 1 Spring VOC Analytical Results

No other significant results were noted in the remaining analytical results for the nine (9) ETTP Zone 1 springs sampled. Several locations had either iron and/or manganese concentrations detected above their corresponding *National Secondary Drinking Water Regulations*, which are guidelines for contaminants that may cause cosmetic or aesthetic effects in drinking water.

4.1.8 Conclusions

No significant results were noted in any samples taken from the private water wells or the springs located within the ETTP Offsite Subarea. Elevated PCE and TCE concentrations were noted in several springs located within Zone 1 of ETTP. The presence of VOCs at these springs is not unexpected and has been documented by DOE. Furthermore, these data correspond to data collected by DOE as part of their *Water Resources Restoration Program* and/or ETTP Zone 1 groundwater remedial investigation efforts.

4.1.9 Recommendations

TDEC DoR-OR recommends continuing monitoring offsite groundwater focusing on one (1) subarea at a time. During FY24, the *Offsite Groundwater Project* will focus on the Bear Creek Valley Offsite Subarea.

4.1.10 References

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5.0 LANDFILL MONITORING

5.1 EMDF SURFACE WATER PARAMETERS MONITORING

5.1.1 BACKGROUND

The EMDF is the proposed landfill for the disposal of low-level radioactive waste (LLRW) and hazardous waste generated by remedial activities on the ORR. This landfill, like EMWMF, will be operated under the authority of CERCLA and DOE. While the EMDF facility will not hold a permit from the State of Tennessee, the EMDF is required to comply with DOE orders and substantive portions of Applicable or Relevant and Appropriate Requirements (ARARs) listed in the upcoming CERCLA Record of Decision (ROD).

Regulatory Guidelines for Radiological Dose Limits

For radionuclides, the limits on releases from the site are currently based on requirements contained in *DOE Order 5400.5.* This federal regulatory limit restricts the discharge of liquid wastes containing radionuclides to an average concentration equivalent to a dose of 100 millirem per year (mrem/yr). The limit for discharges from the site to Bear Creek is based on *TDEC 0400-20-11-.16(2) [10 CFR 61.41].* The State guidelines restrict public dose to radioactive material released from LLRW disposal facilities to limits shown in Table 5.1.1.1. EPA has deemed this rule to be protective under CERCLA. EPA provides an approximate Total Effective Dose Equivalent (TEDE) of 10 mrem/year to assist with applying this requirement to radiation risk assessment at CERCLA sites. Additional site-specific risk-based discharge limits are currently being developed for discharges to Bear Creek from EMDF. Requirements established in the *EPA Administrator's Dispute Resolution Decision*, dated December 31, 2020, will be consulted.

Table 5.1.1.1: Regulations for Water Resources on ORR

	Water Source	Regulation	Dose Limits Public
DOE	Discharge	*CERCLA EMDF ROD: Orders and ARARs*	*(upcoming publication)*
DOE	Discharge	*DOE Order 5400.5*	Whole Body – 25 mrem Thyroid – 75 mrem Major Order – 25 mrem
TN	Discharge	*TDEC 0400-20-11-.16(2) [10 CFR 61.41]*	
TN	SW & GW	*TDEC 0400-02-11.03(21)*	
Tri-Party	Discharge	*Waste Acceptance Criteria (WAC)*	
EPA	Discharge	*Total Effective Dose Equivalent (TEDE)*	10 mrem/year
TN	SW & GW	*TDEC General Water Quality Criteria*	
SW = Surface Water, GW = Groundwater			

Water Resources Monitoring

DoR-OR's monitoring of groundwater and surface water will assist DOE in their efforts to comply with the new landfill requirements. These standards are stated in both the upcoming *EMDF Record of Decision (ROD)* and in the *Tennessee General Water Quality Criteria* (TDEC, 2019). Some surface water monitoring is conducted by DOE using automated multiparameter probes at six (6) flumes which were already installed around the EMDF site.

5.1.2 Problem Statements

1) After EMDF construction, the disposal of waste materials from CERCLA remediation activities could potentially leach out of the landfill and enter the environment.

2) Contamination from wastes placed in the EMDF may migrate offsite through surface water and/or groundwater at concentrations or radiological activities above agreed limits.

3) Low-level radioactive waste (per TDEC and waste acceptance criteria [WAC]) is the only waste that will be approved for disposal in the EMDF.

5.1.3 Goals

The goals of the EMDF Monitoring Project were:

1) To provide background or preliminary data for Bear Creek prior to construction of the EMDF Landfill.
2) To verify that DOE adequately determined background water quality parameter levels for surface water in and around EMDF.
3) To complement DOE's pre-construction site monitoring.

5.1.4 Scope

The scope of the FY23 EMDF Monitoring Project encompasses seven (7) water quality parameter monitoring sites within the Central Bear Creek Watershed. These sites along Bear Creek tributaries are in and around the EMDF Landfill footprint. This project also proposed collecting semi-annual discrete water samples from four (4) locations: three (3) locations downgradient of the EMDF Surface Water Flume sites (SF-1, SF-5, and SF-6) and one (1) upgradient location (Spring D10W) to better understand contaminant conditions prior to EMDF construction and operation.

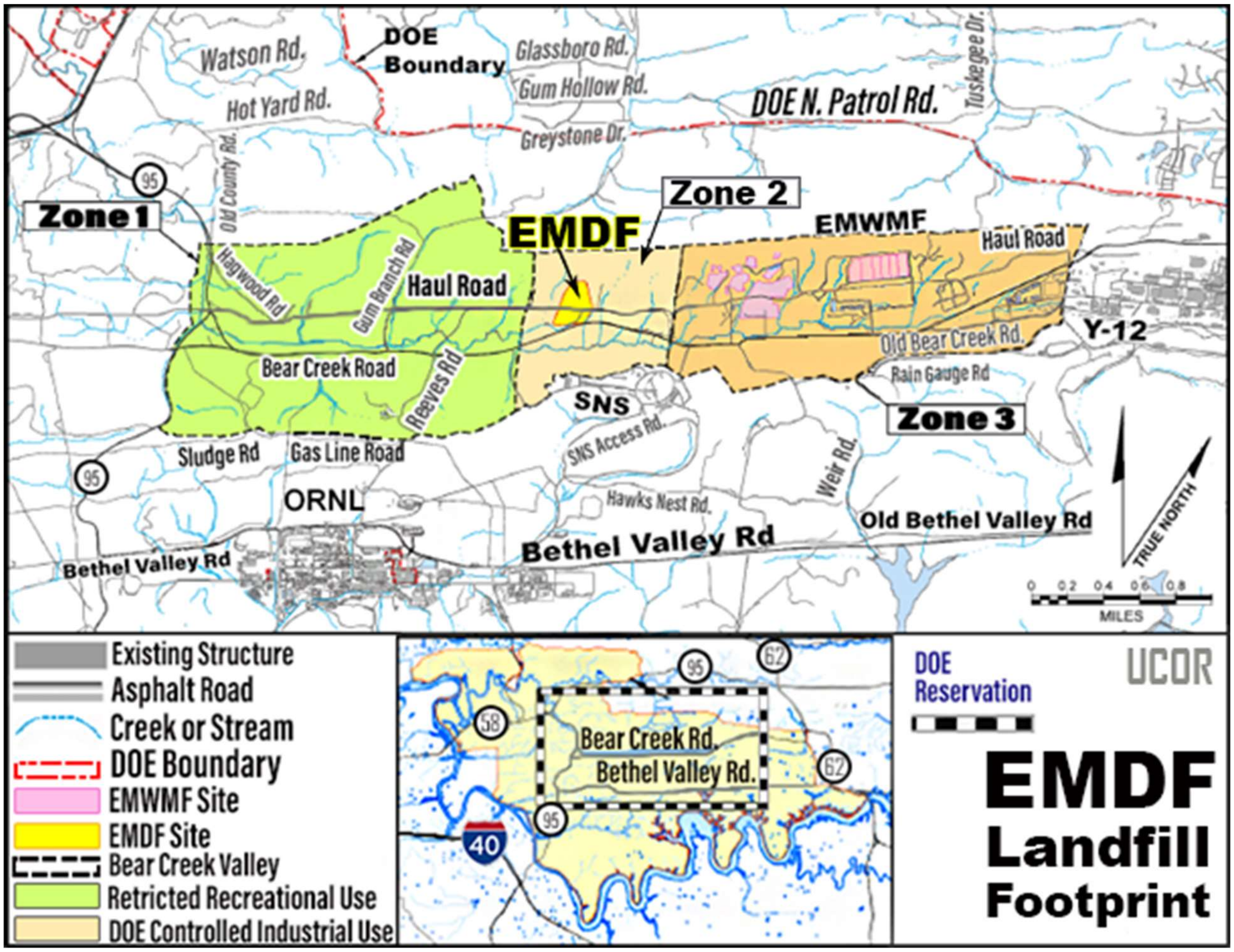

Figure 5.1.4.1 EMDF Site

5.1.5 Methods, Materials, Metrics

Project monitoring included obtaining surface water quality parameters from surface water flumes (SF) along three (3) Bear Creek tributaries that are located in the vicinity of the proposed EMDF Landfill: North Tributary-11 (NT-11), NT-10, and D-10W.

Table 5.1.5.1: EMDF - Bear Creek Sample Sites by Tributary

Bear Creek Tributary	Location with Respect to EMDF	Sample Sites (7 locations)
NT-11	Western Edge	*SF-1, SF-2, SF-3*
NT-10	Eastern Edge	*SF-6*
D-10W	Eastern Edge	*SF-4, SF-5*
** Headwaters D-10W*	Northern Edge	*Spring D10W*

DoR-OR personnel monitored these seven (7) locations for temperature, pH, conductivity, dissolved oxygen at least twice per FY23. The project team utilized a YSI-Professional Plus water quality meter or its equivalent. Calibration and/or confidence check of this instrument was performed prior to field use. Parameter measurements followed the *TDEC DoR-OR Quality Assurance Project Plan* (2015) and the *Sampling and Analysis Plan* (2016).

The project team visited the EMDF site to perform general monitoring and/or observations of the site. The stream observation data included the status of the streams, any noted discharges, water conditions, the condition of the streambanks, and any concerns. Concerns, if any, were brought to the attention of DOE/EMDF personnel. These field notes were recorded in a field book and events were reported in the corresponding project's monthly report.

After site preparation begins in 2024, the project team will sample on a semi-monthly (i.e. true biweekly or twice a month) basis to ensure DOE utilizes best management practices to limit possible contaminant migration in the future.

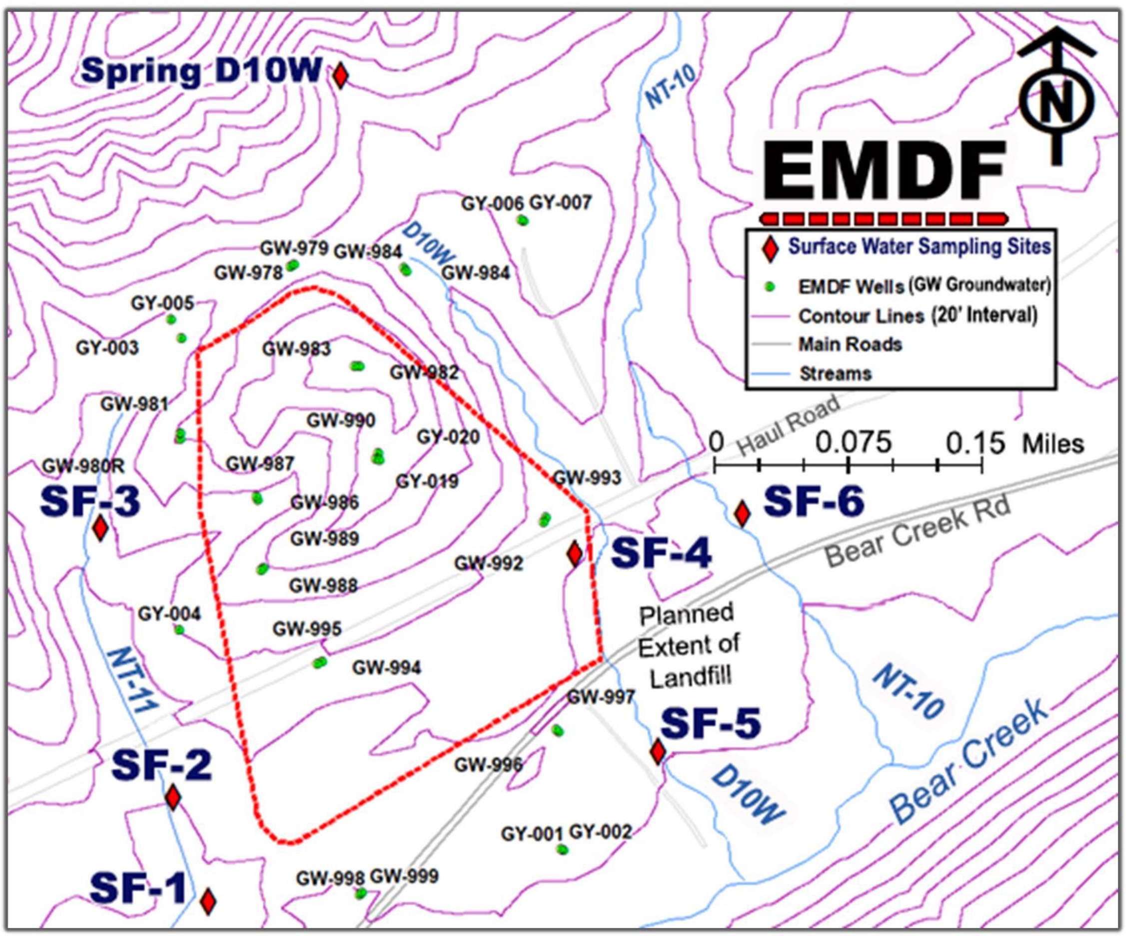

Figure 5.1.7.1: FY23 EMDF Surface Water Flume (SF) Sampling Locations

Data collected from these key locations were entered into a Microsoft Excel database for interpretation. This evaluation included construction of tables and graphs illustrating ranges and limits of parameters over the course of the project.

5.1.6 Deviations from the Plan

Some sampling events were canceled due to unavoidable circumstances. Semi-annual water samples were also not collected in FY23, but all sampling will resume in FY24.

5.1.7 Results and Analysis

Table 5.1.7.1 contains the monthly results for the seven (7) stations in FY23. The stations are surface water flumes (SF) one (1) through six (6) and Spring D10W. The water quality parameters measured were:

1) Temperature - temp (ºC)
2) pH in (SU)
3) conductivity - COND (μSeimens/cm)
4) dissolved oxygen - DO (mg/L)

Some stations were not visited due to periodic accessibility concerns throughout the year. In the table, this is listed as *DNV* for *did not visit*.

On occasion, a flume will not discharge water after extended periods without precipitation. This occurrence is listed as *dry* in the table. Additionally, little to no flow was observed at flumes SF-2, SF-4, SF-5, and SF-6 from August through November 2023, until a rainfall event occurred. Water quality parameters were not measured at stations where no flow was observed.

Table 5.1.7.1. Monthly Water Quality Parameters at EMDF Sample Sites

FY23													
Sites	**WQ**	**2022**						**2023**					
		July	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*June*
SF-1	Temp	20.2	19.3	19.1	11.8	DNV	12.4	DNV	DNV	DNV	12.9	DNV	17.6
	pH	6.56	6.82	5.0	8.3	DNV	9.33	DNV	DNV	DNV	7.72	DNV	5.81
	COND	234.2	285.3	329.5	310.3	DNV	68.5	DNV	DNV	DNV	146.6	DNV	99.6
	DO	7.72	7.95	7.76	7.88	DNV	6.63	DNV	DNV	DNV	9.05	DNV	7.15
SF-2	Temp	20.5	Dry	Dry	Dry	DNV	12.6	DNV	DNV	DNV	DNV	DNV	DNV
	pH	6.55	Dry	Dry	Dry	DNV	8.99	DNV	DNV	DNV	DNV	DNV	DNV
	COND	154.6	Dry	Dry	Dry	DNV	52.8	DNV	DNV	DNV	DNV	DNV	DNV
	DO	7.58	Dry	Dry	Dry	DNV	6.65	DNV	DNV	DNV	DNV	DNV	DNV
SF-3	Temp	21.3	DNV	Dry	Dry	DNV	DNV	DNV	DNV	DNV	12.7	DNV	17.3
	pH	7.27	DNV	Dry	Dry	DNV	DNV	DNV	DNV	DNV	6.85	DNV	5.63
	COND	85.5	DNV	Dry	Dry	DNV	DNV	DNV	DNV	DNV	40.4	DNV	37.1
	DO	7.22	DNV	Dry	Dry	DNV	DNV	DNV	DNV	DNV	8.08	DNV	6.47
SF-4	Temp	20.7	DNV	Dry	Dry	DNV	12.0	DNV	DNV	DNV	DNV	DNV	DNV
	pH	6.9	DNV	Dry	Dry	DNV	8.8	DNV	DNV	DNV	DNV	DNV	DNV
	COND	218.5	DNV	Dry	Dry	DNV	55.5	DNV	DNV	DNV	DNV	DNV	DNV
	DO	7.71	DNV	Dry	Dry	DNV	6.52	DNV	DNV	DNV	DNV	DNV	DNV
SF-5	Temp	22.5	Dry	Dry	Dry	DNV	10.84	DNV	DNV	DNV	DNV	DNV	DNV
	pH	6.11	Dry	Dry	Dry	DNV	11.3	DNV	DNV	DNV	DNV	DNV	DNV
	COND	209.8	Dry	Dry	Dry	DNV	72.6	DNV	DNV	DNV	DNV	DNV	DNV
	DO	7.91	Dry	Dry	Dry	DNV	6.7	DNV	DNV	DNV	DNV	DNV	DNV
SF-6	Temp	21.1	Dry	Dry	Dry	DNV	12.4	DNV	DNV	DNV	10.1	DNV	17.9
	pH	7.15	Dry	Dry	Dry	DNV	8.61	DNV	DNV	DNV	6.73	DNV	5.83
	COND	160.3	Dry	Dry	Dry	DNV	36.4	DNV	DNV	DNV	101.7	DNV	47.6
	DO	7.34	Dry	Dry	Dry	DNV	6.82	DNV	DNV	DNV	7.92	DNV	6.54
Spring D10W	Temp	22.2	Dry	Dry	Dry	DNV	DNV	DNV	DNV	DNV	14.0	DNV	DNV
	pH	5.87	Dry	Dry	Dry	DNV	DNV	DNV	DNV	DNV	6.99	DNV	DNV
	COND	103.7	Dry	Dry	Dry	DNV	DNV	DNV	DNV	DNV	55.6	DNV	DNV
	DO	7.44	Dry	Dry	Dry	DNV	DNV	DNV	DNV	DNV	6.67	DNV	DNV
WQ = Water Quality Parameters, COND = Conductivity, DO = Dissolved Oxygen, DNV = did not visit													
Dates Sampled: July 2022, Aug 2022, Sept 2022, Oct 2022, Nov 2022, April 2023, June 2023													

Water Quality Parameter Graphs

In the following graphs, Figure 5.1.7.2 through Figure 5.1.7.10, each water quality parameter is individually illustrated at the SFs sampled. These parameters could potentially indicate situations that DOE should be aware of during the design planning, construction, and operation of the EMDF.

1) NT-11 Tributary (SF-1, SF-2, and SF-3)

The first four (4) graphs represent the water quality parameters for NT-11. This stream is located at the western edge of the planned landfill footprint. The SF-3 flume is the most upstream monitoring location along NT-11, and the SF-1 flume is the most downstream location. Figure 5.1.7.2 shows the temperature for the period of performance . All the flumes recorded similar temperature measurements. Figure 5.1.7.3 shows the pH of the water at the flumes. The pH shows very little variability during the summer but has much larger variability during the late winter into spring. Conductivity (COND) in NT-11 is seen in Figure 5.1.7.4. The conductivity increases as the water goes downstream especially in the late summer and with similar results in the spring. Dissolved oxygen (DO) showed a large variability in summer with muted variability in spring as is graphed in Figure 5.1.7.5.

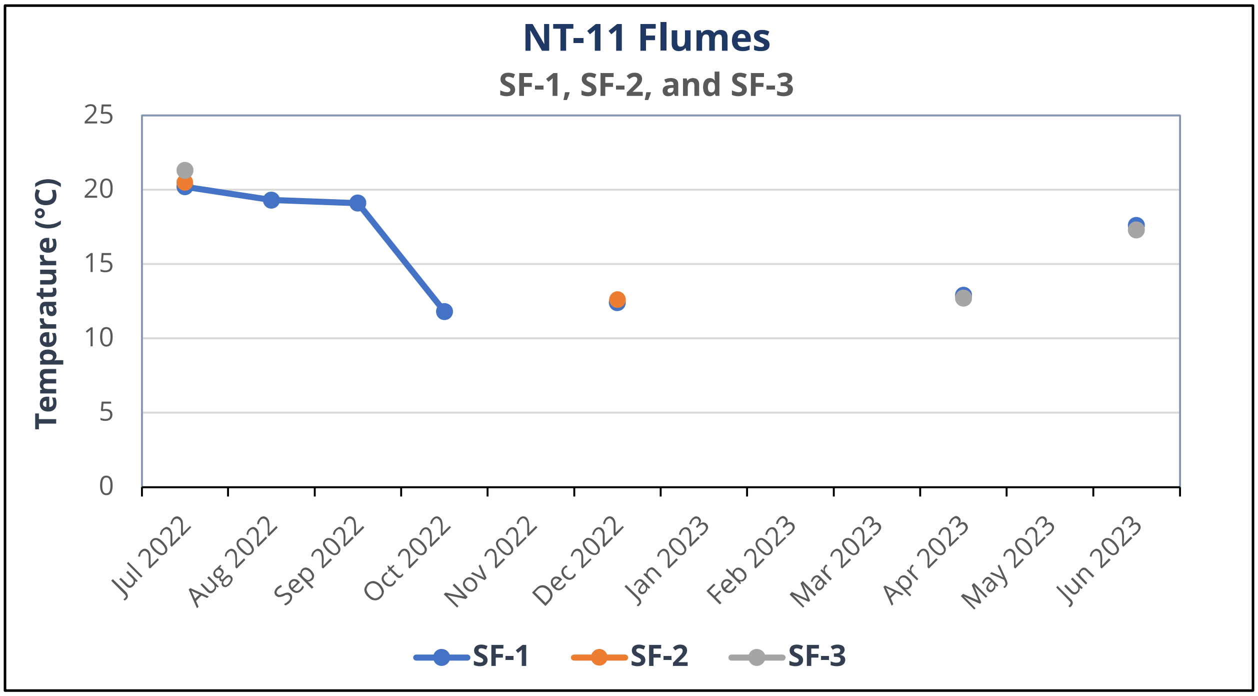

Figure 5.1.7.2: FY23 Temperature within NT-11

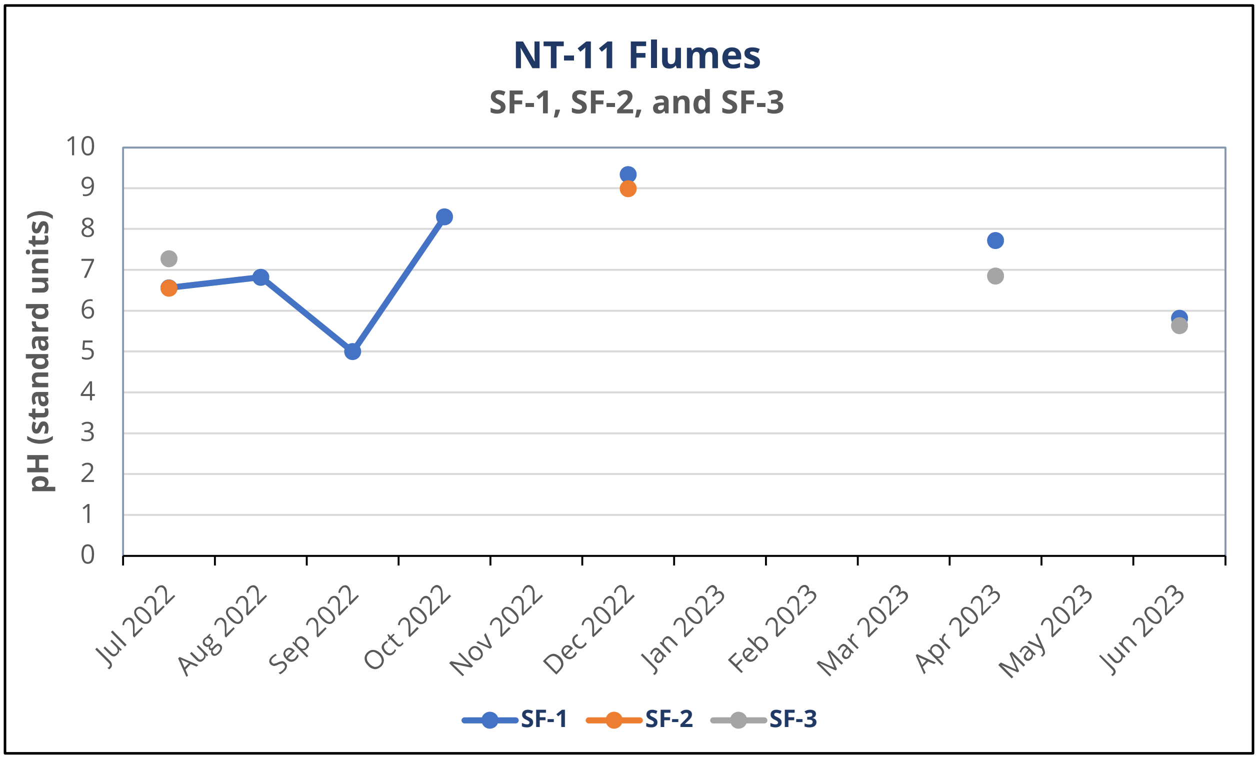

Figure 5.1.7.3: FY23 pH within NT-11

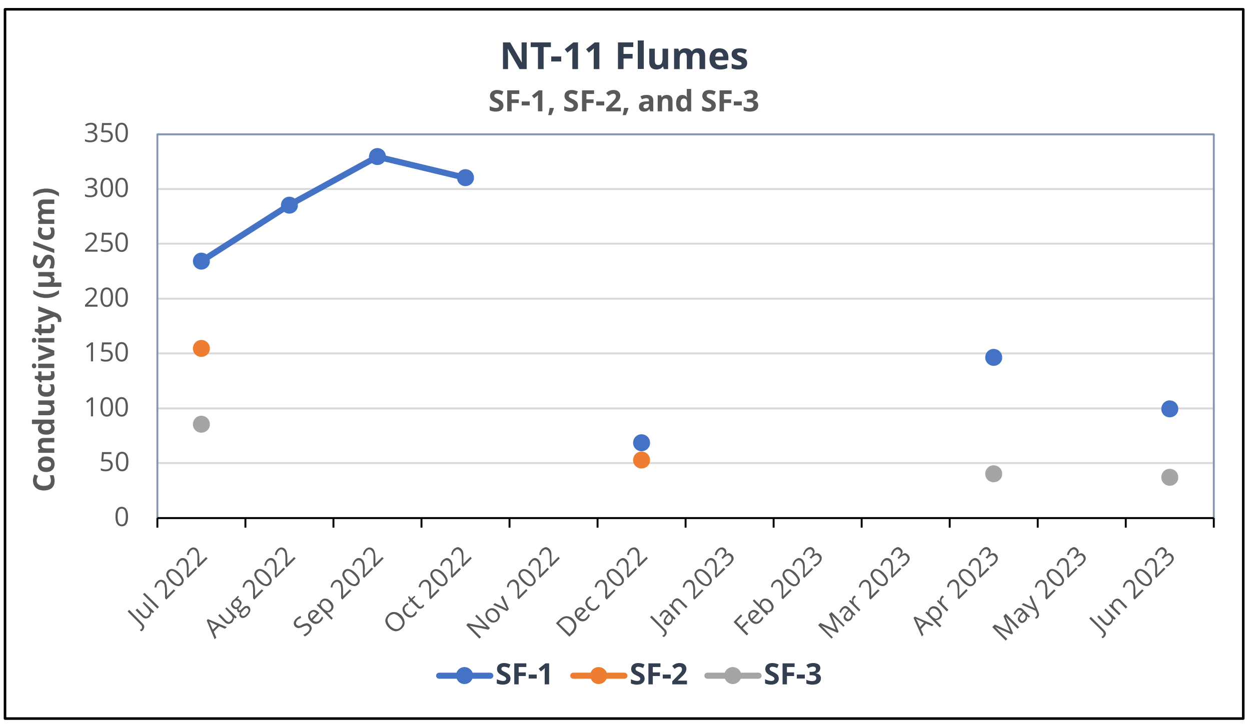

Figure 5.1.7.4: FY23 Conductivity within NT-11

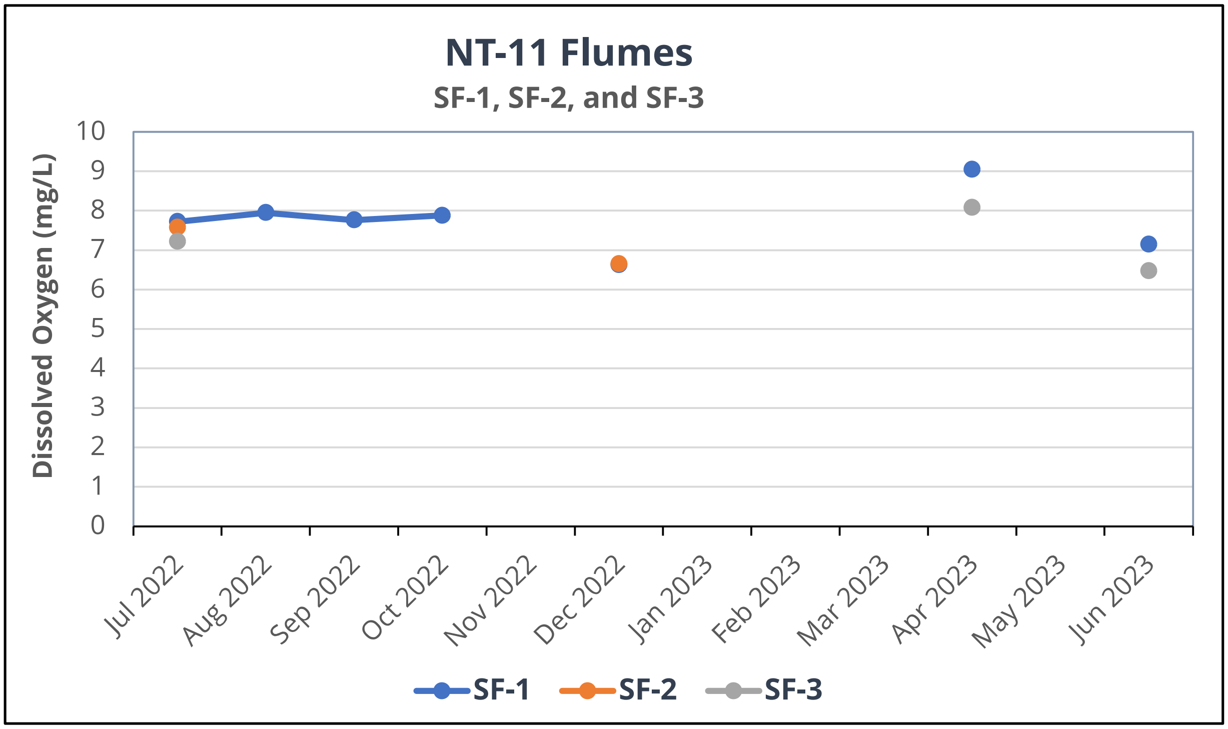

Figure 5.1.7.5: FY23 DO - Dissolved Oxygen within NT-11

2) <u>D-10W Tributary (SF-4, SF-5, Spring D10W)</u>

Tributary D-10W (Figures 5.1.7.6 to Figure 5.1.7.9) has a spring at its head (Spring D10W) and is monitored by two (2) flumes, SF-4, and SF-5. And SF-5 is the most downstream station. The graphs for this tributary show similar trends as those in NT-11. The dissolved oxygen (DO) graph (Figure 5.1.7.7) has one (1) elevated reading of 16.6 mg/L observed in September at SF-4. This may be an artifact of the measuring instrument.

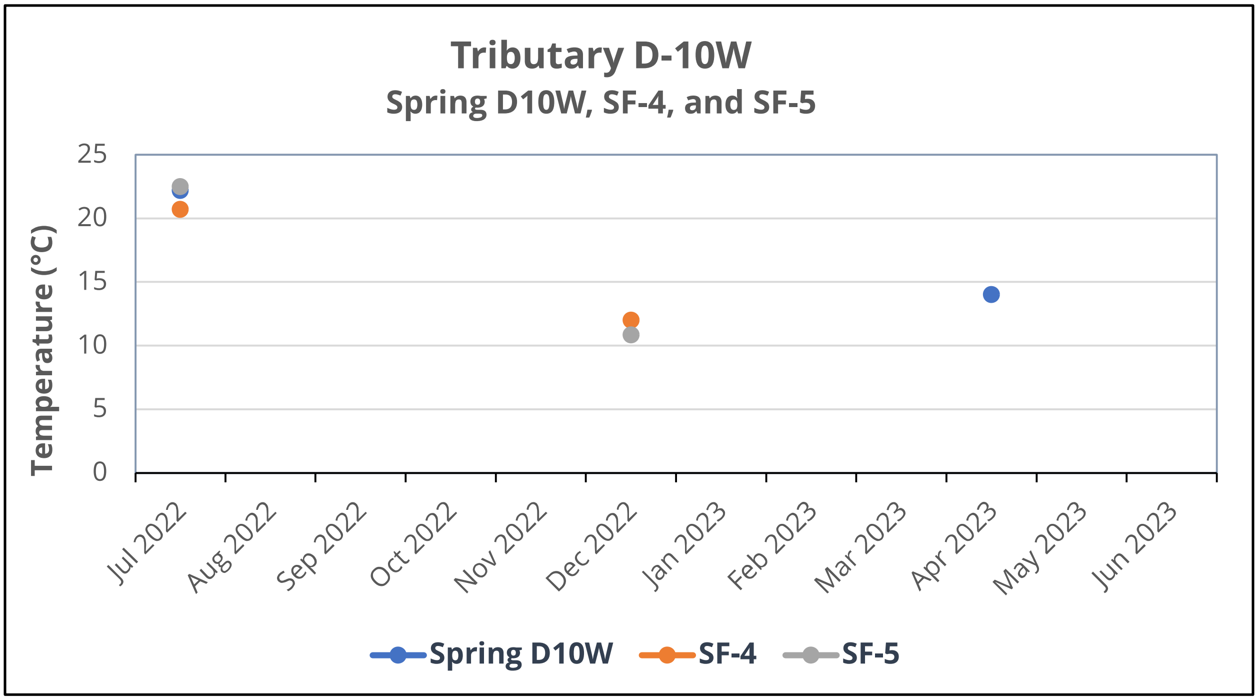

Figure 5.1.7.6: FY23 Temperature within Tributary D-10W

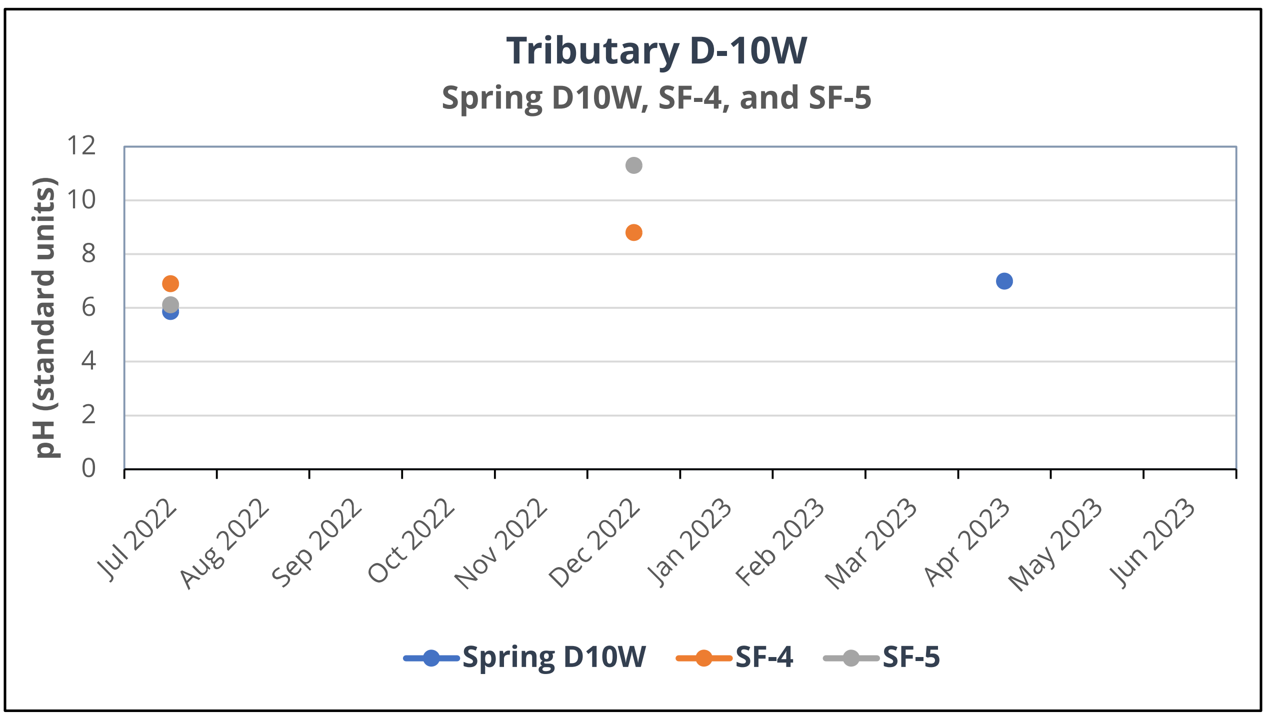

Figure 5.1.7.7: FY23 pH within Tributary D-10W

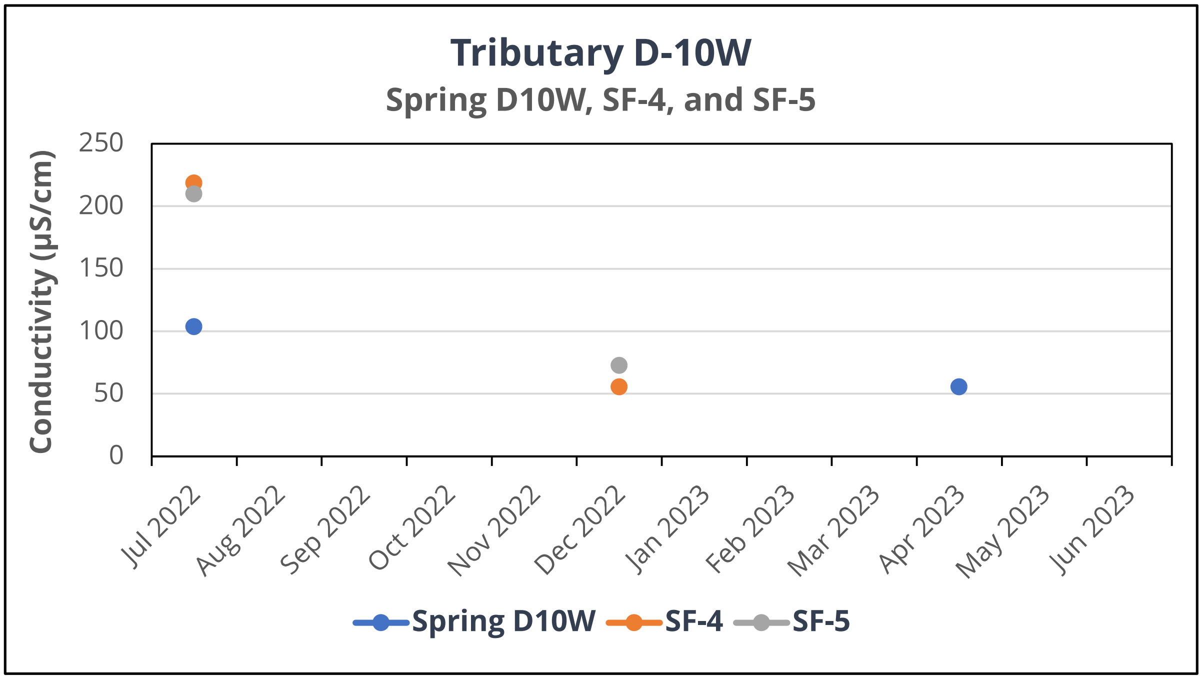

Figure 5.1.7.8: FY23 Conductivity within D-10W

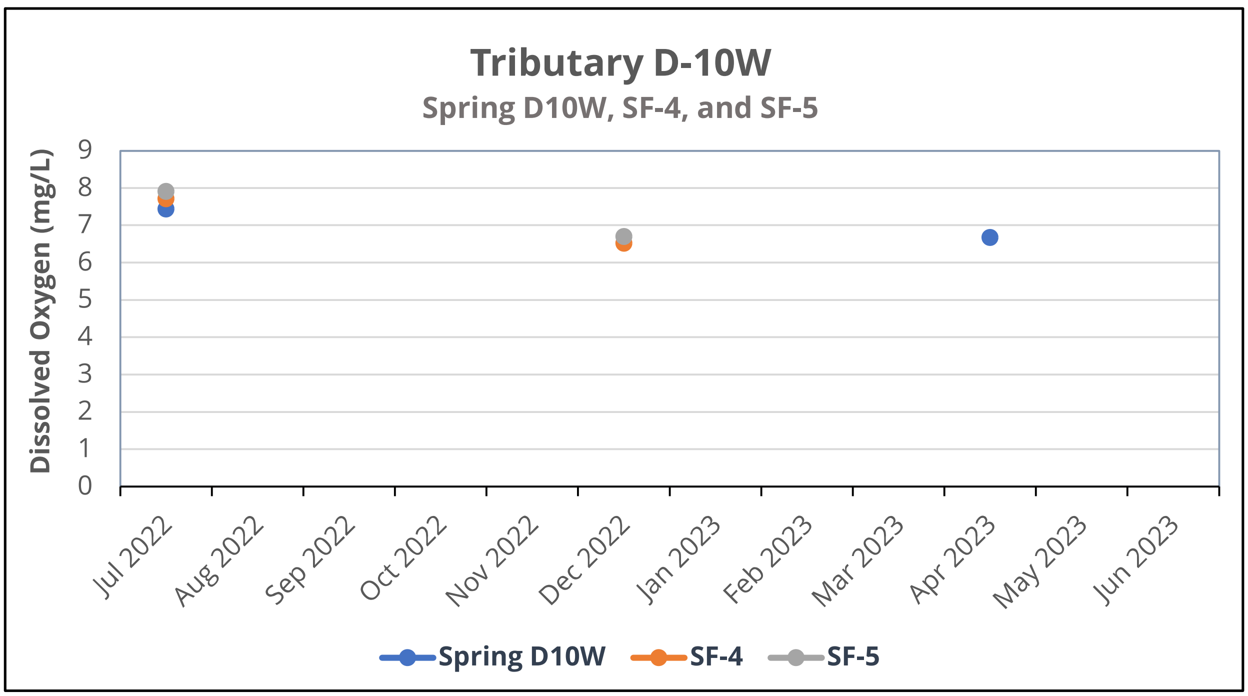

Figure 5.1.7.9: FY23 DO - Dissolved Oxygen within Tributary D-10W

3) <u>NT-10 (SF-6)</u>

Flume SF-6 collects flow from NT-10 which is near the eastern edge of the planned waste footprint. Figure 5.1.7.10 shows the graphs of the water quality parameters measured for the period of performance.

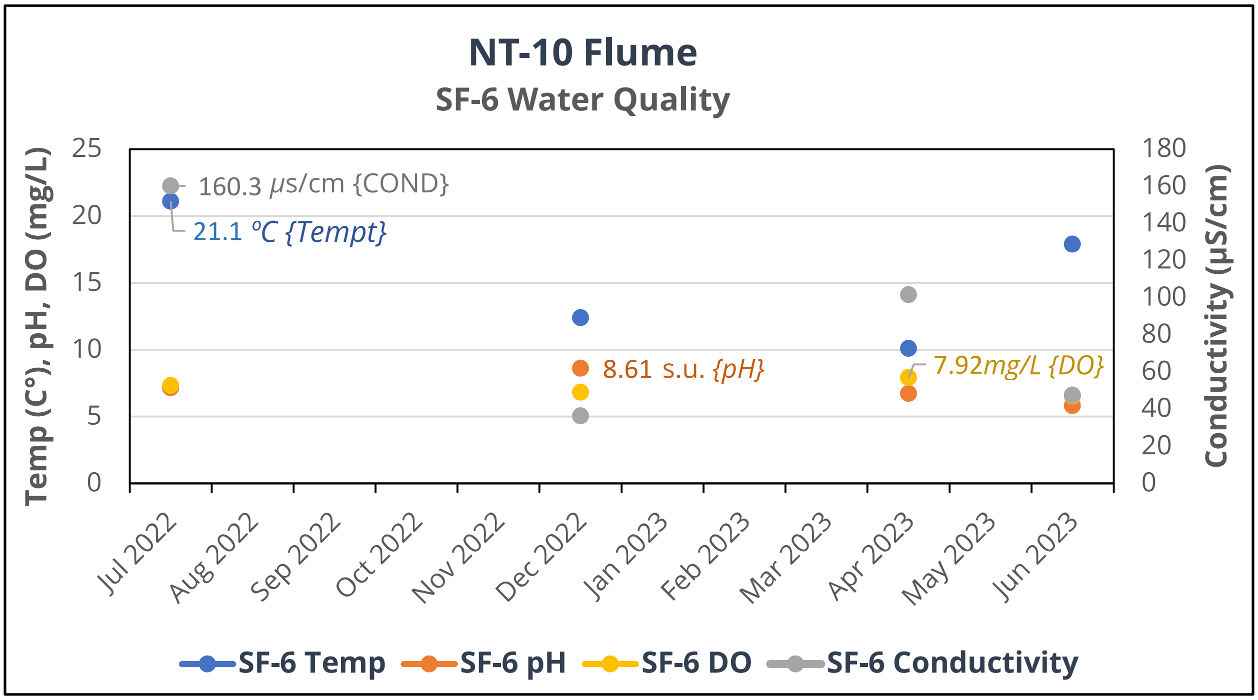

Figure 5.1.7.10. Water Quality Parameters within NT-10

5.1.8 Conclusions

Water quality varies by season and, aside from SF-1, sampling is often interrupted each year from August to November due to dry conditions. These dry periods might warrant adjustments to the water sampling schedule, possibly to limit sampling to rain events in the fall months.

In FY24, Bear Creek will be rerouted around the EMDF footprint. After this site preparation begins, the project data from the previous two (2) years of monitoring will be used as the baseline for water quality data in EMDF.

5.1.9 Recommendations

DoR-OR recommends semi-annual sampling and spot sampling based on field observations. This sampling schedule will allow the team to perform continuity checks and help determine the health of the tributaries that discharge into Bear Creek. The project scope should also include more extensive surface water sampling at the six (6) flumes and the spring into the Bear Creek tributaries. Sampling at these locations should be conducted on a regular basis (i.e. semi-monthly), as appropriate around active construction and site preparations. Sampling should require an analytical suite of radionuclides, metals, and VOCs.

5.1.10 References

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6.0 RADIOLOGICAL MONITORING

6.1 HAUL ROAD SURVEY PROJECT

6.1.1 BACKGROUND

On Friday, May 14, 2004, contaminated waste was lost from a DOE contractor's dump truck on a state highway in Tennessee. DOE conducted a Type B Accident Investigation to determine preventative measures. This investigation resulted in an agreement with the State of Tennessee to construct a separate transportation route for these dump trucks. Haul Road was constructed and is reserved solely for trucks transporting CERCLA LLRW and hazardous waste.

On the ORR, remedial wastes are transported to the EMWMF if certain criteria are met;

1) Only LLRW, as defined in TDEC 0400-02-11.03(21), is allowed.
2) Radiological concentrations must be below limits imposed by WAC.
3) Approval by the FFA tri-parties.

DOE is accountable for compliance with the WAC and has delegated responsibility of WAC attainment decisions to its prime contractor. DOE's prime contractor oversees waste characterization and compares against WAC to make final decisions for disposal in the EMWMF.

The State of Tennessee and EPA oversee and periodically audit associated activities related to this work. The State, for example, reviews approvals authorizing waste lots for disposal. This Haul Road Survey Project was created to augment and verify DOE waste transport safety protocols. TDEC DoR-OR staff performed surveys of the Haul Road and of all associated transportation routes over which remedial wastes traveled to the EMWMF in FY23.

6.1.2 PROBLEM STATEMENTS

Remedial activities and construction continue to increase on the ORR, especially on the Y-12 and ORNL campuses. This increase in waste production has increased the probability that a dump truck could potentially lose contaminated waste items onto these transportation routes in FY23.

6.1.3 GOALS

The primary goal of the project is to prevent the spread of contamination resulting from the transportation of remedial, low-level radioactive and hazardous waste from the cleanup sites to the EMWMF.

6.1.4 SCOPE

The scope of this project was limited to locating, surveying, and reporting to DOE any ORR derived waste materials that were lost from waste-hauling trucks. The Haul Road and all associated access roads being used to transport waste were incrementally surveyed during FY23.

Figure 6.1.4.1: Haul Road (DOE Aerial Photos)

Figure 6.1.4.2: Haul Road (DOE Aerial Photos)

6.1.5 Methods, Materials, Metrics

The nine (9) mile long Haul Road was surveyed in segments, typically consisting of one to two miles per survey event. Additionally, a baseline survey of the Haul Road extension from EMWMF to Y-12, approximately 1.1-miles, was performed after the appropriate approvals were obtained from DOE and its contractors. The Reeves Road access to the Haul Road connects ORNL with the main stem of the Haul Road. Reeves Road was also scheduled to be surveyed in case trucks used this route for hauling waste in FY23.

For safety reasons, DoR-OR staff always coordinated with the Haul Road site personnel prior to all surveys. UCOR (United Cleanup Oak Ridge LLC), as DOE's main contractor, was responsible for providing briefings to surveyors on road conditions and on any known situation that could present a safety hazard. When UCOR was not available, survey staff called the designated DOE site safety office. On occasions when excessive traffic presented a safety concern, the survey was postponed to a later date. In these instances, alternate entrances were sometimes used to survey the road with DOE approval, but the basic requirements remained the same.

When DoR-OR staff members arrived at the segment of the road to be surveyed, the vehicle was parked completely off the road and as far away from vehicular traffic as possible. No fewer than two (2) staff performed the surveys. During some survey events, both staff surveyed using meters while walking in a serpentine pattern along opposite sides of the road. During other surveys, one (1) person walked in a serpentine pattern across the entire road accompanied by an approved safety buddy.

A Ludlum Model 2221 Scaler Ratemeter with a Model 44-10 2"x2" NaI Gamma Scintillator probe was used. The surveyor held the probe approximately six inches (6") above the ground's surface. The road segment was scanned for radioactive contaminants as the walkover proceeded.

Another detection meter, a Ludlum 2224 Scaler with a Model 43-93 Alpha/Beta dual detector, was used to investigate potential surface contamination on the road surfaces and on any anomalous items found along the road that may be associated with waste shipments. Any areas or items with elevated contamination levels are noted for further investigation. Elevated levels are defined below:

1) 200 disintegrations per minute (dpm) per 100 sqaure centimeters (cm^2) removable beta
2) 1000 dpm/100 cm^2 total beta
3) 20 dpm/100 cm^2 removable alpha
4) and/or 100 dpm/100 cm^2 total alpha

Any anomalous items potentially from waste lots were marked with contractor's ribbon and returned to the side of the road. A description of each item and its location were logged and reported to DOE for disposal. These items potentially contained non-radiological hazardous constituents as well. A survey form was completed for each walkover and was retained by DoR-OR. When survey staff conducted subsequent inspections, they performed a follow-up inspection of items found and reported during previous weeks. Items that remained on the road were included in subsequent reports until the item was removed by DOE or until DOE confirmed that the item(s) were free of radioactive and hazardous constituents.

Six (6) surveys were completed over a 12-month period. Surveyors scheduled around any waste hauling activity on the waste transit routes.

6.1.6 Deviations from the Plan

Reeves Road was not surveyed because it was not used for hauling waste in FY23. Surveys will resume when waste hauling activities begin using this road again.

6.1.7 Results and Analysis

Six (6) survey events were conducted in FY23 from October 2022 to June 2023. The Haul Road surveys were conducted after DOE indicated that waste transportation had resumed.

On October 4, 2022, two (2) anomalous items were located between the transportation hub and the Portal 16. The surveyed items potentially originated from hazardous and/or radioactive waste being transported to the EMWMF. The items identified included a bolt and a chrome lug nut. These items were surveyed and found to be free of radiological contamination.

Next, on October 11, 2022, the survey covered the section of the Haul Road from the Transportation Hub to the Firing Range Cut-off. Three (3) anomalous items were found: a wrench, a work glove, and a piece of fiberglass. These items could not be surveyed since the Alpha/Beta dual detector instrument had a light leak (i.e. compromised mylar membrane) and could not report accurate readings. These items were flagged for survey by DOE staff. DOE later retrieved the items and determined that they were not radiologically contaminated.

The third Haul Road survey, which was conducted on March 30, 2023, was on the Y-12 section of the Haul Road and covered from the intersection of Old Bear Creek Road to the east gate of the EMWMF. Three (3) anomalous items were found: a flat metal tag, a glove, and a piece of flat bar steel. Since truck traffic was diverted to Bear Creek Road during the TDEC survey, time was limited. The survey team decided to complete the survey expeditiously and flag items found and inform DOE. DOE retrieved the items and reported that the items were not radiologically contaminated.

Then, on April 18, 2023, the survey team conducted a survey on the section of the haul road from the Firing Range Cut-off to the Heavy Equipment Staging Area. No anomalous items were found on this day.

Three (3) anomalous items were found during the survey on May 3, 2023. This survey covered the roadway between the Heavy Equipment Staging area and the Highway 95 Overpass. The recovered items included a flat piece of steel, a folded piece of metal, and a piece of rebar.

These items were surveyed and were not radiologically contaminated.

The sixth survey conducted on June 27, 2023, covered the section of the Haul Road from the Highway 95 Overpass to the Reeves Road intersection. No anomalous items were found during this survey.

In summary, during FY23, the project team's surveys found eleven (11) anomalous items along waste transit routes. Radiological detection meter screenings show that the total alpha and total beta contamination levels were below the threshold needed for further investigation. No surface contamination readings exceeded the free release limits. All ambient high energy gamma readings were also within the normal background range for the area.

Figure 6.1.7.1: Haul Road with Anomalous Item

6.1.8 Conclusions

The periodic surveys of the transit roads to EMWMF indicated that waste items are intermittently lost from trucks transporting waste. The discovery of eleven (11) items during just six (6) survey events raises concern. Even though the items were within agreed-upon limits, the surveys were by no means exhaustive. Items could potentially remain on the side of the road for 2 months or more. On the other hand, alpha and beta levels of these items were within free release limits.

6.1.9 RECOMMENDATIONS

DOE will be increasing the amount of construction, decommissioning, demolition, and other remedial actions on the ORR campuses in the coming years. The waste produced from all these activities will be transported on the Haul Road to EMWMF. Based on FY23 findings, the DoR-OR recommends the continuation of the Haul Road Survey Project. The accidental release of anomalous items from dump trucks occurs regularly and will potentially increase over the next few years. This transit system should be monitored continuously and closely to protect human health and the environment.

6.1.10 REFERENCES

DOE. 2005. *Remedial Action Work Plan for the Operation of the East Tennessee Technology Park to Environmental Management Waste Management Facility (ETTP-EMWMF) Haul Road on the Oak Ridge Reservation*. US Department of Energy. Oak Ridge, TN.DOE/OR/01-2220&D.

TDEC. 2023a. *Standard Operating Procedure T-532 Operation and Use of a Ludlum Model 2224 (-1) and 43-93 Probe (Dual Phosphorous Meter).* Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office. Oak Ridge, TN.

TDEC. 2023b. *Standard Operating Procedure T-540 Operation and Use of a Ludlum Model 2221 and 44-10 Probe (NaI Meter)*. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office. Oak Ridge, TN.

TDEC. 2023c. *Standard Operating Procedure T-560 Haul Road Surveys.* Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office. Oak Ridge, TN.

TDEC. 2017. *2017 Health and Safety Plan Including Related Policies.* Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office. Oak Ridge, TN.

6.2 REAL TIME MONITORING OF GAMMA RADIATION

6.2.1 BACKGROUND

The three (3) main campuses on the ORR have the potential to release gamma radiation. The *Real Time Monitoring of Gamma Radiation Project* focuses on measuring and determining gamma radiation exposure rates. During early operations on the ORR, leaks and spills were common within these campuses and resulting radioactive materials were released from operations as gaseous, liquid, and solid effluents, with little or no treatment (ORAU, 2003).

Currently, D&D activities may also re-release these contaminants into the environment. For example, the ORNL and Y-12 campuses are undergoing D&D and demolition of older, contaminated buildings. During these remediation activities, contaminants from the sites could possibly become airborne. Therefore, consistent gamma air monitoring within proximity to these structures is an essential tool for remediation of historical contaminants and to ensure the protection of human health and the environment during present day operations.

6.2.2 Problem Statements

ORR campuses have the potential to release variable amounts of gamma radiation, and these emissions can be expected to fluctuate substantially over relatively short periods of time. Constant, ongoing monitoring is needed to accurately record fluctuations.

During one (1) previous project on gamma dose limits, the *Environmental Dosimeters Project,* anomalous results were collected. These monitoring sites need to be re-evaluated to verify the previous data set.

Figure 6.2.2.1: Real-Time Gamma Monitoring Equipment

6.2.3 GOALS

The main goal is to maintain adequate monitoring for potential gamma radiation on the ORR to prevent human exposure to elevated doses. The project team will successfully demonstrate that levels were kept below the Nuclear Regulatory Commission (NRC) maximum dose limit of *2 mrem per hour* and within the DOE primary dose limits for protecting members of the public (*100 mrem per year*).

Table 6.2.3.1: Radiation Dose Limits Per Agency

Regulation	Occupation	Dose Limits
NRC 0400-20-04	Employee	**2.0** mrem/hr.
DOE Order 458.1	Employee	**100.0** mrem/yr. whole body 1500 mrem/yr. lens of eye 5000 mrem/yr. skin or organ
10 CFR 835C § 8308	*Member Public*	**0.1** mrem/yr. (in controlled area)
Regulatory Websites: https://www.nrc.gov/docs; https://www.energy.gov/; https://www.ecfr.gov/		

6.2.4 SCOPE

In preparation for increased remedial operations, candidate sites for new gamma radiation monitoring stations include sites undergoing one or more of the following:

1) D&D
2) Waste disposal operations
3) Pre- and post-operational site investigations
4) Areas of environmental response activities.

Additionally, anomalous results from DoR-OR's previous *Environmental Dosimeters Project* warranted incorporating additional gamma radiation monitoring at other nearby locations to augment this current project.

In Figure 6.2.4.1 below, four (4) sites are shown, and the background site is listed. Data recorded by the gamma monitors was evaluated by comparing the data to background gamma exposure rates. These data were also compared to the dose limits provided in Table 6.2.3.1.

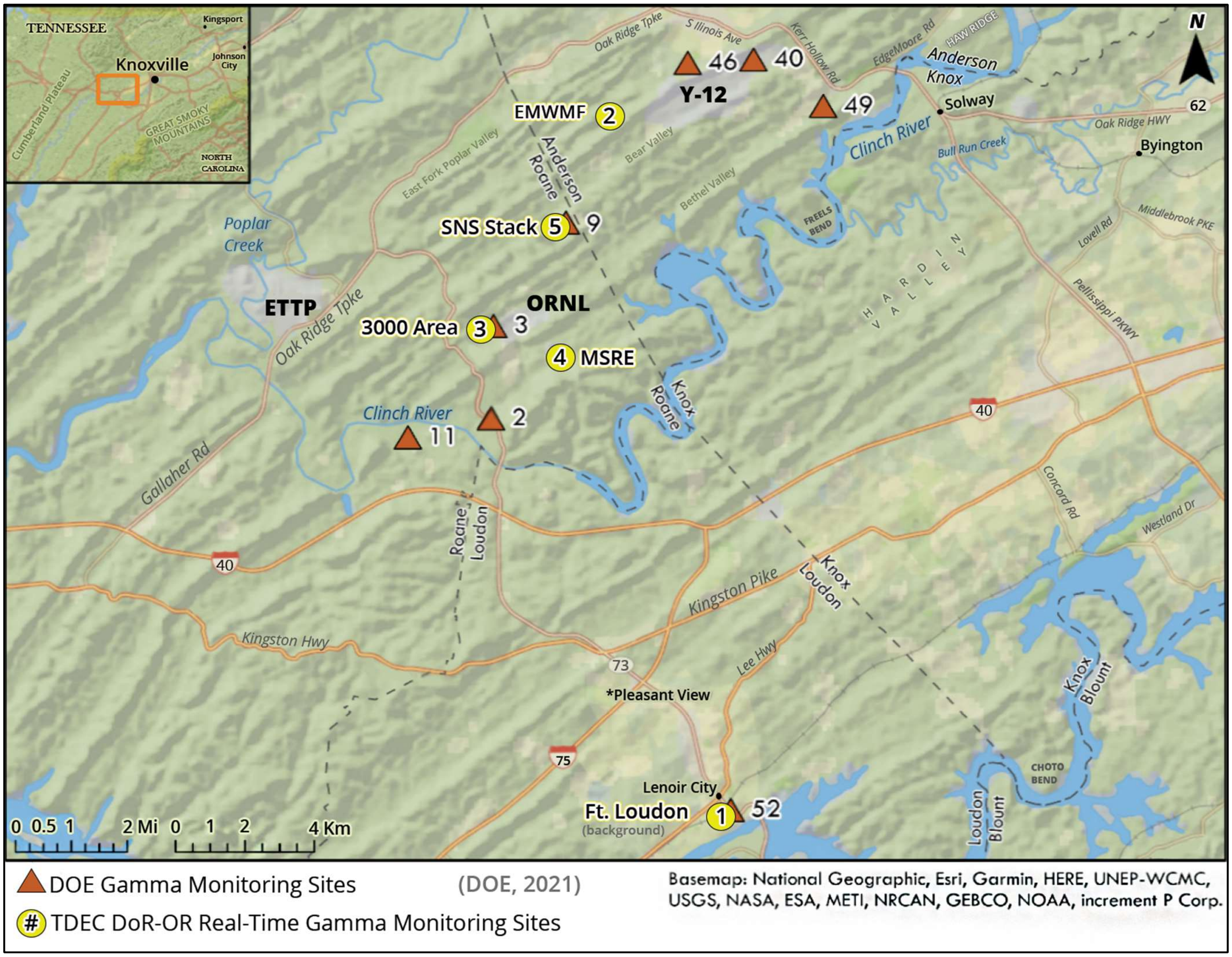

Figure 6.2.4.1: Gamma Monitor Locations

Description of the Gamma Monitoring Sites:

1) FORT LOUDOUN DAM (BACKGROUND): record naturally occurring data, use for comparison.
2) EMWMF: in Bear Creek Valley, landfill for waste disposal from CERCLA activities.
3) ORNL BUILDING 3026: monitor potential radiological releases during the demolition of high-risk facilities, centrally located on ORNL's main campus and in proximity to pedestrian and vehicular traffic.
4) MRSE (MOLTEN SALT REACTOR EXPERIMENT): the major source of the measured gamma radiation dose above background is assumed to result from a salt probe being temporarily stored in the radiation area, adjacent to the monitoring station.
5) SNS (SPALLATION NEUTRON SOURCE): the exposure rate monitor is located on the central exhaust stack used to vent air from process areas inside the linear accelerator (linac). Exposure rates vary based on the operational status of the accelerator. During periods

when the accelerator is offline, the rates are similar to background measurements. However, much higher levels are recorded during operational periods.

6.2.5 Methods, Materials, Metrics

The Real Time Gamma Radiation Project monitors the ORR with gamma exposure rate monitors manufactured by Genitron Instruments under the trade name GammaTRACER®. Each unit contains two (2) Geiger-Muller tubes, a microprocessor-controlled data logger, and lithium batteries. These components are sealed in a weather-resistant case to protect from weather damage. The instruments can be programmed to measure (1) gamma exposure rates from 1 microrem per hour (μrem/hr) to 1 rem per hour and at (2) predetermined intervals from one minute to two hours. The project results reported below are the average of the measurements recorded by the two (2) Geiger-Muller detectors. The data can be obtained at any time interval in that range (i.e. 1 min-2 hrs.) with each detector. The results recorded by the data loggers were downloaded to a computer by project personnel using an infrared transceiver and associated software.

6.2.6 Deviations from the Plan

Due to an instrument set-up error, data for *EMWMF* from 07/01/2022 until 07/18/2022 were lost.

6.2.7 Results and Analysis

Table 6.2.7.1: FY23 ORR Gamma Exposure Rates

Gamma Stations	***Dose (mR)***		
	Highest Monthly Dose		*Cumulative Dose*
	Month	*Dose*	
1. Ft Loudon	22-Dec	6.867	77.682
2. EMWMF	22-Aug	6.153	66.896
3. ORNL 3000	23-Jun	12.670	126.927
4. MRSE	22-Jul	8.627	50.028
5. SNS	23-Feb	165.725	774.558

Gamma Exposure Rate Per Site, both the Monthly Dose and the FY23 Cumulative Dose:

1) Ft Loudon (Background) FY23 Gamma Monitoring Data

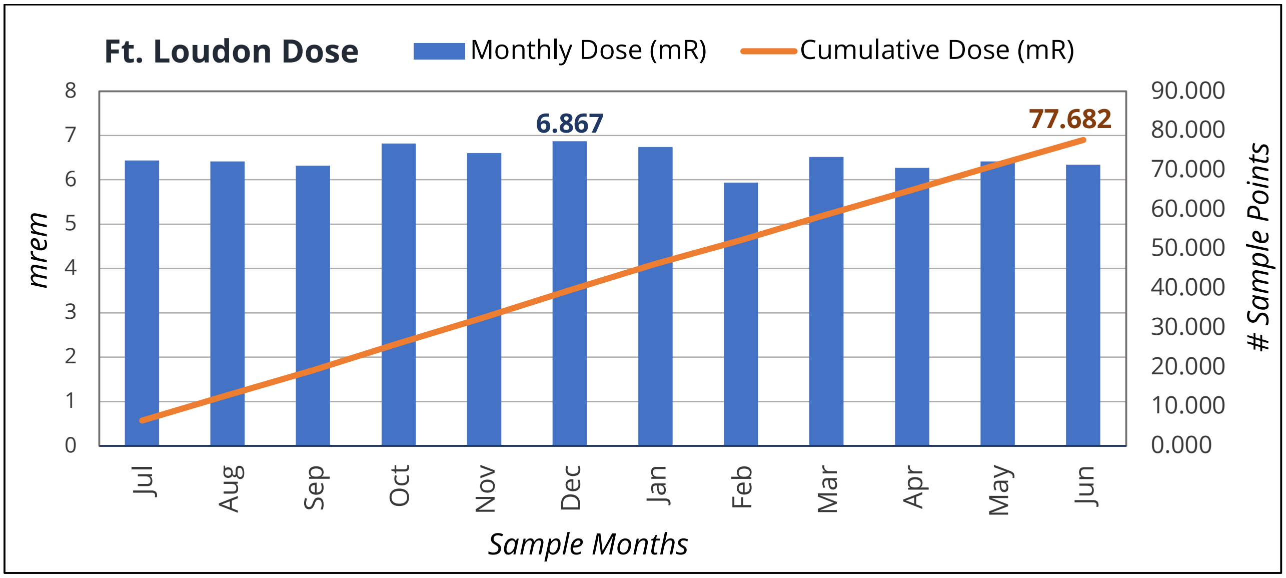

Figure 6.2.7.1: Ft. Loudon Gamma Exposure Rates

2) EMWMF Landfill FY23 Gamma Monitoring Data

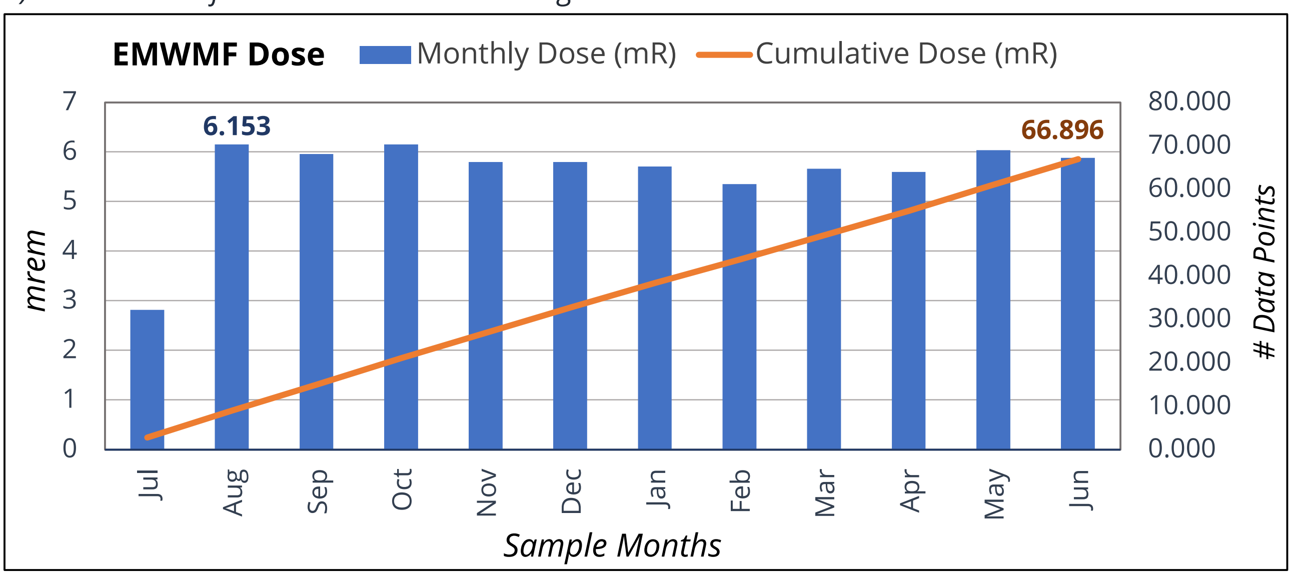

Figure 6.2.7.2: EMWMF Gamma Exposure Rates

3) ORNL 3000 Area (Building 3026) FY23 Gamma Monitoring Data

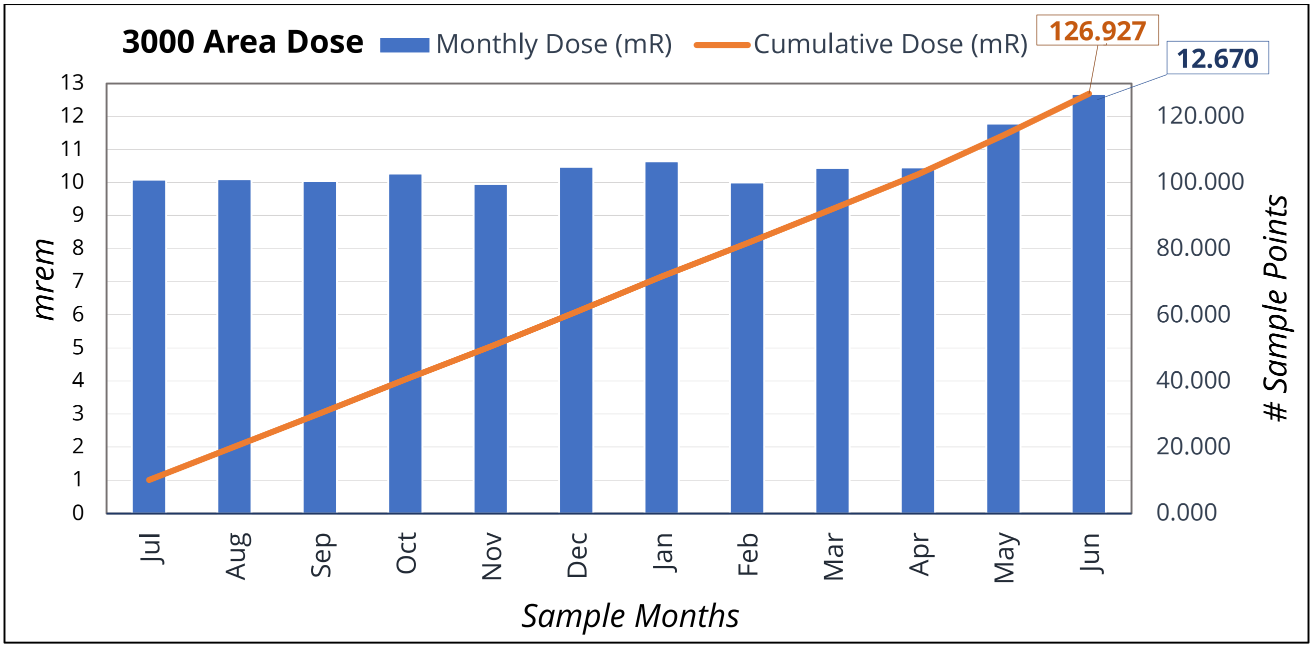

Figure 6.2.7.3: ORNL Central Campus Building 3026 Gamma Exposure

4) MRSE FY23 Gamma Monitoring Data

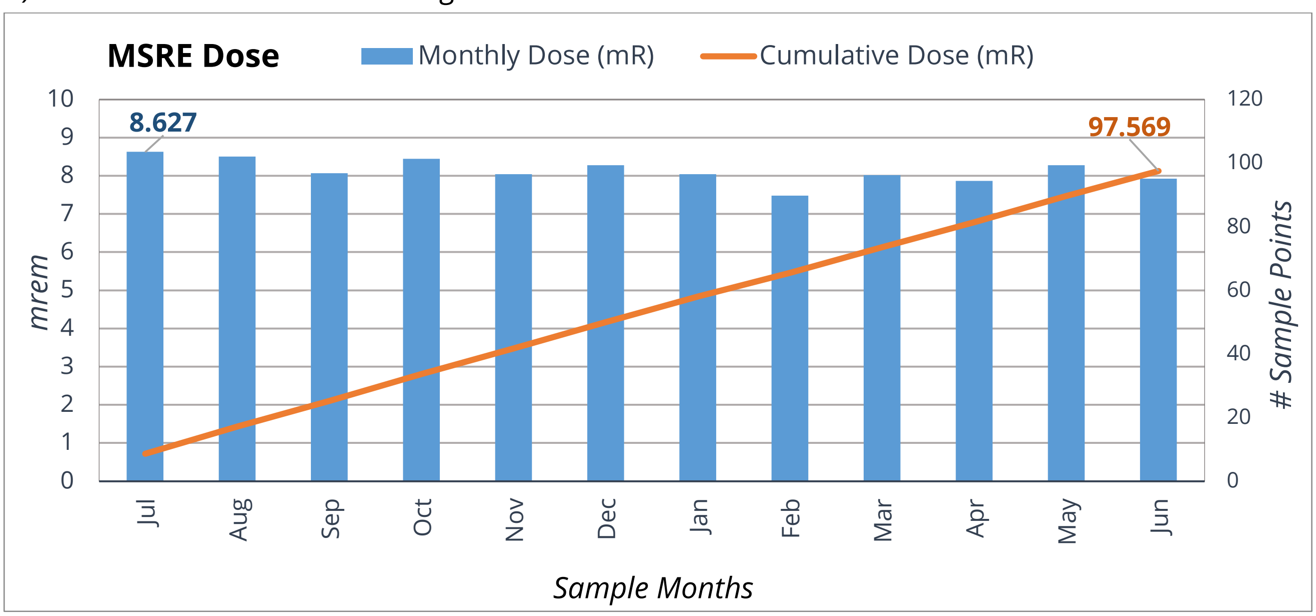

Figure 6.2.7.4: MRSE - Molten Salt Reactor Experiment Gamma Exposure

5) SNS FY23 Gamma Monitoring Data

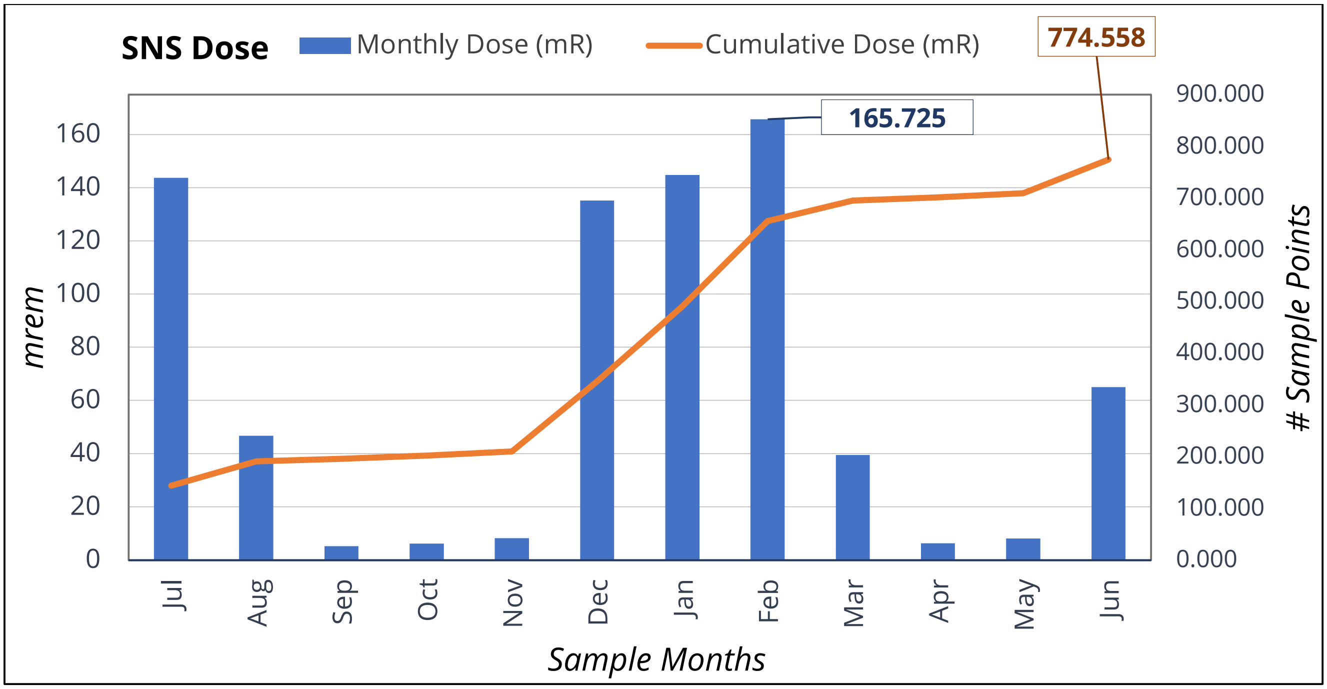

Figure 6.2.7.5: SNS - Spallation Neutron Source Gamma Exposure Rate

Two important results:

1) No monitored location exceeded the 2 mrem limit in any single-hour period.
2) No monitored location exceeded the 100 mrem /year limit for employees.

6.2.8 Conclusions

In conclusion, the project team has found no reason to alter gamma radiological monitoring locations based on the absence of gamma radiation exposures above the recommended limits (i.e. per hour, per year). However, as remedial and construction activities increase at Y-12 and ORNL, monitoring stations may need to be moved to better capture any potential contaminant releases.

6.2.9 Recommendations

1) Since DOE does not have a similar monitoring program, DoR-OR proposes to continue this gamma radiation monitoring to fill this data gap.
2) The Real Time Gamma Project team will review the current monitoring stations on an annual basis and make modifications as needed based on upcoming DOE activities on the ORR.

6.2.10 References

10 CFR 20. *Title 10 of the Code of Federal Regulations, Chapter 1, Subpart D, § 20.1301 Dose limits for individual members of the public.* National Archives. Washington, DC. https://www.ecfr.gov/current/title-10/chapter-I/part-20/subpart-D/section-20.1301

ORAU. 2003. *NIOSH Dose Reconstruction Project*. Oak Ridge National Laboratory (ORNL). Oak Ridge, TN. ORAUT-TKBS-0012-2. https://www.cdc.gov/niosh/ocas/pdfs/arch/ornl2.pdf

6.3 Surplus Sales Verification

6.3.1 Background

As Y-12 and ORNL conduct ongoing research, there is a continual need for labs to purchase new, updated instruments when existing equipment becomes outdated or is no longer ideal for a project. With a goal to recycle and reuse research equipment, DOE staff collect ORR surplus items for resale at auction.

Prior to making items available for auction, DOE relies on process knowledge to identify items appropriate for auction, and DOE Radiation Control personnel are tasked with surveying all items for elevated radiation levels or removable contamination. Radiological detection meters are used for thorough scans. DOE seeks to prevent the spread of contaminants from surplus equipment to members of the public. Once items are checked, and cleaned if warranted, they are displayed for resale. DoR-OR is then invited to perform an additional scan on surplus items. Finally, DOE staff invite contractors that have been pre-approved to bid on surplus materials.

In recent years, DOE has made great strides to adequately screen for contaminated surplus items prior to auctions and contract sales. DOE's *Surplus Materials Release Program* follows guidelines in the *Radiation Protection of the Public and the Environment (DOE Order 458.1)*. In addition, this project also utilized the guidance set forth in the *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual.* To provide further verification of release criteria for these items, TDEC provides support on request. This independent DoR-OR verification team provided spot checks and secondary surveys supporting DOE to ensure that all materials staged for auction were free of radiological surface contamination.

In addition to performing these surveys, DoR-OR reviewed procedures for the release of materials in accordance with DOE radiological regulations.

6.3.2 Problem Statements

1) Associated contaminated items: When incidental radiological contamination is present, the source is most likely related to activities in the area where the material was being used. Any material or equipment from that same area should be located and scanned to ensure that no contaminated equipment is accidentally sold.
2) Radon: Items with surface activity may not ultimately prove to possess COCs. Sometimes elevated levels are attributed to naturally occurring radon and its daughter isotopes. These isotopes are considered *Naturally Occurring Radioactive Material* (NORM), or *Technically Enhanced Naturally Occurring Radioactive Materials* (TENORM). Project staff should be trained to evaluate items for radon and other NORMs and TENORMs.

6.3.3 Goals

The overarching goal of this project is to adequately screen surplus items for potential radiological surface contamination and prevent contaminated items from being sold to the public.

6.3.4 Scope

Upon request, DoR-OR staff performed pre-auction verification surveys. On average, no more than eight (8) events occur during a calendar year. There were only two (2) requests during FY23.

6.3.5 Methods, Materials, Metrics

DoR-OR detection meters were calibrated before the project team left for the auction site. Accordingly, not all items nor all surfaces of those scanned items could be surveyed for potential radiological contamination. Biased measurements were often used where specific attention was paid to well-used items. Areas on these items that were damaged, unclean, or stained were targeted by scans. Well-maintained items were scanned based on their prior usage and former location. When radiological activity (alpha or beta/gamma) measured above the contamination limit, that item was then brought to the attention of the Property Excessing Team.

When survey results were elevated or unclear, the Property Excessing Team had the item rechecked by ORNL Radiation Control. Any recheck was determined by the Property Excessing Team.

Also, while DoR-OR did not attempt to determine if an item met DOE release criteria, project staff actively tried to locate any contaminated items. With regards to certain radionuclides, there is always the possibility that an item will never meet unrestricted release criteria set forth by TDEC Division of Radiological Health. These items would also be removed from auction if found.

DOE and its contractors follow procedures for unrestricted release of material and equipment and have process knowledge; therefore, the necessary action is to verify that procedure is followed and build in redundancy to catch any human error.

6.3.6 Deviation from the Plan

There were no deviations from the plan. The two (2) survey events were conducted according to standard procedures.

6.3.7 Results and Analysis

Project staff responded to a total of two (2) *Surplus Sales Survey*s requests from July 2022 to June 2023. During these two (2) visits to the Property Excessing Facility at 115 Union Valley Road, a total of two (2) items were identified with activity above the ambient background. These items included a magnifying glass, which was probably NORM, and a ramp tread, which was potentially due to radon. The DoR-OR survey results were shared with ORNL in an e-mail message and a trip report was completed.

6.3.8 Conclusions

The independent Surplus Sales Verification Project scans performed by DoR-OR provided a useful service by providing an additional, final check of equipment and materials. All the Surplus Lots were adequately scanned, but there were some small, attached parts with activity that exceeded the ambient background. These independent surveys assisted DOE in deciding whether equipment met release criteria.

6.3.9 Recommendations

DoR-OR staff recommends that the Surplus Sales Verification Project be continued because this service is useful to DOE and is protective of the public. Additional scans provide a way for DOE to have independent confirmation of their own scans.

The verification process also serves to train staff through hands-on experience to become conversant with measuring radioactivity using the proper methods. This skillset can be used in several DOE funded research projects at DoR-OR and, thereby, potentially provide more accurate data to DOE.

6.3.10 REFERENCES

DOE. 2013. *Multi-Agency Radiation Survey and Assessment of Materials and Equipment (MARSAME).* US Department of Energy and Oak Ridge Associated Universities (ORAU). Oak Ridge, TN.

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NRC. 2006*. Consolidated Decommissioning Guidance: Characterization, survey, and determination of radiological criteria, final report.* US Nuclear Regulatory Commission (NRC), Office of Nuclear Material Safety and Safeguards, Division of Waste Management and Environmental Protection. Washington, DC. Vol 2, Rev 1. NUREG-1757. https://www.nrc.gov/docs/ML0630/ML063000252.pdf

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7.0 Surface Water Sampling

7.1 Ambient Surface Water Parameters

7.1.1 Background

Legacy waste across the ORR is responsible for a large portion of the contamination to surface water via the accidental releases of hazardous wastes (e.g. metals, organics, and radioactive materials). Additionally, current projects and processes at these sites also have the potential to significantly contribute to surface water contamination (DOE 1992, DOE 2021, Pickering et al. 1970, Turner et al. 1999).

The DoR-OR *Ambient Surface Water Parameter Project* both complemented and verified the DOE environmental monitoring program. This project has been implemented each year since 2005. The main project goal aims to identify surface water that may be impacted relative to potential contamination displacement. To accomplish this goal, DoR-OR collected stream monitoring data monthly to establish and build upon a database of physical stream parameters.

7.1.2 Problems Statements

ORR exit-pathway streams and the Clinch River are subject to contaminant releases from previous and current activities at ETTP, ORNL, and Y-12. These releases can be detrimental to the environment and to human health.

<u>Identified concerns include, but are not limited to, the following:</u>

1) Mercury, approximately 100 metric tons, was released from Y-12 into EFPC from 1950 to 1963. Mercury exited Y-12 via spills, leakage from subsurface drains, purposed discharge of wastewater, and leaching from contaminated building foundations and soils (Turner and Southworth, 1999).
2) Other metals (e.g. cadmium, chromium, lead, nickel, silver, and zirconium) are present in elevated concentrations in exit-pathway streams (DOE, 1992).
3) Uranium contaminated nitric acid wastes and other liquid wastes (roughly 7.5 million Liters per year) were disposed of in the S3 ponds from 1951 to 1984 near the headwaters of Bear Creek (Moss et al. 1999).
4) Solid and liquid wastes, including approximately 18 million kilograms of uranium metal and 1 million liters of waste oils and chlorinated solvents, were disposed of in the unlined Bear Creek Burial Grounds (BCBG) between 1955 and 1989. BCBG is adjacent to Bear Creek (Moss et al. 1999).

DOE's surface water monitoring program focused solely on the Clinch River (DOE, 2022); therefore, DoR-OR's *Ambient Surface Water Parameters Project* focused on three (3) ORR exit-pathway streams that flow into the Clinch River. Data from these streams can help identify any shifts or changes in water quality that might indicate potential migration of contaminants.

7.1.3 Goals

The goal of this project was to measure surface water parameters in EFPC, Bear Creek (BC), and Mitchell Branch (MI) within the ORR to supplement DOE's surface water monitoring program. In addition, a record of ambient conditions was compiled for future use as a reference in the event of unexpected releases that may impact surface water.

7.1.4 Scope

This project involved the characterization of physical stream parameters of three (3) ORR exit-pathway streams (EFPC, BC, and MI) and one (1) offsite background stream (MB). See Figure 7.1.4.1 and Table 7.1.4.1 below for sample locations.

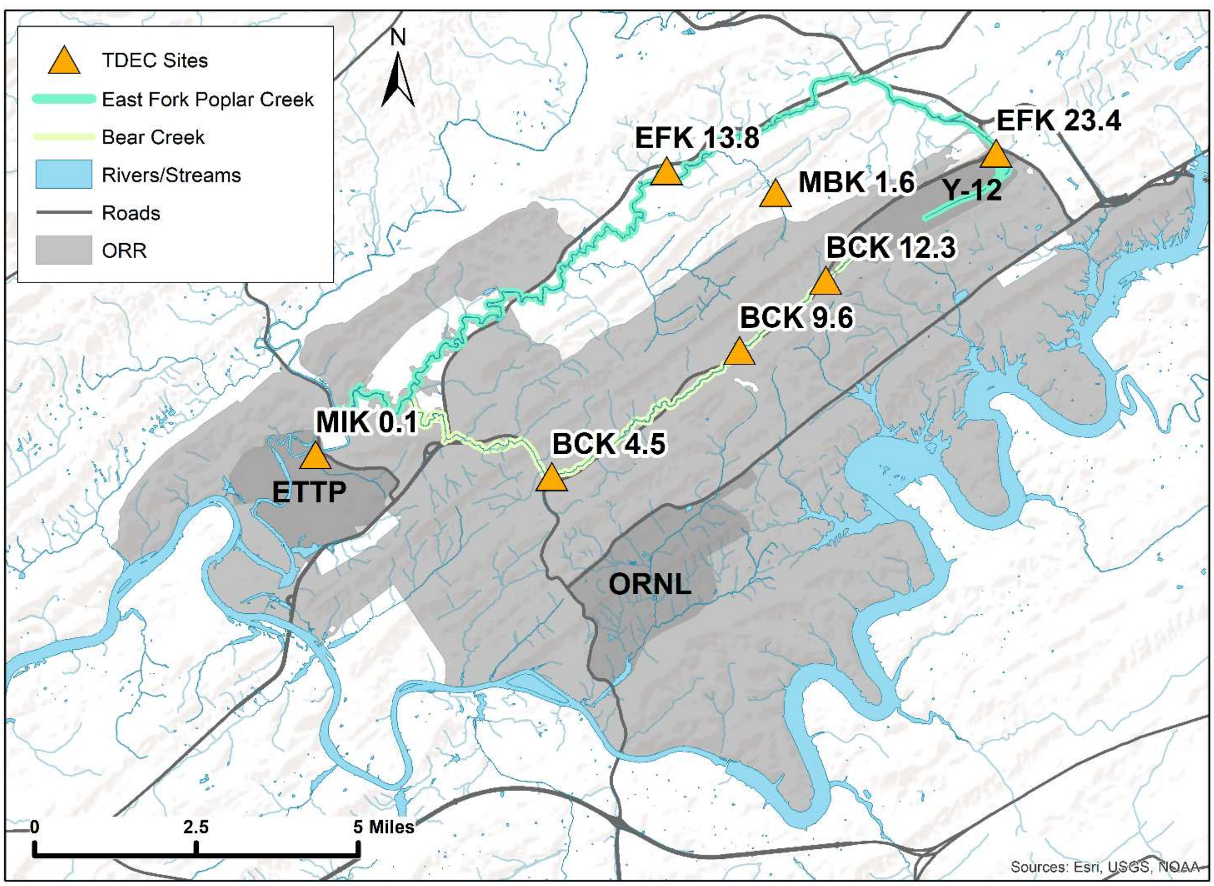


Figure 7.1.4.1: Surface Water Parameter Sites

Table 7.1.4.1: Site Locations

DWR Name	Site Description	TDEC Site	Latitude	Longitude
EFPOP014.5AN	East Fork Poplar Creek Mile 14.5	EFK 23.4	35.99596	-84.24004
EFPOP008.6AN	East Fork Poplar Creek Mile 8.6	EFK 13.8	35.99283	-84.31371
BEAR007.6AN	Bear Creek Mile 7.6	BCK 12.3	35.973	-84.27814
BEAR006.0AN	Bear Creek Mile 6.0	BCK 9.6	35.96032	-84.29741
BEAR002.8RO	Bear Creek Mile 2.8	BCK 4.5	35.9375	-84.33938
MITCH000.1RO	Mitchell Branch Mile 0.1	MIK 0.1	35.94146	-84.3922
FECO67l12	Mill Branch Mile 1.0	MBK 1.6	35.98886	-84.28935

7.1.5 Methods, Materials, Metrics

Field Parameter Measurements

At each site, physical water parameters were measured and recorded. Physical parameters were measured using a multiple parameter water quality meter. Conductivity (µS/cm), dissolved oxygen (mg/L), pH, and temperature (°C) were recorded along with the time of measurement. Measurements were taken in accordance with the Divion of Water Resources *Chemical and Bacteriological Surface Water Sampling Standard Operating Procedure* (TDEC, 2022).

Data Evaluation

Recorded measurements are stored in a DoR-OR managed database. Using R programming language, several statistical analyses were performed to better understand the results. Trend analyses were performed using linear regression to identify any increasing or decreasing trends in data. Basic descriptive statistics (mean, median, minimum, maximum, etc.) were also assessed.

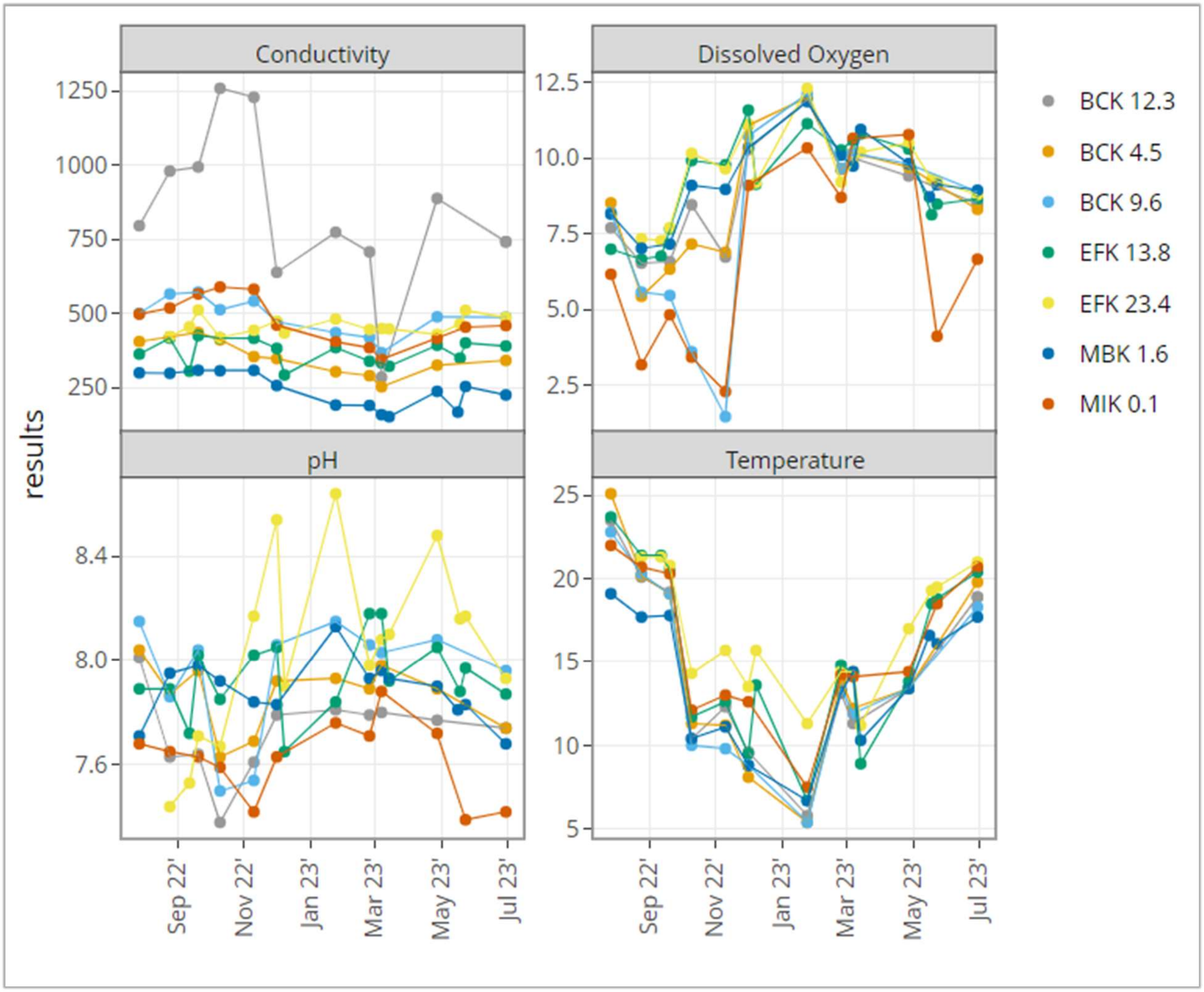
The selected ORR streams were compared to the Mill Branch background stream using statistical approaches such as an analysis of variance to determine if corresponding water quality measurements are significantly similar.

7.1.6 Deviations from the Plan

Two deviations from the plan occurred. In July 2022, location EFK 23.3 was not measured due to inaccessibility from dangerous flooding. In May 2023, the Bear Creek locations could not be measured due to DOE stream access restrictions. All other measurements were taken monthly at each location as planned.

7.1.7 RESULTS AND ANALYSIS

Field parameters, including conductivity, dissolved oxygen, pH, and temperature, were collected monthly during FY23 (July 2022 to June 2023) from the seven (7) monitoring locations (Figure 7.1.7.1). These data generally seemed to follow similar patterns over time for each respective parameter. However, a few monitoring locations had slight deviations for certain parameters. These significant differences among streams will be analyzed and discussed below.



Notes: Units for plots include conductivity (µS/cm), dissolved oxygen (mg/L), pH (std. unit), and temperature (ºC)

Figure 7.1.7.1. FY23 Field Parameter Results

Conductivity

One (1) of the field parameters with significant differences among streams was conductivity. Mean conductivity values from measurements collected July 2022 to June 2023 ranged from

834 to 240 microSiemens per centimeter (μS/cm) among all of the monitoring sites. Bear Creek sites BCK 12.3 and BCK 9.6 had the highest mean conductivity values measured at 836 and 488 μS/cm, respectively. These two (2) locations have been consistently high in previous years. Further downstream, BCK 4.5 had a lower mean value of 354 μS/cm. On EFPC, site EFK 23.3, near the eastern border of the Y-12 NSC, had a mean conductivity of 459 μS/cm. Downstream of EFK 23.3, site EFK 13.8 had a lower mean value of 371 μS/cm. The Mitchell Branch site MIK 0.1 at ETTP had a mean conductivity value of 473 μS/cm. Lastly, Mill Branch (MBK 1.6), an ecological reference site, had the lowest conductivity among all streams measured with a mean value of 240 μS/cm.

An *analysis of variance* (ANOVA) was performed to determine if mean conductivity differed significantly among streams. Results from the ANOVA indicated statistically significant differences with $p < 0.05$. A post hoc Tukey Test was performed to distinguish which monitoring sites are significantly different in conductivity. Results indicate that Bear Creek site BCK 12.3 is statistically significantly higher in conductivity than all other monitored sites with $p < 0.05$ (see Table 7.1.7.1). Similarly, the ecological reference site, Mill Branch (MBK 1.6), was found to be statistically significantly lower in conductivity than all other monitored sites with $p < 0.05$, except for BCK 4.5. These findings are consistent with historical comparisons of these streams.

Table 7.1.7.1: *Tukey Comparison of Means Test*: Conductivity Results

Site	Mean Conductivity (μS/cm)
BCK 12.3‡	836.4
BCK 9.6*	487.7
MIK 0.1*	473.3
EFK 23.4*	458.5
EFK 13.8*	371.0
BCK 4.5*†	353.9
MBK 1.6†	240.0

**, †, and ‡ represent statistically similar groupings defined by Tukey test with p < 0.05.*
If a site does not share a grouping with another site, then they are considered statistically different.

Dissolved Oxygen (DO)

DO values were also evaluated from measurements collected in FY23. Mean values of the DO ranged from 9.5 to 6.7 mg/L. EFPC site EFK 23.3, had the highest oxygen concentration among all sites. The ETTP Mitchell Branch site, MIK 0.1, had the lowest mean concentration of DO. In general, streams were similar in DO concentrations.

An ANOVA was performed to determine if any significant differences exist among streams for DO concentrations. Results from the ANOVA indicated statistically significant differences with $p < 0.05$. A post hoc Tukey Test was performed to distinguish which monitoring sites were significantly different. While all sites are relatively similar, only location EFK 23.3 significantly differed from MIK 0.1. Mean DO concentrations for each site are shown below (Table 7.1.7.2).

Table 7.1.7.2: *Tukey Comparison of Means Test*: Dissolved Oxygen (DO) Results

Site	Mean Dissolved Oxygen (mg/L)
EFK 23.4*	9.5
MBK 1.6*	9.3
EFK 13.8*	9.2
BCK 12.3*†	8.7
BCK 4.5*†	8.7
BCK 9.6*†	7.8
MIK 0.1†	6.7

**, †, and ‡ represent statistically similar groupings defined by Tukey test with $p < 0.05$.*
If a site does not share a grouping with another site,then they are considered statistically different.

pH

Stream pH was analyzed for measurements collected in FY23, from July 2022 to June 2023 Mean pH values ranged from 8.03 to 7.62 among all sites. EFPC site EFK 23.3 had the highest pH readings. Mitchell Branch site MIK 0.1, while similar to other streams, was lower with an average pH of 7.6.

Table 7.1.7.3: Average pH

Site	Mean pH (Std. Unit)
EFK 23.4	8.03
BCK 9.6	7.95
EFK 13.8	7.94
MBK 1.6	7.89
BCK 4.5	7.87
BCK 12.3	7.73
MIK 0.1	7.62

Temperature

Temperature data were evaluated for all sites measured in FY23. Mean water temperatures ranged from 16.7 to 13.8°C, with EFPC being the warmest and Mill Branch being the coolest among all sites. An ANOVA indicated no statistically significant differences in water temperature among sites (see Table 7.1.7.4).

Table 7.1.7.4: Average Temperatures

Site	Mean Temperature (°C)
EFK 23.4	16.7
MIK 0.1	15.8
EFK 13.8	15.7
BCK 12.3	14.7
BCK 4.5	14.5
BCK 9.6	13.9
MBK 1.6	13.8

Field Parameter Summary

The above-mentioned FY23 field parameter data were also analyzed in conjunction with data collected annually from 2005 to 2023 (Figure 7.1.7.2).

Notes: Units for plots include conductivity (µS/cm), dissolved oxygen (mg/L), pH (std. unit), and temperature (ºC)

Figure 7.1.7.2: Mean Annual Parameter Values from 2005 to 2023

Data were evaluated for significant increasing or decreasing trends with data for each parameter averaged by year. Significant linear trends with $p < 0.05$ were found for conductivity at two (2) different stations. Additionally, a statistically significant negative correlation was found between mean annual conductivity and time for BCK 12.3 with $p < 0.05$. This correlation was found through linear regression, with mean annual conductivity as the dependent variable and time as the independent variable. The coefficient of determination (R^2) was 0.79, indicating a good fit. This indicates that there is a trend of decreasing conductivity with time for site BCK 12.3. The slope of the regression line illustrates that this decrease is occurring at roughly 28 µS/cm annually. Similarly, a statistically significant positive correlation was found with mean annual conductivity and time for EFK

23.3 with $p < 0.05$. The coefficient of determination (R^2) was 0.85, which indicates the regression fits the data well. This trend illustrates that conductivity has increased with time since 2005 for EFK 23.3. The slope of the regression line shows that this increase is occurring at roughly 8 μS/cm annually (Figure 7.1.7.3).

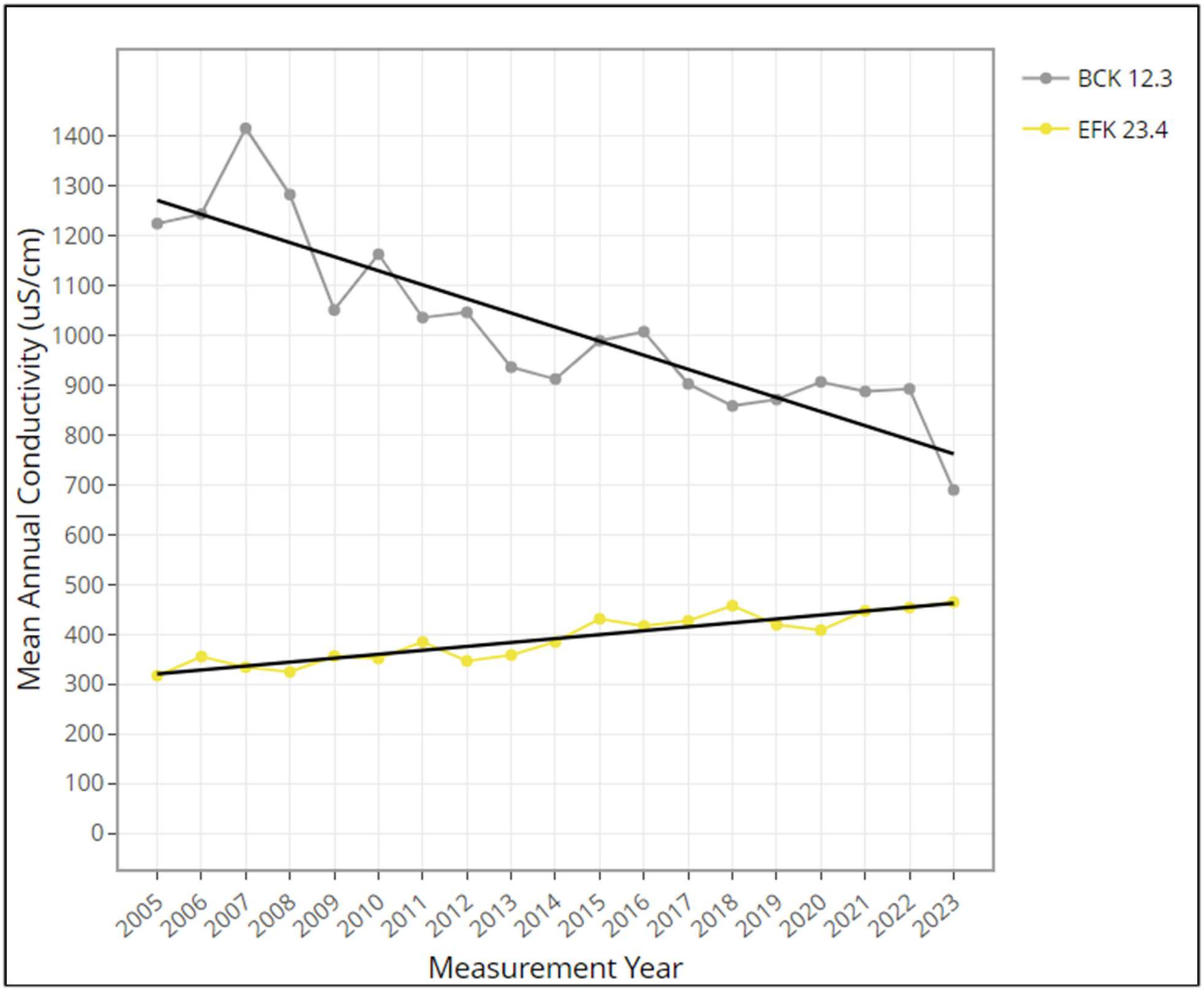


Figure 7.1.7.3: Linear Regression of Mean Annual Conductivity Over Time on Bear Creek (BCK 12.3) and East Fork Poplar Creek (EFK 23.3)

7.1.8 Conclusions

Field parameters including conductivity, dissolved oxygen, pH, and temperature were collected monthly from the seven (7) monitoring locations. These data serve to populate a database and baseline for surface water conditions for many streams in the ORR as well as help to assess impact of remediation efforts and identify accidental releases. Of these measurements, all readings were within the *State of Tennessee Water Quality Criteria* [AWQC]

(TDEC, 2019). Significant findings were identified for conductivity and DO.

Conductivity

While there is no existing AWQC for conductivity, Bear Creek site BCK 12.3 was found to be statistically significantly higher than all other streams. Despite having a higher conductivity at this location, historical data (2005-2022) indicate that BCK 12.3 has a decreasing trend in conductivity. This trend is declining at an estimated rate of 28 µS/cm annually. In all, this stream is still considered quite high in conductivity but is trending downward. One explanation for this higher conductivity may be related to the proximity of this site to the capped S-3 ponds and the Y-12 West End Water Treatment Facility on the Y-12 National Security Complex (NSC). This area is known for containing high concentrations of metals (Brooks, 2001). The decrease in conductivity at BCK 12.3 since 2005 may be the result of attenuation of these contaminant sources. On the other hand, East Fork Poplar Creek, site EFK 23.3, has shown a steadily increasing trend of conductivity through time, albeit a small increase. This trend has been increasing at an average rate of roughly 8 µS/cm annually. The reason(s) for this increase have not yet been determined. Alternatively, Mill Branch (MBK 1.6), which is an ecological reference site, was statistically significantly lower in conductivity than all ORR streams measured. This may be due to operations on the ORR that have the potential to load these streams with more solutes.

Dissolved Oxygen (DO)

Mitchell Branch (MIK 0.1) was found to have lower dissolved oxygen levels relative to other streams measured around the ORR. These dissolved oxygen levels were especially low during the summer months when the weather is hotter. For a typical stream, an increase in water temperature results in a decrease in dissolved oxygen concentrations. These higher water temperatures, which would be typical for this time of year, could perhaps explain this decrease in oxygen concentrations. However, sites on EFPC, specifically EFK 23.3 and EFK 13.8, maintain higher water temperatures than Mitchell Branch for much of the year, yet these sites still maintain higher dissolved oxygen concentrations. One explanation for low DO at MIK 0.1 may be the growth of oxygen demanding plants that may be more likely to thrive in warmer weather. Algae was identified covering much of the stream in the summer months.

7.1.9 RECOMMENDATIONS

As legacy DOE ORR pollution has negatively impacted East Fork Poplar Creek, Bear Creek, and Mitchell Branch, TDEC recommends continued physical parameter monitoring at the seven (7) monitoring stations in order to identify, categorize, and interpret changing trends such as the upward trend of conductivity in East Fork Poplar Creek at site EFK 23.3 and the downward trend of conductivity at Bear Creek site BCK 12.3. This is especially important with upcoming construction projects and demolition of buildings at Y-12 that may influence East Fork Poplar Creek water quality. In addition, more research is needed to fully understand why Mitchell Branch tends to have these lower dissolved oxygen concentrations and to understand its effects on aquatic plants and animals.

7.1.10 References

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7.2 Ambient Surface Water Sampling

7.2.1 Background

Activities at the three (3) ORR campuses have resulted in the discharge of hazardous substances (e.g. metals, organics, and radioactive materials) causing contamination of waterbodies on the ORR and in the surrounding areas (DOE, 1992; DOE, 2022a; Pickering, 1970; Turner & Southworth, 1999).

While legacy waste across the ORR may be responsible for a significant portion of contamination to surface water, current projects and processes at these sites also have the potential to contribute to and/or exacerbate surface water contamination. To monitor potential contamination in waterways that have been impacted by past and present activities on the ORR, DoR-OR *Ambient Surface Water Sampling Project* has been implemented each year since 1993. This monitoring project began by investigating the water quality of the Clinch River at five (5) locations near the ORR. The sampling locations for this project have been modified throughout the years, sometimes adding, or discontinuing sampling at a particular location. Most recently, monitoring has focused on Bear Creek, East Fork Poplar Creek, and the Clinch River.

DOE has similarly implemented a surface water monitoring program for several years that consists of sample collection and analysis from a few locations along the Clinch River (DOE, 2018; DOE, 2020; DOE, 2021; DOE, 2022). Currently, DOE collects samples quarterly at four (4) sites along the Clinch River at river kilometers 16, 32, 58, and 66 (Figure 7.2.1.1) (DOE, 2022). Of these sites, Clinch River kilometer (CRK) 58 is near the water supply intake for Knox County, and CRK 66 is upstream of the Oak Ridge City water supply intake. Grab samples are collected at these four (4) sites and are analyzed for water quality parameters such as dissolved oxygen, pH, and water temperature. Samples are also screened for radioactivity by investigating gross alpha, gross beta, and gamma disintegrations. At three (3) of the four (4) sites, analyses are performed to investigate concentrations of mercury. However, mercury samples are not collected by DOE from the Knox County water supply site (CRK 58). Additionally, strontium-90 is analyzed at three (3) of the sites: at the confluence of the White Oak Creek and Clinch River near ORNL (CRK 32), upstream of the Oak Ridge City water supply intake (CRK 66), and downstream of the ORR (CRK 16).

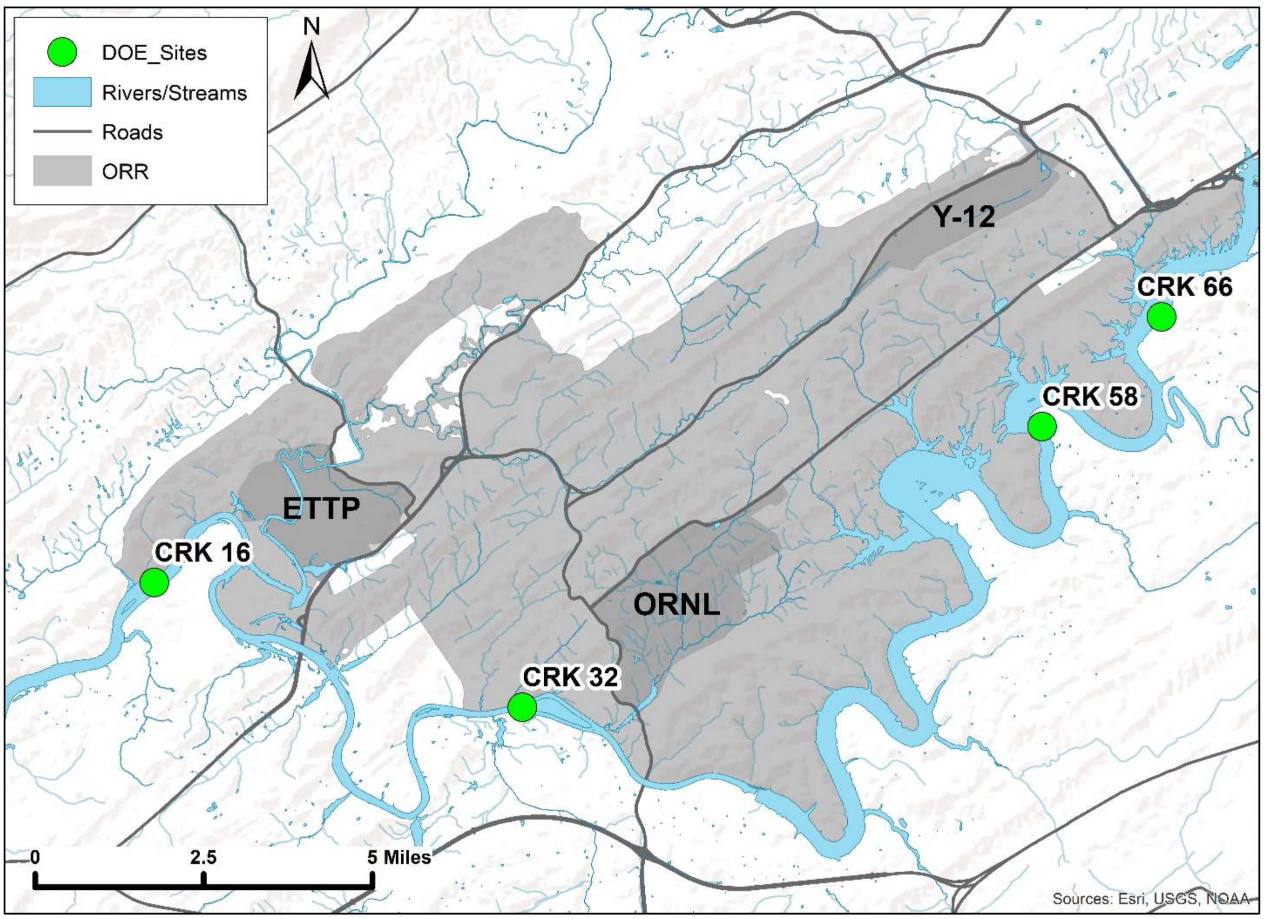


Figure 7.2.1.1: Clinch River (CR) DOE Sampling Sites

The purpose of the current *DOE Surface Water Monitoring Project* is to assess the impacts from both past and present site operations to surface water bodies. This project, the *DoR-OR Ambient Surface Water Sampling Project,* supplements DOE's study of the Clinch River to better understand impacts of exit-pathway streams to human health and the environment.

7.2.2 Problems Statements

It is estimated, based on 2020 US census data, that nearly 1.1 million people live in the counties surrounding the ORR (DOE, 2020). A large portion of these people are direct downstream receptors of streams that drain from the ORR. All of the exit-pathway streams on the ORR eventually flow into the Clinch River which is an important drinking water source for the surrounding communities. The Clinch River surface waters are also used by facilities at Y-12, ORNL, and ETTP. It is important to monitor exit-pathway streams such as EFPC and BC, as well as the Clinch River, to better understand the ORR's impact on the region's widely used water resources. Identified concerns include but are not limited to the following:

EFPC

Mercury, which is bio-accumulative when methylated, is and has been a major contaminant of EFPC. It is estimated that over 20 million pounds of mercury were used at the Y-12 in the 1950s and 1960s for lithium processing. Of that 20 million pounds, 700,000 pounds were suspected to be released into buildings and to the surrounding environment (DOE, 2020a). Discharges of mercury through spills and leaks, or even intentional discharges of mercury bearing wastewater added nearly 100 metric tons of mercury directly to EFPC (Southworth et al., 2010). Several remedial actions have helped address mercury in soils and sediments, yet mercury is still present at elevated concentrations. In a recent DOE Remediation Effectiveness Report, DOE determined that the mercury flux at EFK 23.3 ranged from 6.3 kilograms per year (kg/yr) to 21.5 kg/yr from 2012 to 2022, with an average of 11.75 kg/yr (DOE, 2022a).

BC

Bear Creek has many contamination sources along the Bear Creek Valley. Near the headwaters of Bear Creek, it is estimated by DOE that roughly 7.5 million liters per year of uranium contaminated nitric acid wastes and other liquid wastes were disposed in the S3 ponds between 1951 and 1984 (Moss et al. 1999). Near the middle section of BC, solid and liquid wastes, including approximately 18 million kilograms of uranium metal and 1 million liters of waste oils and chlorinated solvents, were disposed in the unlined Bear Creek Burial Grounds between 1955 and 1989 which are adjacent to Bear Creek (Moss et al. 1999). In a recent 2023 study by DOE at the Bear Creek Burial Grounds, high concentrations of PCBs were identified at NT-8, which flows into Bear Creek (DOE, 2023). In general DOE has stated, "The primary contaminants in [Bear Creek] are uranium, nitrate, and cadmium." (DOE, 1999).

7.2.3 Goals

The goal of this *Ambient Surface Water Monitoring Project* is to evaluate the presence and quantity of bio-accumulative or toxic contaminants (e.g. metals and PCBs) to better understand possible pathways and sources for biota intake from exit pathway streams within the ORR, Bear Creek and East Fork Poplar Creek, that discharge to the Clinch River.

7.2.4 Scope

The scope of this project was to characterize stream conditions and assess contaminant presence through quarterly sampling and analysis of surface water from Bear Creek (BC) and East Fork Poplar Creek (EFPC), which ultimately flow into the Clinch River (CR). In addition, a section of the CR was also assessed. This reach spanned from the Oak Ridge City water supply intake at CRK 66 and downstream to CRK 16.1, which is downstream of all ORR exit stream inputs.

7.2.5 Methods, Materials, Metrics

Sample Collection

Surface water samples were collected at several locations for this project. The specific locations and respective frequencies of sampling were as follows:

1) EFPC was sampled quarterly at four (4) sites. Sampling included bio-accumulative and toxic metals, and nutrients. Radionuclides (gross alpha and beta activity) as well as PCBs were analyzed in the spring quarter sampling events.
2) BC was sampled quarterly at three (3) sites. Sampling included bio-accumulative and toxic metals, and nutrients. Radionuclides (gross alpha and beta activity) as well as PCBs were analyzed in the spring quarter sampling. Two (2) additional locations (BCK 10.6 and BCK 9.2) were sampled during the spring PCB sampling events.
3) CR locations were each sampled one (1) time, with one (1) location sampled each quarter. Each location was sampled for radionuclides and mercury, with CRK 32 also being sampled for strontium-90.
4) Mill Branch and Clear Creek were both sampled as background reference streams. Mill Branch was sampled quarterly for metals and nutrients. Clear Creek was sampled one (1) time as a PCB background stream.

Stream locations are shown in the figure below (Figure 7.2.5.1). The number associated with each site represents the distance in kilometers from the mouth of the stream or river to that location. EFK represents (East Fork Poplar Creek Kilometer) and BCK represents (Bear Creek Kilometer). CRK and MBK represent (Clinch River Kilometer) and (Mill Branch Kilometer), respectively. Clear Creek, which was also sampled, is roughly 22 miles northeast of the ORR but is not shown on the figure.

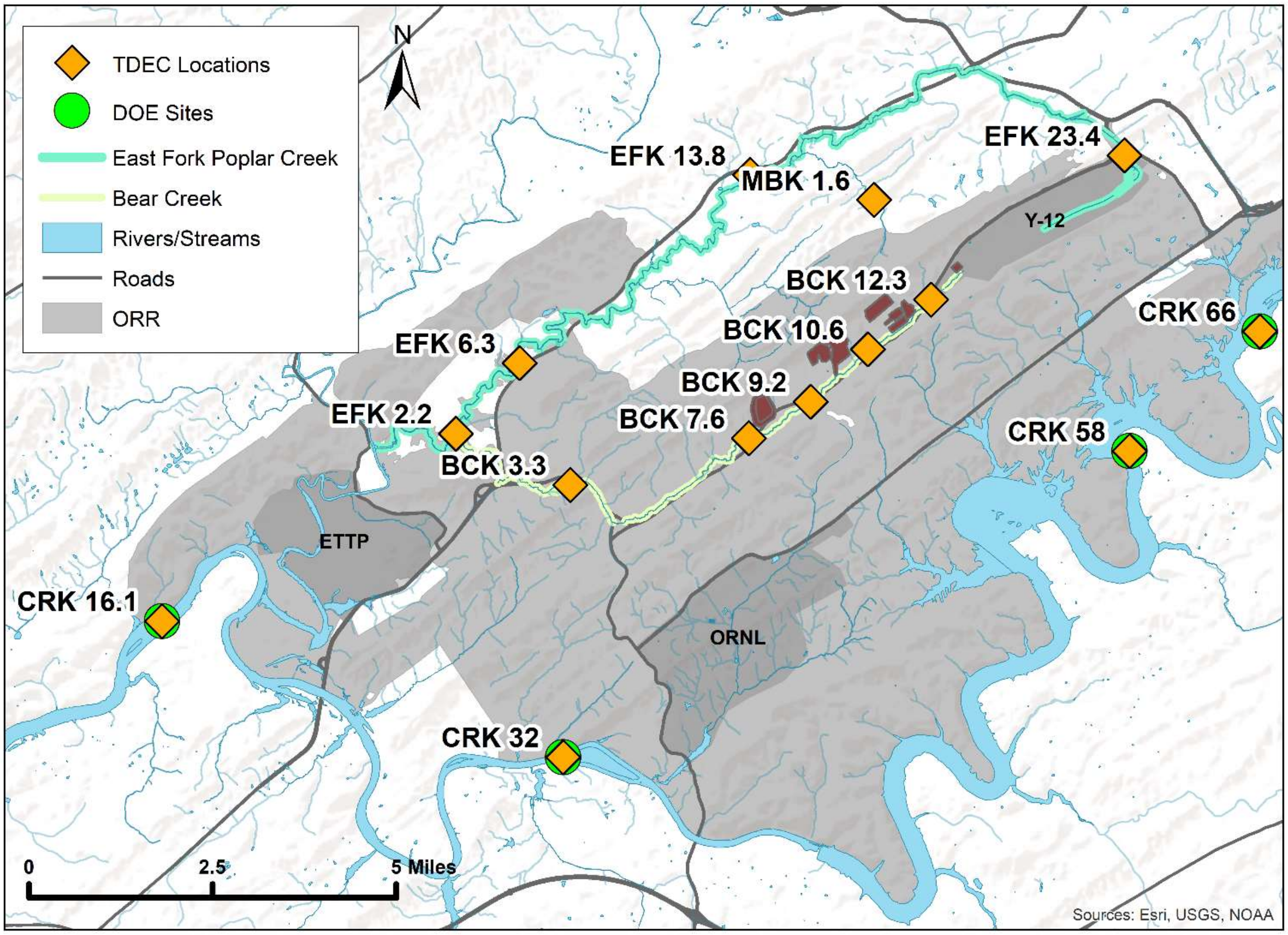


Figure 7.2.5.1: DoR-OR and DOE Surface Water Sampling Sites

QA/QC samples were collected for every 10th sample of any given analyte (Table 7.2.5.2). Sampling protocols followed the *TDEC DWR Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water* (TDEC, 2022). The methods used for each analyte are shown in Table 7.2.5.1.

Table 7.2.5.1. Sample and Site Information

		Sampled					
DOE-O Site Description	DoR-OR Site	Sr-90	PCBs	Rads*	Mercury	Nutrients*	Metals*
Clinch River Mile 10.0	CRK 16.1			1	1		
Clinch River Mile 19.7	CRK 32	1		1	1		
Clinch River Mile 36.0	CRK 58			1	1		
Clinch River Mile 41.0	CRK 66			1	1		
Bear Creek Mile 7.6	BCK 12.3		2	1	1	4	4
Bear Creek Mile 6.6	BCK 10.6		1				
Bear Creek Mile 5.7	BCK 9.2		1				
Bear Creek Mile 4.7	BCK 7.6		2	1	1	4	4
Bear Creek Mile 2.0	BCK 3.3		2	1	1	4	4
East Fork Poplar Creek Mile 14.5	EFK 23.4		2	1	1	4	4
East Fork Poplar Creek Mile 8.6	EFK 13.8		1	1	1	4	4
East Fork Poplar Creek Mile 3.9	EFK 6.3		1	1	1	4	4
East Fork Poplar Creek Mile 1.4	EFK 2.2		2	1	1	4	4
Mill Branch Mile 1.0	MBK 1.6		1	1	1	4	4
Clear Creek Mile 1.0	CCK 1.6		1				
DOE Co-Sample	FD		2	1	3	3	3
Ambient	**Total for FY**	**1**	**18**	**13**	**15**	**35**	**35**
QA/QC							
Not Planned in EMP							

Note:

Rads: Gross alpha, Gross Beta

Nutrients: Nitrate/Nitrite and Total Phosphorus (Bear Creek sampled for Nitrates each quarter; No phosphorus sampled)

Metals: Arsenic, Barium, Beryllium, Boron, Cadmium, Chromium, Copper, Lead, Nickel, and Uranium

Table 7.2.5.2. Sample Methods and Analytes

Metals					
Parameter	**Description**	**Method**	**MDL**	**MQL**	**Unit**
Mercury, Low Level	Mercury in Water CVAF Spectrometry	EPA 1631	0.00185	0.005	ug/L
Metals digestion	ICP Digestion (water)	EPA 200.2	-	-	-
Arsenic	ICP-MS	EPA 200.8	0.388	1	ug/L
Barium	ICP-MS	EPA 200.8	0.107	1	ug/L
Beryllium	ICP-MS	EPA 200.8	0.123	1	ug/L
Boron	ICP-MS	EPA 200.8	3.01	10	ug/L
Cadmium	ICP-MS	EPA 200.8	0.219	1	ug/L
Chromium	ICP-MS	EPA 200.8	1.5	5	ug/L
Copper	ICP-MS	EPA 200.8	0.17	1	ug/L
Lead	ICP-MS	EPA 200.8	0.288	1	ug/L
Nickel	ICP-MS	EPA 200.8	0.3	1	ug/L
Uranium	ICP-MS	EPA 200.8	0.143	1	ug/L
General Inorganics					
Parameter	**Description**	**Method**	**MDL**	**MQL**	**Unit**
Alkalinity (Total)	Alkalinity By Titration	2320-B	10	10	mg/L
PCBs	HRGC/HRMS	EPA 1668A-C	0.0013 -0.061	0.04 - 0.24	ng/L
Nitrate/Nitrite	Nitrate-Nitrite Nitrogen by Automated Colorimetry	EPA 353.2	0.0241	0.1	mg/L
Total Phosphorus	Phosphorus by Semi-Automated Colorimetry	EPA 365.1	0.00829	0.01	mg/L
Radionuclides					
Parameter	**Description**	**Method**	**MDL**	**MQL**	**Unit**
Gross Alpha/Beta	Liquid Scintillation Counting	ASTM D7283-17 LSC	-	-	pCi/L
Strontium-89,90	Radioactive Strontium in Drinking Water	EPA 905	-	-	pCi/L

Field Parameter Measurements

At each site, during the time of sampling, physical water parameters were measured using a multiple parameter water quality meter. Parameters of conductivity (µS/cm), dissolved oxygen (mg/L), pH, and temperature (°C) were recorded along with the time of measurement. Discharge was also measured at some stream sites where it was most relevant.

7.2.6 Deviations from the Plan

An additional round of PCB sampling was added to the project, which included two (2) additional locations on Bear Creek (BCK 10.6 and 9.2) and one (1) background location on Clear Creek (CCK 1.6). These locations were chosen to help identify any PCB contamination that may be coming from the EMWMF and the BCBG (see Figure 7.2.6.1). Clear Creek was chosen as a location that was likely to be a good background stream away from landfills and other sources of PCB contamination.

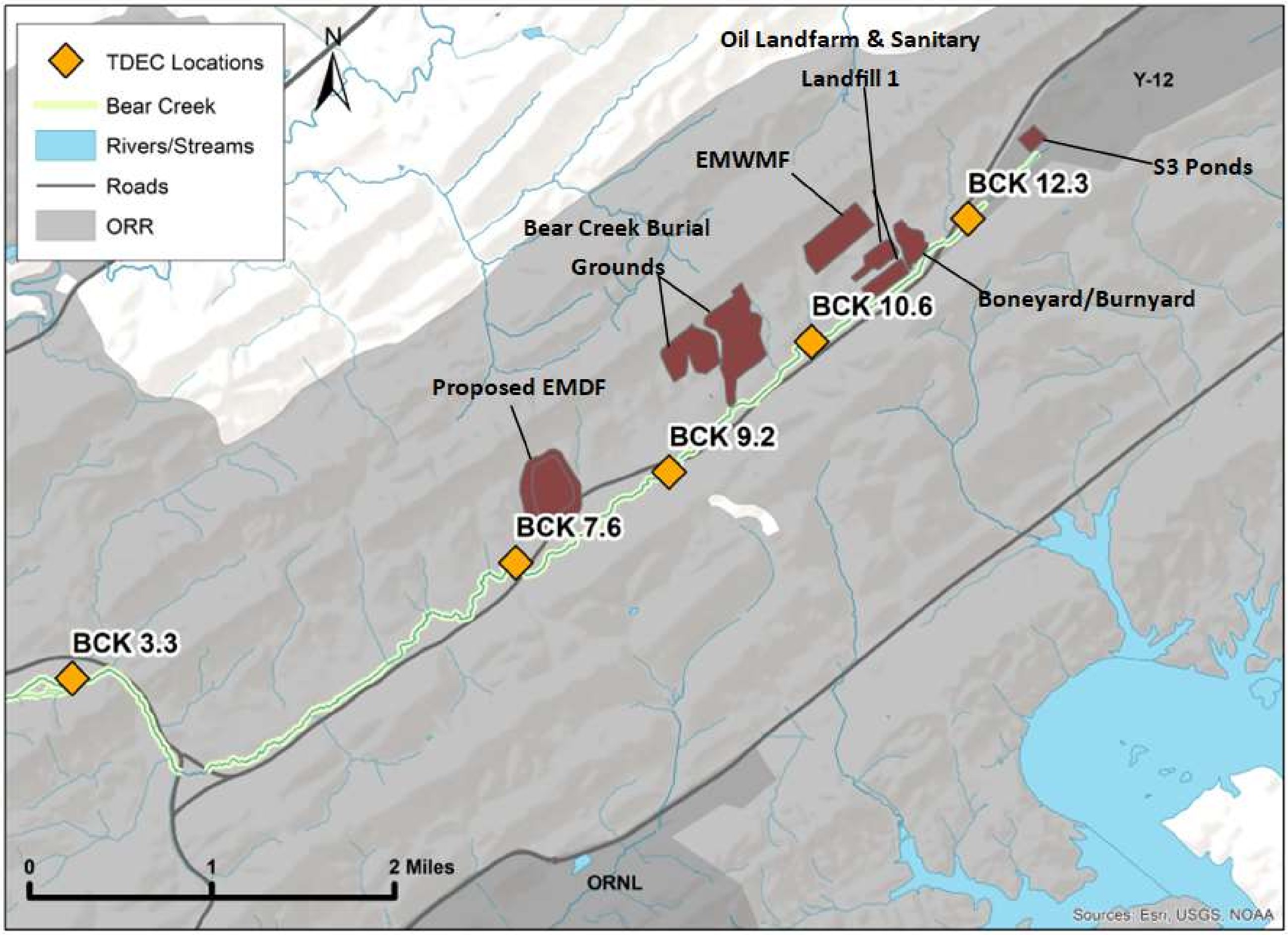


Figure 7.2.6.1: Bear Creek Locations and Potential Contaminant Sources

7.2.7 Results and Analysis

Data summaries of sampled constituents are shown in the tables below. See tables 7.2.7.1 – 7.2.7.7 for quarterly sampling results. The marking of "-" indicates that a sample was not taken for that given analyte. The "U" indicates that a constituent was not detected by the laboratory equipment. A "J" after a number indicates that the constituent was detected but was estimated by the laboratory. Highlighted cells indicate an exceedance of screening criteria.

Field Parameters

Results for all parameters for exit pathway and background streams are shown in Table 7.2.7.1. Clinch River parameters are shown in Table 7.2.7.2.

Table 7.2.7.1: Quarterly Water Quality Parameters and Discharge Measurements

Stream	DoR-OR Site	Temperature (C)	pH	Dissolved Oxygen (mg/L)	Conductivity (uS/cm)	Discharge (cfs)	Turbidity (NTU)	Date	Quarter
Bear Creek	BCK 12.3	19.2	7.64	6.58	994	0.1	-	9/20/2022	1
Bear Creek	BCK 12.3	12.4	7.6	9.47	479.9	1.0	-	11/30/2022	2
Bear Creek	BCK 12.3	11.3	7.8	10	285.4	1.2	-	3/7/2023	3
Bear Creek	BCK 12.3	18.9	7.74	8.49	742	0.6	4.55	6/29/2023	4
Bear Creek	BCK 10.6	21.6	7.68	7.6	378	-	33.43	6/29/2023	4
Bear Creek	BCK 9.2	16.7	7.48	8.57	427.7	-	8.18	6/29/2023	4
Bear Creek	BCK 7.6	18.8	8.03	7.6	537.2	0.4	-	9/20/2022	1
Bear Creek	BCK 7.6	11.4	7.85	10.04	276.5	9.0	-	11/30/2022	2
Bear Creek	BCK 7.6	11.8	8.16	10.35	310	5.2	-	3/7/2023	3
Bear Creek	BCK 7.6	18.2	8.06	9.13	401.3	1.1	8.05	6/29/2023	4
Bear Creek	BCK 3.3	18.8	7.96	7.18	427.5	1.0	-	9/20/2022	1
Bear Creek	BCK 3.3	11.3	7.53	9.36	181.4	21.8	-	11/30/2022	2
Bear Creek	BCK 3.3	12.6	7.93	10.4	227.8	15.8	-	3/7/2023	3
Bear Creek	BCK 3.3	19.2	7.9	8.92	333.7	3.5	8.18	6/29/2023	4
East Fork Poplar Creek	EFK 23.4	21.3	7.53	7.27	455.4	4.4	-	9/12/2022	1
East Fork Poplar Creek	EFK 23.4	15.7	7.9	9.19	434.6	9.0	-	12/8/2022	2
East Fork Poplar Creek	EFK 23.4	11.2	8.1	10.2	448.2	4.5	-	3/14/2023	3
East Fork Poplar Creek	EFK 23.4	19.3	8.16	9.29	465.2	3.4	3.04	5/18/2023	4
East Fork Poplar Creek	EFK 13.8	21.4	7.72	6.76	305.8	13.2	-	9/12/2022	1
East Fork Poplar Creek	EFK 13.8	20.6	8.02	7.66	425.6	49.7	-	12/8/2022	2
East Fork Poplar Creek	EFK 13.8	13.6	7.65	9.14	293	23.4	-	3/14/2023	3
East Fork Poplar Creek	EFK 13.8	14.3	8.18	-	333.3	13.1	6.32	5/18/2023	4
East Fork Poplar Creek	EFK 6.3	21.4	7.73	6.9	301.3	24.3	-	9/12/2022	1
East Fork Poplar Creek	EFK 6.3	13.7	7.65	9.14	293	104.2	-	12/8/2022	2
East Fork Poplar Creek	EFK 6.3	9.7	8.02	10.82	312.3	48.3	-	3/14/2023	3
East Fork Poplar Creek	EFK 6.3	19	7.82	7.8	352.2	28.3	6.85	5/18/2023	4
East Fork Poplar Creek	EFK 2.2	21.4	7.8	7.1	327.8	29.4	-	9/12/2022	1
East Fork Poplar Creek	EFK 2.2	13	7.66	9.61	238.7	168.0	-	12/8/2022	2
East Fork Poplar Creek	EFK 2.2	9.6	8.19	-	269	69.1	-	3/14/2023	3
East Fork Poplar Creek	EFK 2.2	19.3	7.81	7.62	299.4	34.0	6.87	5/18/2023	4
Mill Branch	MBK 1.6	17.8	7.98	7.16	308.8	0.2	-	9/20/2022	1
Mill Branch	MBK 1.6	11.7	7.53	9.36	181.4	1.2	-	11/30/2022	2
Mill Branch	MBK 1.6	10.3	7.93	10.95	152.4	2.8	-	3/14/2023	3
Mill Branch	MBK 1.6	16.6	7.81	8.72	168	1.5	-	5/16/2023	4
Clear Creek	CCK 1.6	17.6	8.13	9.15	252.6	-	-	6/9/2023	4

Table 7.2.7.2: Clinch River (CR) Water Quality Parameter Results

Stream	DoR-OR Site	Temperature (C)	pH	Dissolved Oxygen (mg/L)	Conductivity (uS/cm)	Date	Quarter
Clinch River	CRK 66	17.8	7.51	7.56	283	9/19/2022	1
Clinch River	CRK 58	11.9	7.76	7.39	286.2	12/5/2022	2
Clinch River	CRK 32	11.7	8.74	-	282.5	3/21/2023	3
Clinch River	CRK 16.1	23.8	8.69	-	275.6	5/16/2023	4

Metals

Metals were sampled quarterly at each of the exit-pathway stream locations investigated within this project. Many locations were sampled on each stream. In general, upstream locations tend to be closer to DOE main plant areas and downstream locations tend to be more distal. Of the metals sampled, arsenic, cadmium, and chromium were infrequently detected and often were only detected in only one or two quarters out of the year (see Table 7.2.7.3). Beryllium was not detected in any samples at any stream locations. The CR was only sampled for mercury and was not sampled for other metals mentioned above. This section focuses on those metals that had more frequent detections in the streams investigated.

Table 7.2.7.3: Quarterly Metal Results (µg/L)

Stream	DoR-OR Site	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Uranium	Date	Quarter
Bear Creek	BCK 12.3	U	170	U	62	0.31J	U	U	U	-	1.5	200.0	9/20/2022	1
Bear Creek	BCK 12.3	0.388U	78.6	U	58.2	0.508J	U	1.31	U	-	2.0	94.3	11/30/2022	2
Bear Creek	BCK 12.3	U	52.9	U	79.3	0.385J	U	1.12	U	0.00692	1.5	28.6	3/7/2023	3
Bear Creek	BCK 12.3	0.298J	121	U	70.2	0.406J	1.24	1.64J	0.849	-	1.82J	141.0	6/29/2023	4
Bear Creek	BCK 7.6	0.41J	94	U	67	0.34J	U	U	0.34J	-	1.2	49.0	9/20/2022	1
Bear Creek	BCK 7.6	0.509J	51.7	U	33.7	U	U	1.43	0.566J	-	1.2	19.2	11/30/2022	2
Bear Creek	BCK 7.6	U	56.2	U	28	U	U	0.31J	U	U	0.564J	32.1	3/7/2023	3
Bear Creek	BCK 7.6	U	42.4	U	14.8	U	U	0.34J	U	U	0.463J	33.2	3/7/2023	3
Bear Creek	BCK 7.6	0.337J	76.9	U	46.9	0.15	1.24	1.51	2.08	-	0.831J	34.4	6/29/2023	4
Bear Creek	BCK 3.3	U	68	U	34	U	U	7	U	-	0.39J	15.0	9/20/2022	1
Bear Creek	BCK 3.3	0.542J	55.3	U	31.3	U	U	1.4	0.791J	-	1.5	15.8	11/30/2022	2
Bear Creek	BCK 3.3	U	54.6	U	27.9	U	U	0.274J	U	0.00216J	0.469J	10.2	3/7/2023	3
Bear Creek	BCK 3.3	0.324J	59.7	U	23.9J	0.15	1.24	1.51	0.849	-	0.8	13.0	6/29/2023	4
East Fork Poplar Creek	EFK 23.4	U	60	U	30	U	U	4.1J	0.28J	-	0.61J	14.0	9/12/2022	1
East Fork Poplar Creek	EFK 23.4	0.406J	61.9	U	36.1	U	U	3.73	0.306J	-	0.544J	60.0	12/8/2022	2
East Fork Poplar Creek	EFK 23.4	0.43J	57.5	U	123	0.13J	U	3.3	0.342J	0.185	0.443J	28.4	3/14/2023	3
East Fork Poplar Creek	EFK 23.4	0.448J	65.9	U	43.7	0.15	1.24	2.87J	0.849	-	0.8	22.1	5/18/2023	4
East Fork Poplar Creek	EFK 13.8	U	40	U	20	U	U	2J	0.41J	-	0.46J	4.6	9/12/2022	1
East Fork Poplar Creek	EFK 13.8	U	35.1	U	17	U	U	1.99	0.439J	-	0.965J	9.8	12/8/2022	2
East Fork Poplar Creek	EFK 13.8	U	34.7	U	17.6	U	U	1.6	0.409J	-	0.526J	9.9	12/8/2022	2
East Fork Poplar Creek	EFK 13.8	U	33.9	U	26.3	U	U	0.796J	U	0.192	U	8.0	3/14/2023	3
East Fork Poplar Creek	EFK 13.8	0.44J	43.5	U	16.6J	0.15	1.24	1.51	1.05J	-	0.8	7.5	5/18/2023	4
East Fork Poplar Creek	EFK 6.3	U	34	U	38	U	U	2.1J	0.68J	-	1.3	3.0	9/12/2022	1
East Fork Poplar Creek	EFK 6.3	1.41	29.8	U	21.2	U	U	1.7	0.773J	-	0.864J	4.0	12/8/2022	2
East Fork Poplar Creek	EFK 6.3	U	27.2	U	28.5	U	U	0.966J	U	0.0315	0.533J	3.8	3/14/2023	3
East Fork Poplar Creek	EFK 6.3	0.448J	36.6	U	35.9	0.15	1.94J	1.88J	1.51J	-	1.32J	3.8	5/18/2023	4
East Fork Poplar Creek	EFK 2.2	U	42	U	37	U	U	U	0.46J	-	0.96J	6.1	9/12/2022	1
East Fork Poplar Creek	EFK 2.2	0.462J	34.7	U	20.1	U	U	1.82	0.923J	-	1.1	4.8	12/8/2022	2
East Fork Poplar Creek	EFK 2.2	U	31.6	U	21.4	U	U	0.649J	U	0.0259	0.447J	7.0	3/14/2023	3
East Fork Poplar Creek	EFK 2.2	-	-	-	-	-	-	-	-	0.0176	-	-	3/14/2023	3
East Fork Poplar Creek	EFK 2.2	0.486J	40.5	U	32.7	0.15	1.24	1.52J	0.849	-	0.8	5.1	5/18/2023	4
Mill Branch	MBK 1.6	U	48	U	19	U	U	U	U	-	U	0.27J	9/20/2022	1
Mill Branch	MBK 1.6	0.422J	35.2	U	14.4	U	U	1.02	0.527J	-	0.864J	U	11/30/2022	2
Mill Branch	MBK 1.6	U	26.2	U	15.4	U	U	0.25J	U	-	U	U	3/14/2023	3
Mill Branch	MBK 1.6	0.253J	29.4	U	14.6J	0.15	1.24	1.51	0.849	-	0.8	0.111J	5/16/2023	4

Notes: Highlight indicates an exceedance. Mercury exceeded the TN recreation criterion of 0.051 µg/L; Uranium exceeded the EPA Primary Drinking water criterion of 30 µg/L

East Fork Poplar Creek (EFPC)

EFPC had elevated concentrations of barium, boron, copper, and uranium at EFK 23.3 relative to the background MB stream. However, these concentrations tended to decrease to levels at or only slightly above background at downstream locations. Lead and nickel concentrations were higher at EFPC downstream locations relative to the median MB background stream, but these metals were near background levels at upstream locations. Uranium exceeded a screening criterion with a sample at EFK 23.3 yielding a concentration of 60 µg/L in December 2022. This concentration is well above the EPA's MCL of 30 µg/L (EPA, 2009) (Table 7.2.7.3). Other sampling events yielded concentrations just below this criterion at EFK 23.3. While EFPC is not used for drinking water, this criterion in only used as a reference. Another metal that exceeded screening criteria is mercury. Mercury was sampled one (1) time in the spring of 2023 at each stream location and yielded high concentrations at EFK 23.3 (0.185 µg/L) and EFK 13.8 (0.192 µg/L). Concentrations on this sampling event were over three (3) times the *TN Recreational Water Criterion for Organisms* of 0.051 µg/L (see Figure 7.2.7.1 below). Locations downstream of EFK 13.8 had concentrations below the mercury criterion, yet much higher than the background MB stream.

Bear Creek (BC)

For many of the metals sampled, BC had decreasing concentrations from upstream to downstream. Barium, boron, nickel, and uranium were all much higher relative to background concentrations at the upstream BCK 12.3. Concentrations all decreased downstream yet remained above background levels. Copper and lead were quite similar to background concentrations at upstream locations and were only slightly higher than background at downstream BCK 3.3. Cadmium, while generally not detected, was notably higher only at BCK 12.3 compared to other locations and to the background stream (see Table 7.2.7.3). However, cadmium concentrations at BCK 12.3 did not exceed any ambient water quality criteria. Uranium was the only metal that exceeded screening criteria. Uranium was detected at concentrations above the EPA MCL of 30 µg/L at BCK 12.3 and BCK 7.6. Concentrations were rather high at BCK 12.3 and reached 200 µg/L on a September 2022 sampling event which is nearly seven (7) times the MCL. Again, it should be noted that Bear Creek is not used for drinking water and that this MCL is used as a reference only. Mercury concentrations were close to background levels and below the 0.051 µg/L *TN Recreational Water Criterion for Organisms* (see Figure 7.2.7.1 below).

Mill Branch (MB)

Mill Branch is used as a reference stream for this project. MB did not exceed the screening criteria for any of the metals sampled, with most metals never being detected (see Table

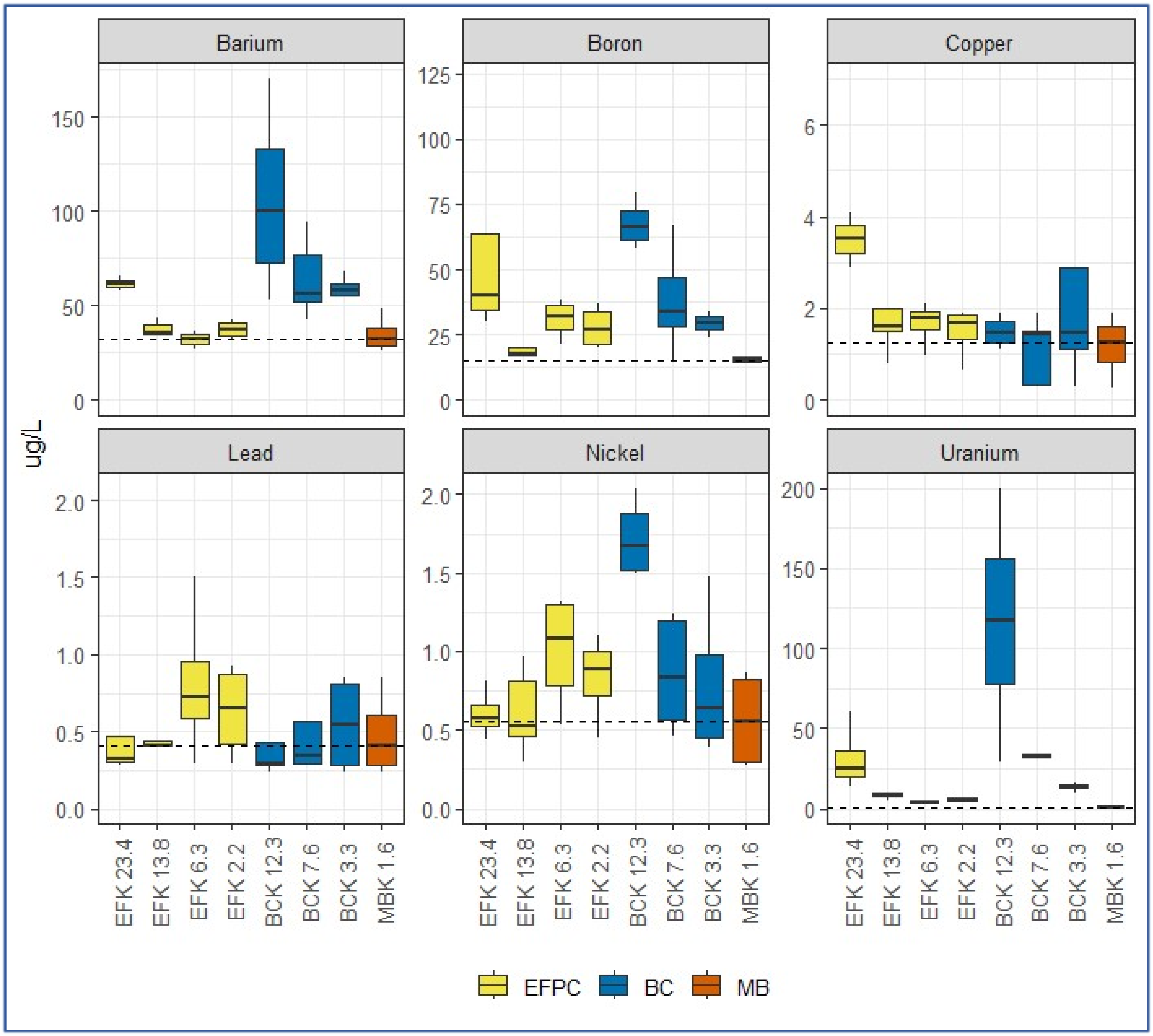
7.2.7.3). MB yielded lower metal concentrations than all other streams sampled (see Figure 7.2.7.1 below).

Clinch River (CR)

The Clinch River was co-sampled quarterly with UT-Battelle. Mercury samples were taken at each sampling location. Mercury results were all below screening criteria and were relatively low in concentrations. The most downstream location CRK 16.1 yielded the highest concentration among CR sites with a result of 0.00422 μg/L. (see Table 7.2.7.4).

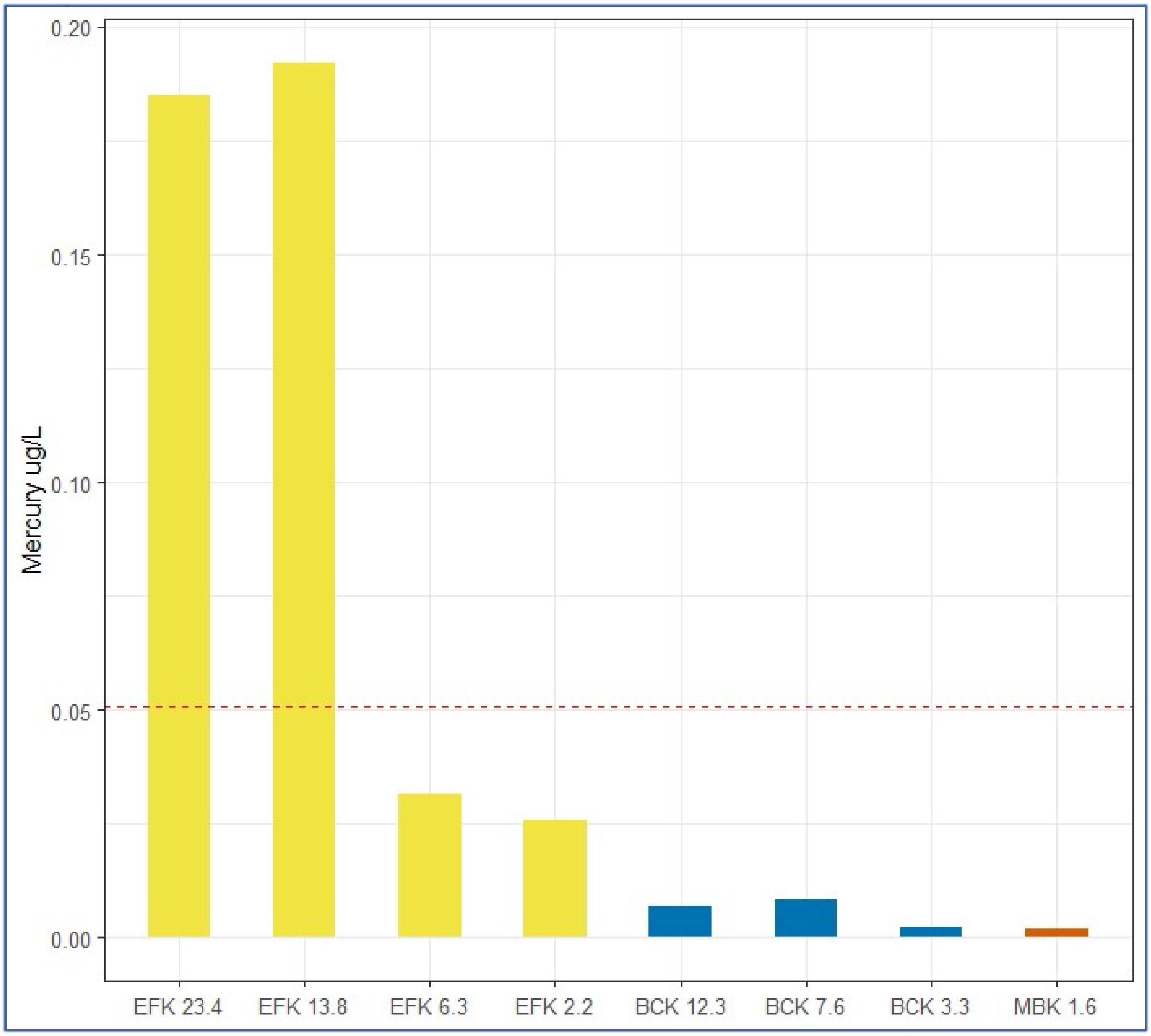
Table 7.2.7.4: Clinch River Sampling Results

Stream	DoR-OR Site	Alpha Activity (pCi/L)	Mercury (ug/L)	Strontium-89 (pCi/L)	Strontium-90 (pCi/L)	Date	Quarter
Clinch River	CRK 66	-0.02 ± 0.45	U	-	-	9/19/2022	1
Clinch River	CRK 58	0.29 ± 0.45	U	-	-	12/5/2022	2
Clinch River	CRK 32	1.06 ± 0.47	U	0.05 ± 1	0.56 ± 0.78	3/21/2023	3
Clinch River	CRK 16.1	-0.416 ± 0.806	0.00422	-	-	5/16/2023	4



Notes: Other infrequently detected metals in Table 6.2.7.3.
Boxplot: results from four sampling events
dashed line: median result for MB reference/background site
***BCK:** Bear Creek Kilometer*
***EFK:** E. Fork Poplar Creek Kilometer*
***MBK:** Mill Branch Kilometer*

Figure 7.2.7.1: Results for Routinely Detected Metals



Notes:
red dashed line: TN recreational water criterion for organisms (0.051 µg/L)

Figure 7.2.7.2: Mercury Results (March 2023)

Nutrients

Nutrients such as nitrate and phosphorus were sampled quarterly at the exit-pathway stream locations. Due to historical non-detects of phosphorus in BC, only nitrate/nitrite samples were taken for that stream. The CR was not sampled for nutrients. Results are shown in Table 7.2.7.5. In 2004, the TN Department of Water Resources (DWR) evaluated nutrient concentrations of streams in eco region 67f, which includes the valley and ridge eastern portion of Tennessee. DWR identified that the 90th percentile of all streams was 1.22 mg/L for nitrate/nitrite and 1.22 mg/L for phosphorus (TDEC, 2004). These 90^{th} percentile values were used to screen nutrients for each stream.

Table 7.2.7.5: Quarterly Nutrient Results

Stream	DoR-OR Site	Nitrate/Nitrite (mg/L)	Phosphorus (mg/L)	Date	Quarter
Bear Creek	BCK 12.3	13.30	-	9/20/2022	1
Bear Creek	BCK 12.3	7.90	-	11/30/2022	2
Bear Creek	BCK 12.3	4.28	-	3/7/2023	3
Bear Creek	BCK 12.3	14.70	-	6/29/2023	4
Bear Creek	BCK 7.6	4.16	-	9/20/2022	1
Bear Creek	BCK 7.6	2.45	-	11/30/2022	2
Bear Creek	BCK 7.6	1.13	-	3/7/2023	3
Bear Creek	BCK 7.6	1.15	-	3/7/2023	3
Bear Creek	BCK 7.6	1.41	-	6/29/2023	4
Bear Creek	BCK 3.3	0.47	-	9/20/2022	1
Bear Creek	BCK 3.3	1.47	-	11/30/2022	2
Bear Creek	BCK 3.3	0.29	-	3/7/2023	3
Bear Creek	BCK 3.3	0.45	-	6/29/2023	4
East Fork Poplar Creek	EFK 23.4	2.44	0.12	9/12/2022	1
East Fork Poplar Creek	EFK 23.4	2.15	0.11	12/8/2022	2
East Fork Poplar Creek	EFK 23.4	2.12	0.11	3/14/2023	3
East Fork Poplar Creek	EFK 23.4	2.27	0.15	5/18/2023	4
East Fork Poplar Creek	EFK 13.8	0.97	0.06	9/12/2022	1
East Fork Poplar Creek	EFK 13.8	1.02	0.05	12/8/2022	2
East Fork Poplar Creek	EFK 13.8	1.01	0.05	12/8/2022	2
East Fork Poplar Creek	EFK 13.8	Pending	Pending	3/14/2023	3
East Fork Poplar Creek	EFK 13.8	0.79	0.0504J	5/18/2023	4
East Fork Poplar Creek	EFK 6.3	1.99	0.43	9/12/2022	1
East Fork Poplar Creek	EFK 6.3	1.14	0.14	12/8/2022	2
East Fork Poplar Creek	EFK 6.3	2.43	0.24	3/14/2023	3
East Fork Poplar Creek	EFK 6.3	3.78	0.69	5/18/2023	4
East Fork Poplar Creek	EFK 2.2	1.67	0.34	9/12/2022	1
East Fork Poplar Creek	EFK 2.2	0.89	0.11	12/8/2022	2
East Fork Poplar Creek	EFK 2.2	1.36	0.13	3/14/2023	3
East Fork Poplar Creek	EFK 2.2	-	-	3/14/2023	3
East Fork Poplar Creek	EFK 2.2	2.70	0.46	5/18/2023	4
Mill Branch	MBK 1.6	U	0.05	9/20/2022	1
Mill Branch	MBK 1.6	U	0.05	11/30/2022	2
Mill Branch	MBK 1.6	0.09	0.02	3/14/2023	3
Mill Branch	MBK 1.6	0.05J	0.0411J	5/16/2023	4

Notes: Highlighted = nutrients > TN 90th percentile for all streams within Ecoregion 67f (i.e. Total phosphorus > 0.04 mg/L or > 1.22 mg/L nitrate/nitrite) (TDEC, 2004)

East Fork Poplar Creek (EFPC)

Nitrate and Nitrite

Nitrate and nitrite were sampled quarterly at each location of EFPC and were noticeably higher than the MB background stream. The highest concentrations occurred at EFK 23.3 and EFK 6.3 (see Figure 7.2.7.3). Nearly all sampling events in EFPC yielded results above, and in many cases much higher than, the 90th percentile of all streams in this region. EFK 13.8 was the only EFPC location below the 1.22 mg/L regional standard (see Table 7.2.7.5 above).

Phosphorus

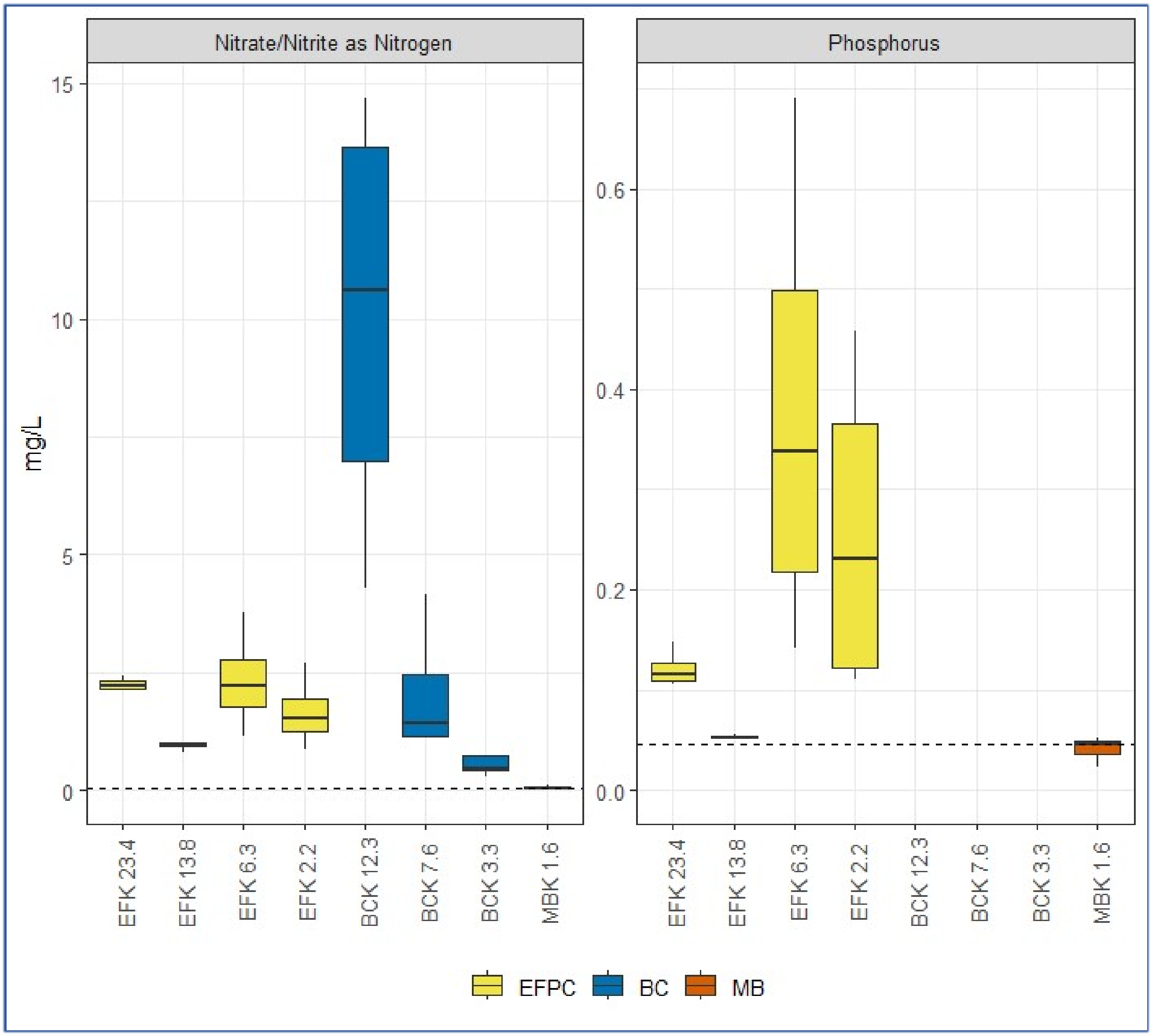
Phosphorus concentrations were taken quarterly at EFPC locations. Phosphorus concentrations were generally much higher than the background MB stream. The highest concentrations of phosphorus were observed at EFK 6.3, with the next highest value at EFK 2.2. All sampling locations had concentrations greater than the TN 90th percentile of all eco-region 67f streams (TDEC, 2004). These high values may be attributed to the creek flowing into more rural landscapes where farms may have more influence, or due to possibility of being downstream of the wastewater treatment system near EFK 13.8.

Bear Creek (BC)

Nitrate/nitrites were sampled quarterly at each BC site. Nitrate/nitrite concentrations were noticeably higher than the MB background stream. The highest concentrations were observed at BCK 12.3 (see Figure 7.2.7.3). Most sampling events yielded results higher than the 90th percentile of all streams within the eco-region 67f (i.e. >1.22 mg/L) (TDEC, 2004). Of note, concentrations at BCK 12.3 are often greater than ten (10) times the 90th percentile of 1.22 mg/L for eco region 67f. BCK 12.3 is greatly impaired for nitrates.

Mill Branch (MB)

Mill Branch is used as a reference stream for this project. MB did not yield any AWQC screening criteria exceedances for any of the nutrients sampled (see Table 7.2.7.3). MB yielded lower nutrient concentrations than all other streams sampled (see Figure 7.2.7.3 below).



Notes:
<u>boxplot</u>: results from four sampling events
<u>black dashed line</u>: median result at MB reference/background site

Figure 7.2.7.3: Nutrient Results

Radionuclides

Radionuclides were sampled once at all sites (i.e. EFPC, BC, CR) in spring 2023 (Table 7.2.7.6). BC had higher alpha activities, nearing the 15 pCi/L EPA drinking water MCL (i.e. conservative reference limit). Elevated alpha activity can be attributed to alpha emitting radionuclides such as uranium. The uranium concentration detected during the March 2023 sampling event was the lowest concentration detected at this location over the four (4) quarters. As such, it is anticipated that higher alpha activity would have been noted if sampled during the other three (3) quarters, which yielded up to nearly seven (7) times the uranium. Other locations were lower in alpha and beta activity. A few results are still pending for EFPC which limits a proper evaluation. Radionuclides measured at the CR locations were low in activity and are shown in Table 7.2.7.6.

Table 7.2.7.6: Spring Radionuclide Results

Stream	DoR-OR Site	Alpha Activity (pCi/L)	Beta Activity (pCi/L)	Date	Quarter
Bear Creek	BCK 12.3	12.41 ± 0.99	26.1 ± 1.9	3/7/2023	3
Bear Creek	BCK 7.6	13.9 ± 1.1	12.4 ± 1.7	3/7/2023	3
Bear Creek	BCK 7.6	13.5 ± 1	11.9 ± 1.7	3/7/2023	3
Bear Creek	BCK 3.3	4.6 ± 0.65	1.5 ± 1.6	3/7/2023	3
East Fork Poplar Creek	EFK 23.4	Pending	Pending	3/14/2023	3
East Fork Poplar Creek	EFK 23.4	Pending	Pending	3/14/2023	3
East Fork Poplar Creek	EFK 13.8	Pending	Pending	3/14/2023	3
East Fork Poplar Creek	EFK 6.3	1.85 ± 0.56	3.1 ± 1.6	3/14/2023	3
East Fork Poplar Creek	EFK 2.2	3.33 ± 0.61	2.29 ± 1.6	3/14/2023	3

PCBs

PCBs were sampled twice during the spring season of 2023 at BC, EFPC, and Clear Creek (CC) using the EPA 1668 method. This method allows for comparison to the TN AWQC criterion of 0. 64 nanograms per liter (ng/L) and allows for resolution of the PCBs at the congener level, a more sensitive analysis, rather than at the more common Aroclor level. The second round of sampling was taken to isolate and confirm locations of high PCB concentrations identified from the first round of sampling. PCB results are shown in Table 7.2.7.7.

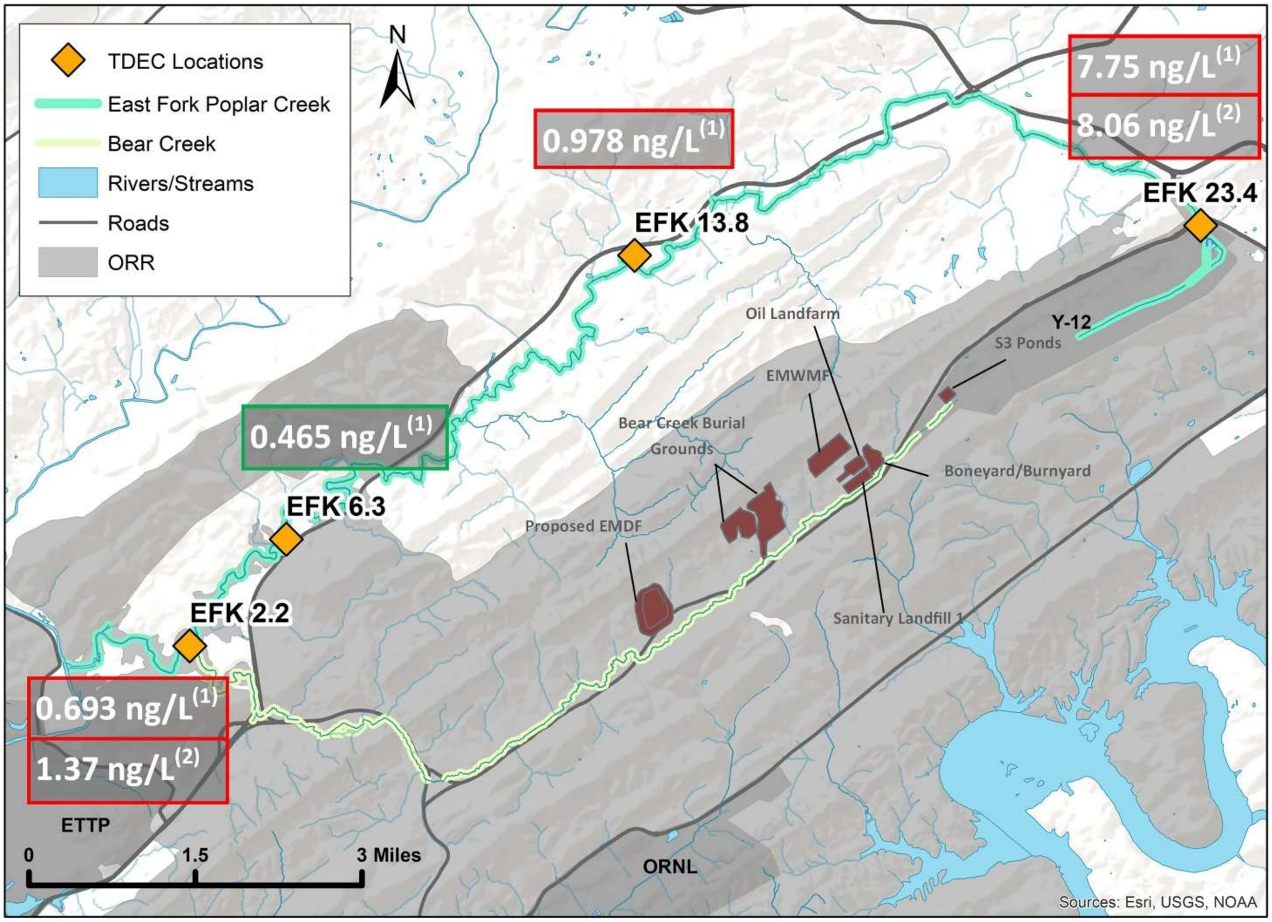
Table 7.2.7.7: Spring PCB results

Stream	DoR-OR Site	Total PCBs* (ng/L)	Date	Quarter
Bear Creek	BCK 12.3	0.57	3/7/2023	3
Bear Creek	BCK 12.3	1.10	6/29/2023	4
Bear Creek	BCK 10.6	0.98	6/29/2023	4
Bear Creek	BCK 9.2	9.90	6/29/2023	4
Bear Creek	BCK 9.2	8.30	6/29/2023	4
Bear Creek	BCK 7.6	3.33	3/7/2023	3
Bear Creek	BCK 7.6	3.49	3/7/2023	3
Bear Creek	BCK 7.6	7.70	6/29/2023	4
Bear Creek	BCK 3.3	1.69	3/7/2023	3
Bear Creek	BCK 3.3	5.60	6/29/2023	4
East Fork Poplar Creek	EFK 23.4	7.75	3/14/2023	3
East Fork Poplar Creek	EFK 23.4	8.06	5/18/2023	3
East Fork Poplar Creek	EFK 13.8	0.98	3/14/2023	3
East Fork Poplar Creek	EFK 6.3	0.47	3/14/2023	3
East Fork Poplar Creek	EFK 2.2	0.69	3/14/2023	3
East Fork Poplar Creek	EFK 2.2	1.37	5/18/2023	4
Clear Creek	CCK 1.6	U	6/9/2023	4

Notes:
**Total PCBs = summation of congeners that were detected; note that some congeners were identified as detected but were estimated by the lab using a J-qualifier.*
highlighted cells = exceed the TN recreational water criterion for organisms (0.64 ng/L)

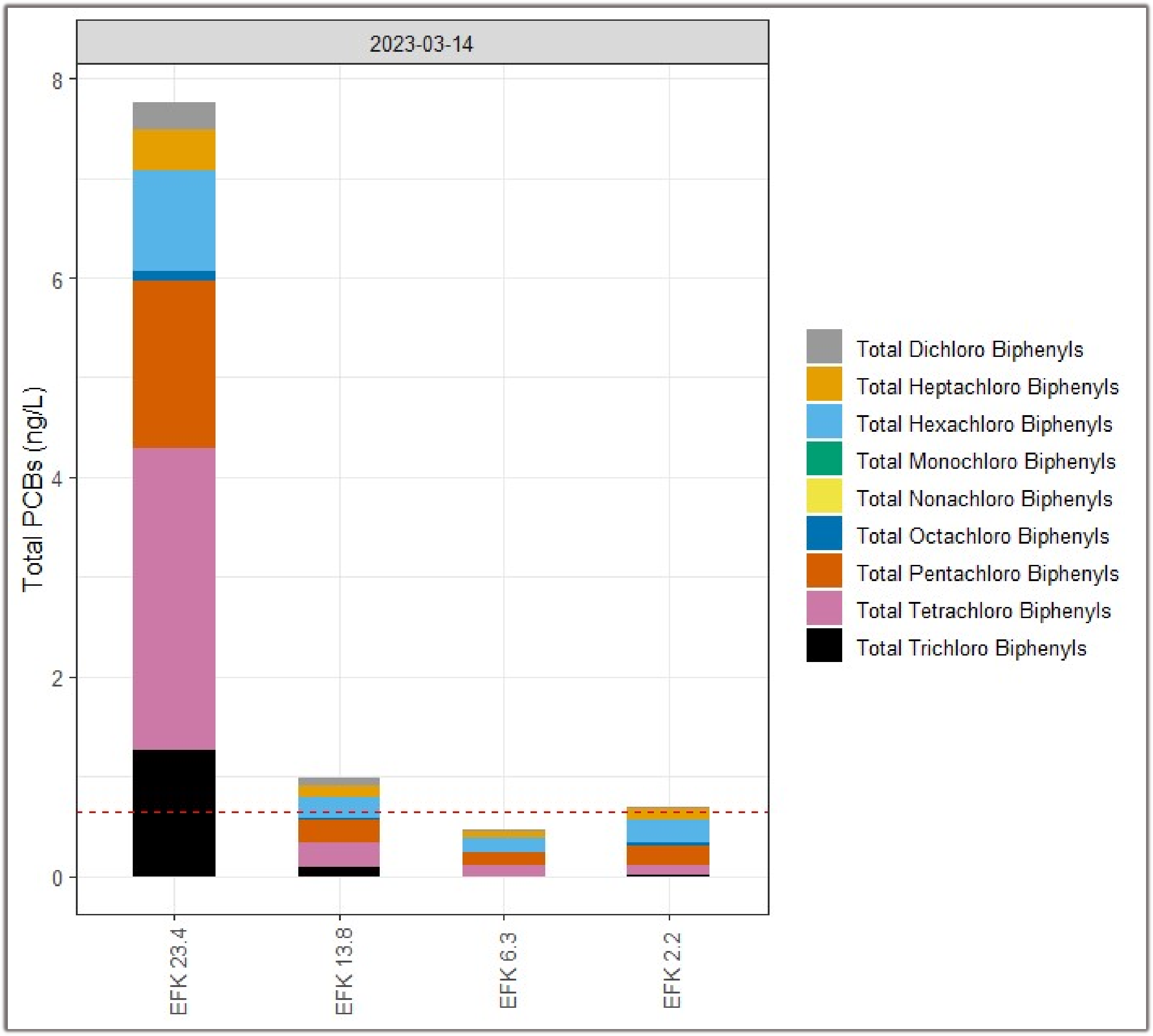
East Fork Poplar Creek (EFPC)

EFPC had higher concentrations of total PCBs at EFK 23.3, close to the Y-12 plant area (Table 7.2.7.7). This location was well above the *TN Recreation-Organisms Criterion* of 0.64 ng/L, with two (2) samples around 8.0 ng/L. PCB concentrations decreased substantially in EFPC downstream from EFK 24.3. However, EFK 13.8 was still elevated with a concentration of 0.98 ng/L. EFK 6.3 was below the screening criterion. At the confluence with BC, EFK 2.2 concentrations again rose slightly over the screening criterion (Figure 7.2.7.4). The makeup of the total PCBs is similar for all EFPC sampling sites, making it difficult to identify any obvious point sources (Figure 7.2.7.5).



Notes: EFPC – PCB samples from (1) March 2023 or (2) May 2023
<u>red boxes</u> = exceed TN recreational water criterion for organisms (>0.64 ng/L)
<u>green boxes</u> = below criterion (< 0.64 ng/L)

Figure 7.2.7.4: PCB results for EFPC: Sample (1) March 2023, (2) May2023

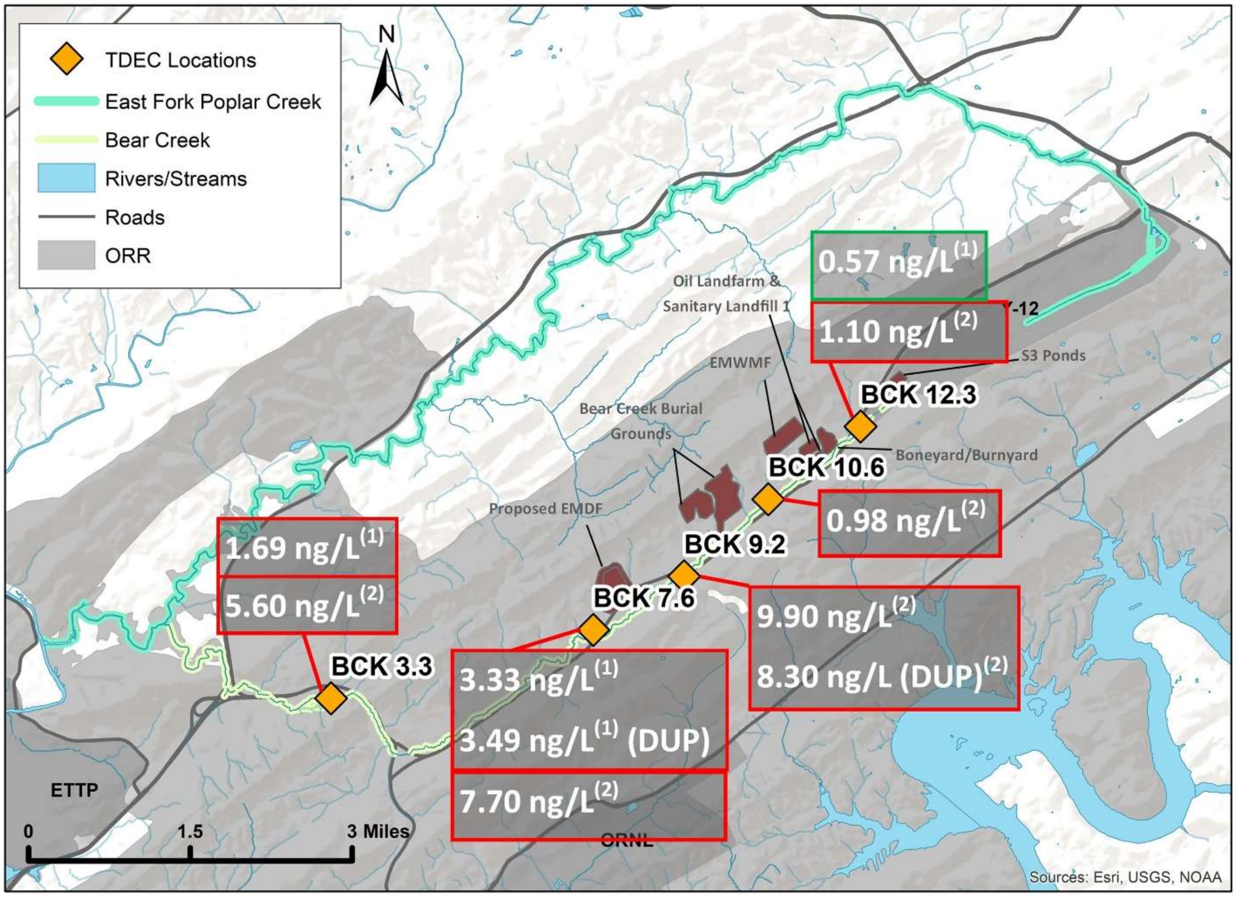


Notes: EFPC – PCB samples from 3/14/2023
red dashed line = TN recreational water criterion for organisms (0.64 ng/L)

Figure 7.2.7.5: EFPC Total PCBs Colored by PCB Mixtures

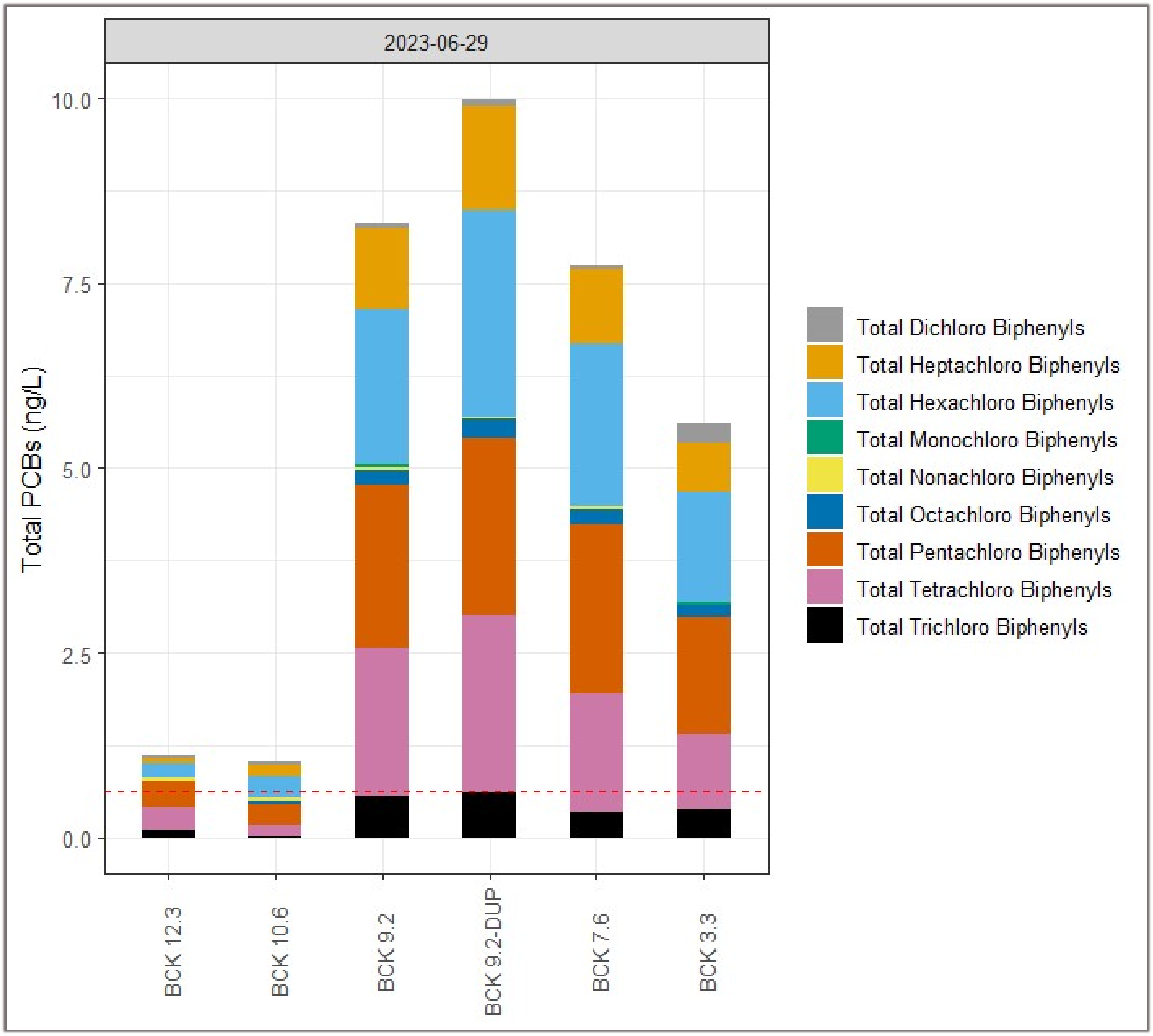
Bear Creek (BC)

BC total PCB concentrations were relatively low at upstream BCK 12.3 and BCK 10.6 locations, yet these two (2) sites still exceeded the *TN Recreational Organism Criterion* (Table 7.2.7.7). At BCK 9.2 and at downstream locations, PCB levels dramatically increased to concentrations nearing 10 ng/L (Figure 7.2.7.6). The PCB signature is quite consistent downstream of BCK 9.2, indicating a potential point source near the BCBG (Figure 7.2.7.7).



Notes: BCK – PCB samples from (1) March 2023 or (2) June 2023
*<u>red boxes</u> = **exceed** TN recreational water criterion for organisms (>0.64 ng/L)*
<u>green boxes</u> = below criterion (< 0.64 ng/L)

Figure 7.2.7.6: PCB Results for BC



Notes: BCK – PCB samples from 6/29/2023
red dashed line = TN recreational water criterion for organisms (0.64 ng/L)

Figure 7.2.7.7: Total PCBs Colored by PCB Mixtures for BC

Clear Creek (CC)

Clear Creek was used as a background stream for PCBs. CC is a clean stream that flows into the Clinch River roughly 25 miles northeast of the ORR. CC was sampled in May 2023 and had no detections of PCBs.

Contaminant Flux (Loading)

Discharge was measured at each location at the time of sampling (Table 7.2.7.1). Flux, or contaminant loading, was calculated for mercury and uranium by multiplying the discharge (cubic feet per second [cfs]) by the contaminant concentration. In EFPC, mercury was shown to have higher concentrations at EFK 23.3 and lower concentrations farther from Y-12. When looking at loading, mercury can actually have higher rates downstream. One example of this can be seen in mercury concentrations taken in March 2023. During typical flows (i.e. non-storm event), mercury flux can be approximately 2 to 11 grams per day (g/day). Higher mercury concentrations at EFK 23.3, which is closer to the likely Y-12 source, doesn't necessarily translate to the highest loading of mercury (see Table 7.2.7.8).

Table 7.2.7.8: EFPC Mercury Flux (3/14/2023)

Stream	DoR-OR Site	Discharge (cfs)	Hg (ug/L)	Hg Flux (g/day)	Date	Quarter
East Fork Poplar Creek	EFK 23.4	4.5	0.185	2.0	3/14/2023	3
East Fork Poplar Creek	EFK 13.8	23.4	0.192	11.0	3/14/2023	3
East Fork Poplar Creek	EFK 6.3	48.3	0.032	3.7	3/14/2023	3
East Fork Poplar Creek	EFK 2.2	69.1	0.026	4.4	3/14/2023	3

Notes: *flux was extrapolated to g/day and is only an approximation based on an instantaneous discharge measurement taken on 3/14/2023*
Units: *grams per day =* ***g/day;*** *discharge =* ***cfs*** *(cubic feet per second)*

Storm events and prolonged rain can also have a significant impact on contaminant loading. EFPC experienced a week of heavy rain preceding a December 2022 sampling event. This caused for elevated flow and loading of contaminants (see Table 7.2.7.9). During these prolonged rain events, uranium loading was shown to be approximately 1 to 2 kilogramsof uranium per day.

Table 7.2.7.9: EFPC Uranium Flux (12/08/2022)

Stream	DoR-OR Site	Discharge (cfs)	U (ug/L)	U Flux (g/day)	Date	Quarter
East Fork Poplar Creek	EFK 23.4	9.0	60.0	1321.2	12/8/2022	2
East Fork Poplar Creek	EFK 13.8	49.7	9.9	1201.4	12/8/2022	2
East Fork Poplar Creek	EFK 6.3	104.2	4.0	1007.0	12/8/2022	2
East Fork Poplar Creek	EFK 2.2	168.0	4.8	1977.0	12/8/2022	2

Notes: *flux was extrapolated to g/day and is only an approximation based on an instantaneous discharge measurement taken on 12/08/2022*
Units: *grams per day =* ***g/day;*** *discharge =* ***cfs*** *(cubic feet per second)*

Bear Creek has similar capacity to load a significant amount of uranium. A sampling event was conducted a day following a heavy rain event and showed elevated uranium flux in BC with loading from 225 g/day to 841 g/day. Despite having higher concentrations at BCK 12.3, flux tends to be higher downstream where discharge is higher (see Table 7.2.7.10)

Table 7.2.7.10: BC Uranium Flux (11/30/2022)

Stream	DoR-OR Site	Discharge (cfs)	U (ug/L)	U Flux (g/day)	Date	Quarter
Bear Creek	BCK 12.3	1.0	94.3	224.6	11/30/2022	2
Bear Creek	BCK 7.6	9.0	19.2	422.6	11/30/2022	2
Bear Creek	BCK 3.3	21.8	15.8	841.4	11/30/2022	2

Notes: *flux was extrapolated to g/day and is only an approximation based on an instantaneous discharge measurement taken on 11/30/2022*
Units: *grams per day =* ***g/day;*** *discharge =* ***cfs*** *(cubic feet per second)*

7.2.8 Conclusions

East Fork Poplar Creek (EFPC)

EFPC has been shown to receive high concentrations of both mercury and uranium, both of which are likely sourced from the Y-12 NSC. Mercury concentration exceedances were seen above the *TN Recreational Organism Criterion* for mercury. Uranium levels were elevated above the *EPA Drinking Water Criterion* for uranium (used only as a reference).

Concentrations of these metals tend to be higher near upstream locations closest to Y-12 and decrease downstream. As discharge increases downstream, the loading of metals can actually increase resulting in a range of 2 to 11 g/day of mercury under normal flows and up to 1 to 2 kg/day of uranium during storm events. With years of loading mercury downstream, higher flows are likely able to liberate mercury and increase loading even at locations far distant from the probable Y-12 source.

In addition to metals, EFPC was also shown to be elevated for nutrients. Phosphorus and nitrate/nitrite were above the 90th percentile for streams within ecoregion 67f, which is the valley and ridge region of eastern Tennessee. Loading of both nitrate and phosphorus can lead to the production of harmful algae, which in turn can reduce the stream's dissolved oxygen, and can be harmful for aquatic organisms.

Lastly, EFPC was shown to have elevated levels of PCBs with concentrations exceeding the AWQC screening criteria. EFK 23.3 yielded total PCB concentrations at over 8 ng/L. As the reach of EFPC from the headwaters to EFK 23.3 is within the Y-12 NSC boundary, Y-12 NSC is the most likely source for PCB contamination. PCBs were shown to generally decrease downstream of Y-12. PCB concentrations do slightly elevate again at EFK 2.2. This may be due to this site's proximity to the BC and EFPC confluence. These slightly elevated concentrations at EFK 2.2 are likely associated with PCB loading from BC. The PCB concentrations in EFPC were starkly different than the Clear Creek reference stream, which did not have any detections of PCBs.

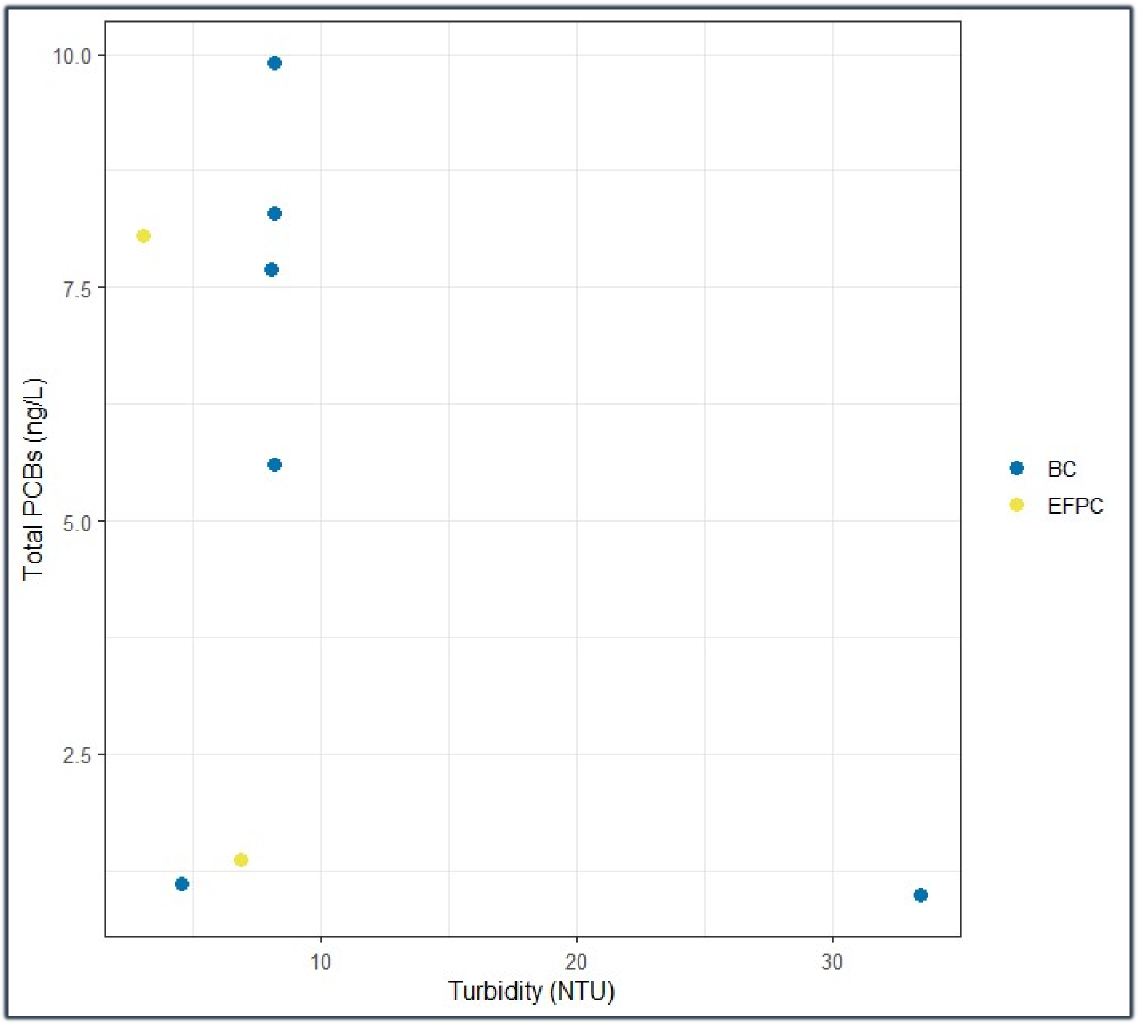
Bear Creek (BC)

Sampling efforts have shown that Bear Creek tends to have elevated concentrations of uranium, especially in its upper reaches. These high concentrations of uranium likely originate from the now capped S3 ponds near the headwaters of BC. Roughly 248 million liters of uranium contaminated nitric acid wastes and other liquid wastes were disposed in the S3 ponds between 1951 and 1984, which were able to leach directly to groundwater and surface water (Moss et al. 1999). Even through many years of leaching, uranium concentrations within BC are still high, reaching 200 μg/L at times. These concentrations are well over the EPA MCL of 30 μg/L (used as reference only). While BC is not used directly for drinking water, this increased uranium has the ability to cause negative impacts on aquatic life due to the toxic nature of the metal. Loading of uranium during fall months was found to produce nearly 300 to 900 g/day increasing downstream. BC, being an exit pathway stream, has the potential to load uranium off of the ORR to downstream receptors.

In addition to uranium, Bear Creek had elevated nitrate/nitrite concentrations at BCK 12.3, with concentrations of nearly 14 mg/L. These high nitrate values are well above the 90th percentile for eco region 67f, which is 1.22 mg/L. Similar to EFPC, the elevated nutrient concentrations can promote enhanced aquatic plant growth and algae growth which can lower dissolved oxygen content and ultimately harm aquatic life.

PCB concentrations were elevated in BC, well above the TN limit of 0.64 ng/L. PCBs are carcinogenic, man-made compounds, that are difficult to breakdown. These compounds tend to bioaccumulate, which can cause not only harm to those species affected, but to those higher trophic level species that may eat PCB contaminated organisms. PCB sampling locations were chosen within Bear Creek Valley to try and isolate potential PCB sources. An obvious spike in PCB concentrations was identified at BCK 9.2. Since the site BCK 10.6 which is downstream of EMWMF had lower concentrations, EMWMF is not the likely source. BCBG is the most likely source causing this spike in PCBs. All downstream locations of the BCBG were elevated for PCBs.

While not originally part of the study, turbidity was also measured during the second round of PCB events to develop a better understanding of the association of turbidity and PCB concentrations. As shown in figure 7.2.7.3, the first round of turbidity was not strongly associated with PCB concentrations. With a better understanding of the source of BC PCBs, further sampling solely focused on this area may provide more information about the correlation, if any, of turbidity and PCB concentrations. In all, PCB concentrations in BC, much like EFPC, were starkly different than the Clear Creek reference stream, which did not have any detections of PCBs. The elevated PCB concentrations downstream of BCK 9.2 may have a negative impact on fish and aquatic life. PCBs loaded to this part of the stream may have the ability to bio-accumulate and bio-magnify within the food web.



Notes: Turbidity measurements taken on the last round of PCB sampling.

Figure 7.2.8.1: EFPC and BC Total PCBs by Turbidity

7.2.9 Recommendations

PCBs have been rarely studied at the ORR utilizing PCB congener method EPA 1668. This project has identified elevated PCB concentrations along EFPC and BC utilizing this method. It is recommended that PCBs be investigated further in upper EFPC and along the BC near known contaminant sources. Additionally, it is recommended that further investigations occur to better understand the PCB source near the BCBG. Furthermore, the inclusion of turbidity measurements when sampling is recommended to better understand any associations with PCBs. This may help to understand the effects of PCB migration during heavy rainfall and storm events. Monitoring for ORR COCs should continue, to help observe any changes to surface water quality that may result from new or ongoing remediation efforts.

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7.3 White Oak Creek Radionuclides monitoring

7.3.1 Background

White Oak Creek (WOC) was initially monitored under the *Ambient Surface Water Sampling Project*, but since 2020, DoR-OR has focused on this stream under a separate project. WOC became a focal ORR exit-pathway stream due to specific concerns regarding the elevated radionuclide strontium-90 (Sr-90). Sr-90 was first detected at a CR sampling station (CRK 33.5) in 2017. CRK 33.5 is located at the WOC-CR confluence, immediately downstream of the WOC Embayment sediment retention structure (Figure 7.3.2.1). Because this radionuclide entered the Clinch River via WOC, DoR-OR has prioritized monitoring WOC surface water quality. These data results also supplement DOE's ongoing investigations of Sr-90 migration and CR monitoring.

The ORR exit-pathway streams, such as WOC, and the CR have historically, and are currently, subject to contaminant releases from activities at Y-12, ORNL, and ETTP. Monitoring WOC provides a better understanding of its contributions to surface water contamination and may provide insights into helping protect human health and the environment.

7.3.2 Problem Statements

Approximately 1.1 million people live in the counties surrounding the ORR (DOE, 2021). Migration of contaminants from WOC to CR has the potential to impact human health and the environment. Legacy contaminant migration along with continued industrial releases from the ORR into WOC can also be detrimental to the environment and to human health. Identified concerns for WOC include, but are not limited to, the following:

1) Release of low-level radioactive liquid wastes to the CR via WOC since 1943 (Pickering, 1970).

2) Release of approximately 665 curies of cesium-137 to the CR from WOC between 1954 and 1959 (DOE, 1992).
3) Continued release of Sr-90 from the Process Waste Treatment Complex. This water treatment system does not entirely remove Sr-90 from the waste stream and ultimately discharges treated wastewater containing elevated levels of Sr-90 into WOC through Outfall X12 (Figure 7.3.2.1) (DOE, 2022a).
4) Historic and ongoing discharges of Sr-90 and Cs-137 into WOC. Known sources include, but are not limited to, impacted floodplain soils from the former Surface Impoundment Operable Unit area (Figure 7.3.2.1) and baseflow groundwater seepage into WOC (DOE, 2022b).

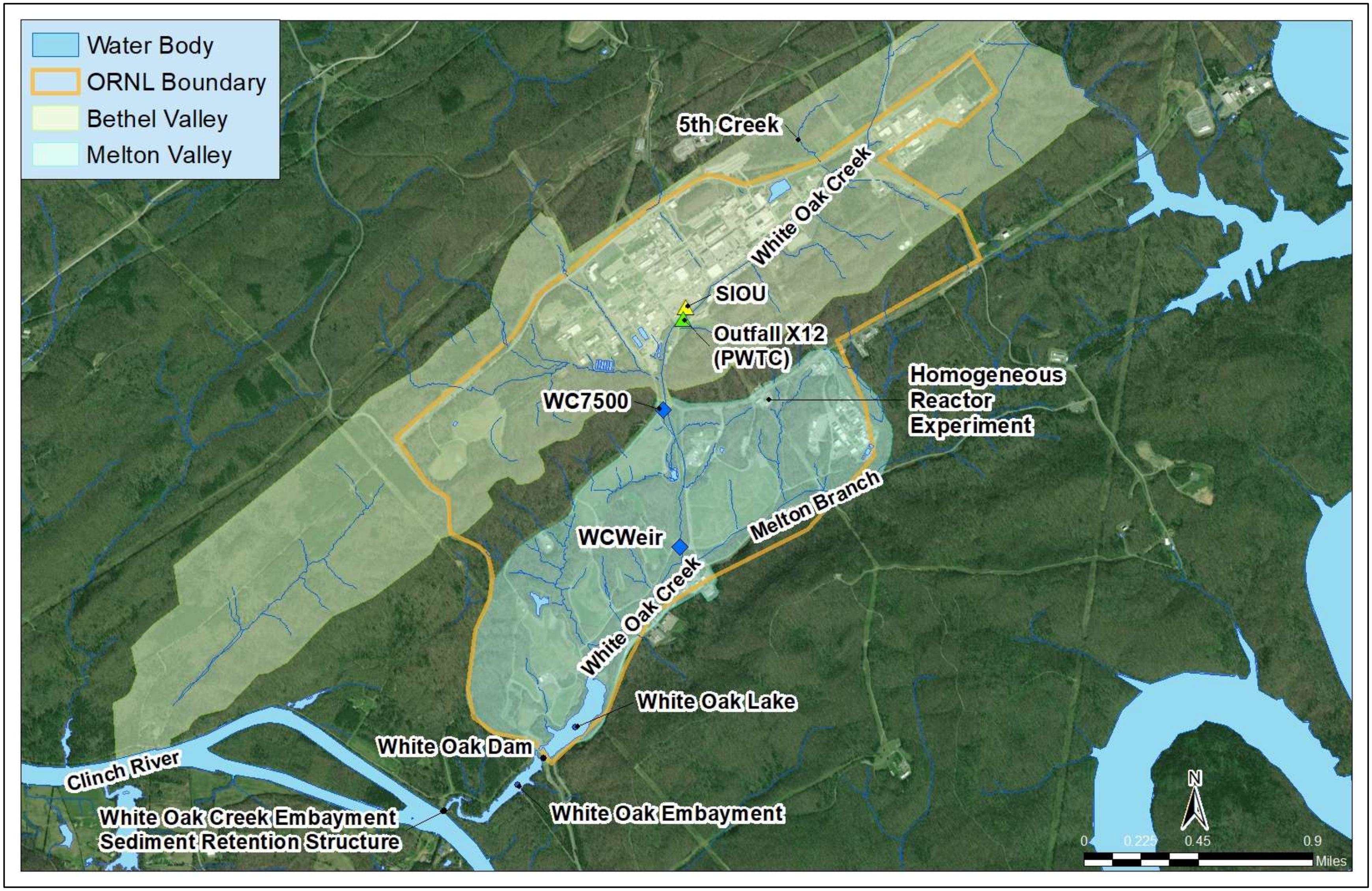


Figure 7.3.2.1: White Oak Creek (WOC) Map and Pertinent Landmarks

7.3.3 Goals

The goal of the *White Oak Creek Radionuclides Monitoring Project* is to evaluate the impacts of DOE ORR contamination to WOC, its tributaries, and the CR at the WOC confluence.

7.3.4 Scope

The scope of this project was to collect surface water samples quarterly at seven (7) monitoring locations. Four (4) monitoring locations (WCK 6.8, WCK 3.9, WCK 3.3, WCK 2.3) were within WOC, one (1) monitoring location (CRK 33.5) was at the confluence of WOC and the CR, and the remaining two (2) monitoring locations (HRT-3, MEK 0.3) were in tributaries of WOC (Figure 7.3.4.1).

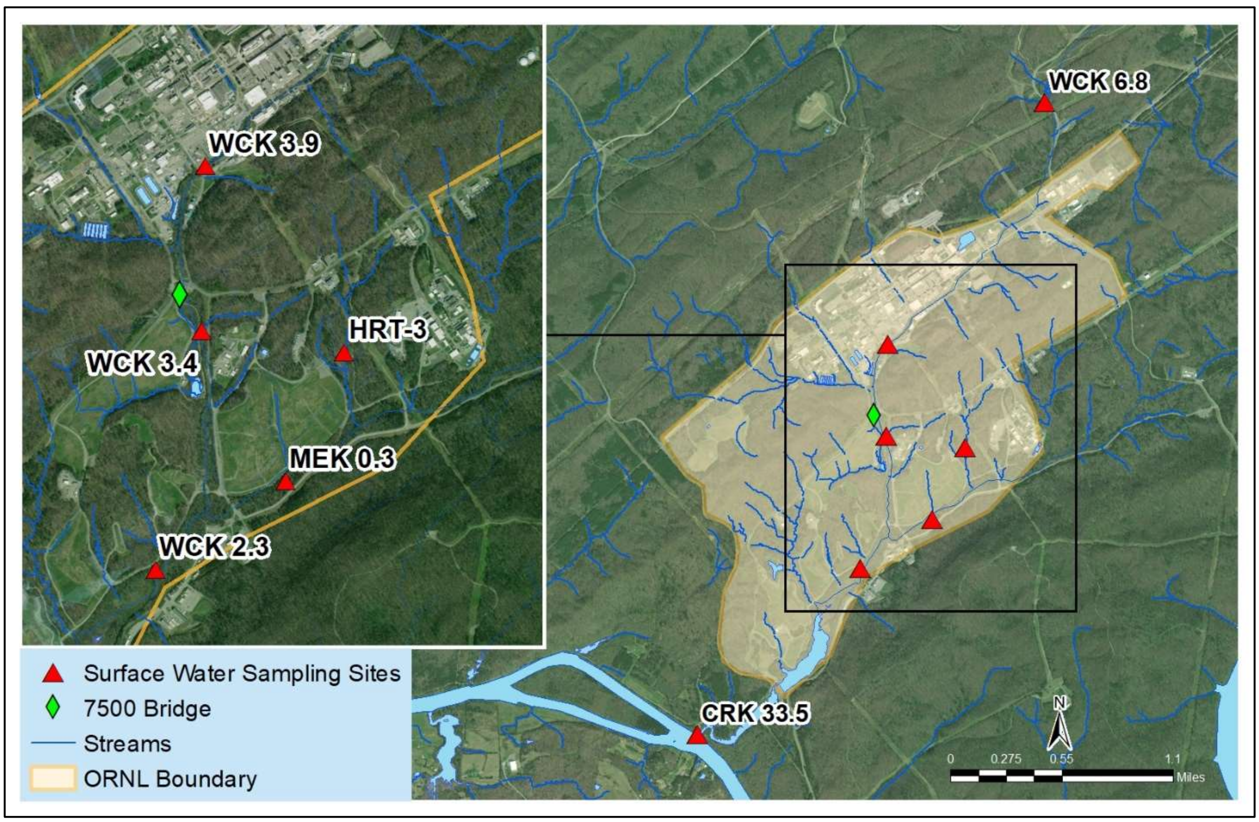


Figure 7.3.4.1: White Oak Creek (WOC) Surface Water Sampling Locations

7.3.5 Methods, Materials, Metrics

Sample Collection

Surface water samples were collected quarterly at seven (7) monitoring sites (WCK 6.8, WCK 3.9, WCK 3.3, WCK 2.3, CRK 33.5, HRT-3, MEK 0.3) illustrated on Figure 7.3.4.1. These water samples were submitted for laboratory analysis of Sr-90, isotopic uranium, isotopic plutonium, and gamma isotopes. Sampling protocols followed the TDEC DWR guidelines outlined in the *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water* (TDEC, 2022).

Field Water Quality Parameter Measurements

At each site, water quality parameters were measured in the field at the time of sampling using a calibrated multi-parameter water quality meter. The following water quality parameters were measured: pH, temperature, and specific conductivity.

7.3.6 Deviations from the Plan

No deviations occurred during this monitoring period.

7.3.7 Results and Analysis

Streamflow

Although streamflow was not directly measured in the field, project staff downloaded available streamflow records for WOC from the Oak Ridge Environmental Information System (OREIS) to evaluate the hydrologic regime of WOC. DoR-OR identified two (2) DOE maintained weirs (Figure 7.3.7.1), WC7500 and WCWeir, that had daily streamflow measurements. For the period between 2009 and 2021, the average annual flow was 8.6 cubic feet per second (cfs) at WC7500 and 16.3 cfs at WCWeir. Figure 7.3.7.1 presents daily weir streamflow data for the period from June 1, 2019, to September 30, 2022, which corresponds to surface water sampling efforts. As evident in this figure below, streamflow was highly variable, and likely as a result from precipitation events. Additionally, the streamflow data presented in Figure 7.3.7.1 suggests WOC is a gaining stream, evident by the increase in measured streamflow moving downstream from the weir at the 7500 Bridge (WC7500) to the WCWeir.

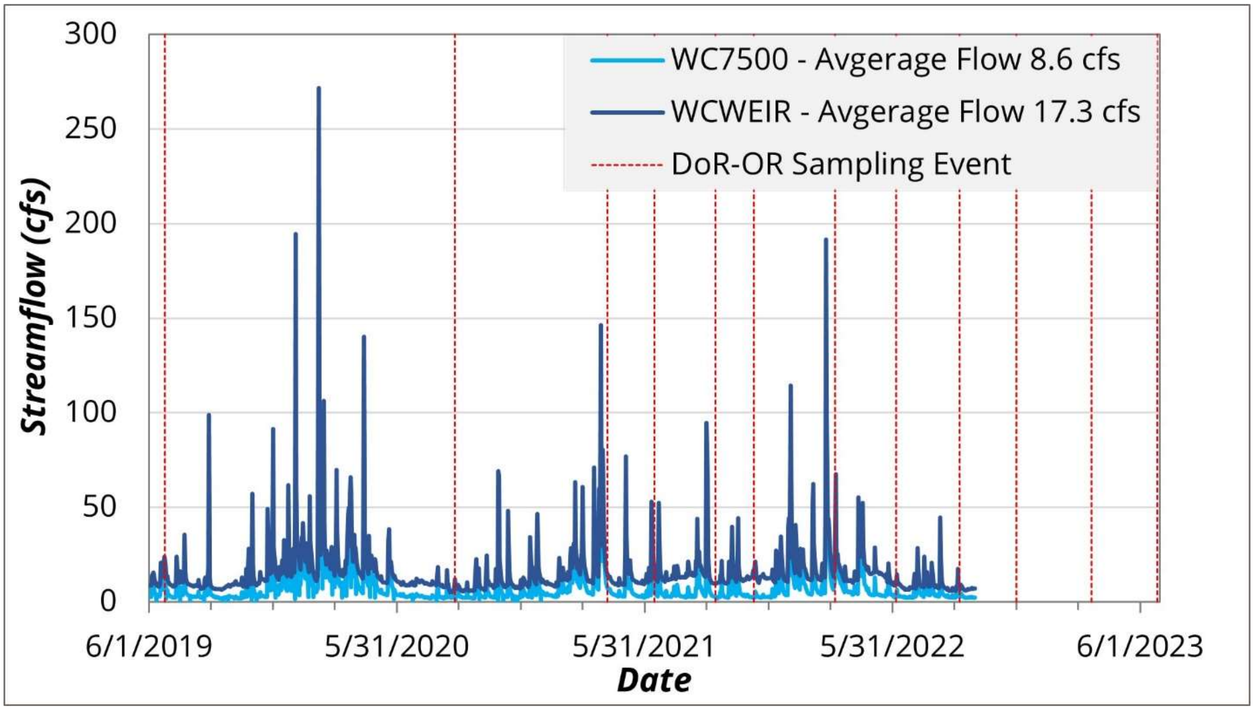
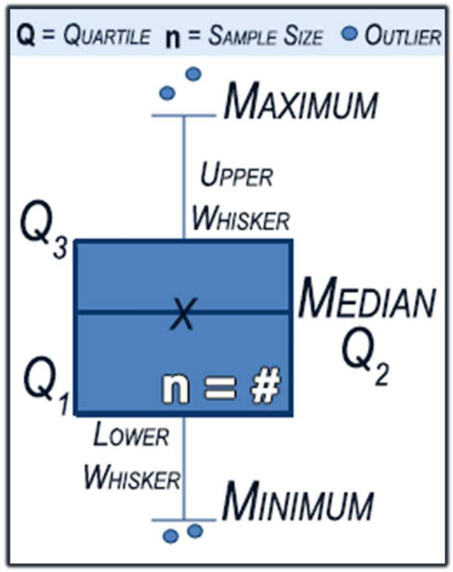


Figure 7.3.7.1: Streamflow from WC7500 weir and WCWeir

Increases in streamflow moving downstream could be a result of various contributions such as smaller tributaries/drainages, outfalls, and baseflow groundwater seepage. The DoR-OR surface water sampling locations did not coincide with these two weirs; therefore, contaminant fluxes were not calculated.

Field Water Quality Parameter

Water quality parameters, including pH, temperature, and specific conductivity, were measured in the field during sample collection. A summary of the measured water quality parameters during the FY23 sampling events is provided below and the variability of these field parameters across the five (5) surface water sampling locations are visually displayed using box plots. A box plot is generated using five (5) numbers which include the minimum, 25th percentile (Q_1), median, 75th percentile quartile (Q_3), and maximum. During generation of these plots, outliers are visually illustrated but are not included when calculating the five (5) numbers.



Generic Box Plot

As shown above in the generic box plot, the top and bottom horizontal lines (at the end of the upper and lower whiskers) are the maximum and minimum values. The bottom portion of the box is the lower quartile (Q_1) and the top of the box is the upper quartile (Q_3). The horizontal line across the box is the median (Q_2) and the "X" marker displays the mean value. The dots represent outlier values. The sampling station labels include the sample size (n) at each sampling location for the box plot.

pH

The pH is a measure of the hydrogen ion concentration and has a measurement unit of standard units (s.u.). Values measured over the four quarters ranged from 6.34 (WCK 6.8) to 8.69 (MEK 0.3). As illustrated in Figure 7.3.7.2, the mean pH values across the seven (7) sample locations are very similar.

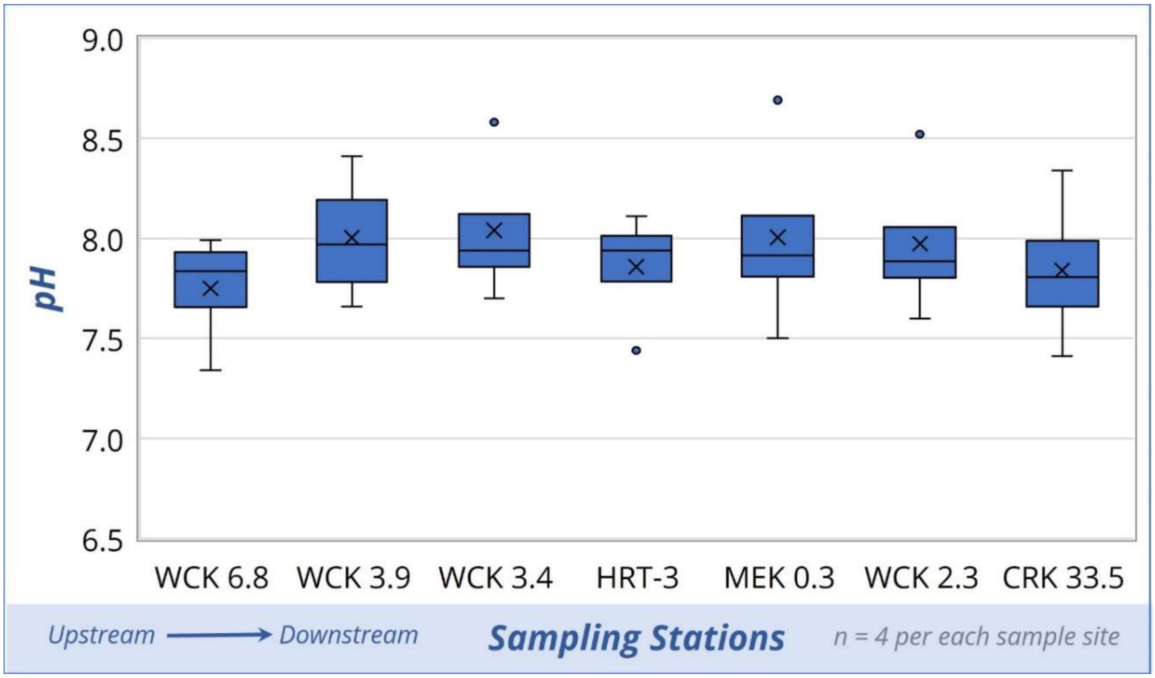


Figure 7.3.7.2: pH Box Plot Per Sampling Station

Temperature

Surface water temperatures ranged from 6.5 degrees Celsius (ºC) at HRT-3 to 21.3 ºC at CRK 33.5. In general, as shown on Figure 7.3.7.3, the mean temperature among the seven (7) sample stations is similar.

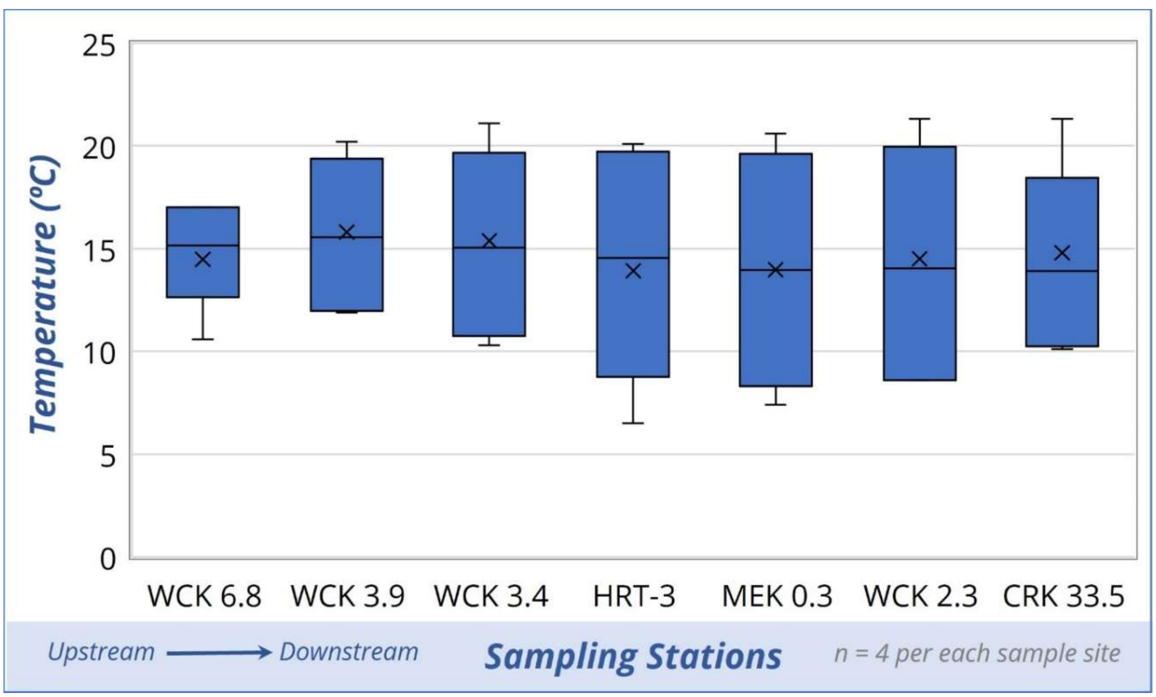


Figure 7.3.7.3: Temperature Box Plot Per Sampling Station

Specific Conductivity

Specific conductivity is an indirect measurement of the concentration of dissolved ions in solution. Higher specific conductivity values can indicate more dissolved minerals or salts in the water. Specific conductivity values ranged from 185.5 microsiemens per centimeter (μS/cm) at HRT-3 to 506.2 μS/cm at WCK 3.3. As illustrated in Figure 7.3.7.4, the mean specific conductivity values at WCK 3.9, WCK 3.3, and WCK 2.3 were similar and on average were approximately 400 μS/cm. In contrast, the mean specific conductivity values at HRT-3 (277 μS/cm), MEK 0.3 (308 μS/cm), and CRK 33.5 (301 μS/cm) were much lower, with the most upstream location WCK-6.8 (256 μS/cm) having the lowest value. The highest specific conductivity values were noted within the known impacted stream section of WOC. This stream section also receives permitted wastewater discharges from ORNL processes via several outfalls. These elevated specific conductivity values could also be indicative that surface water from these three (3) sample locations contained more dissolved ions compared to the other sample locations.

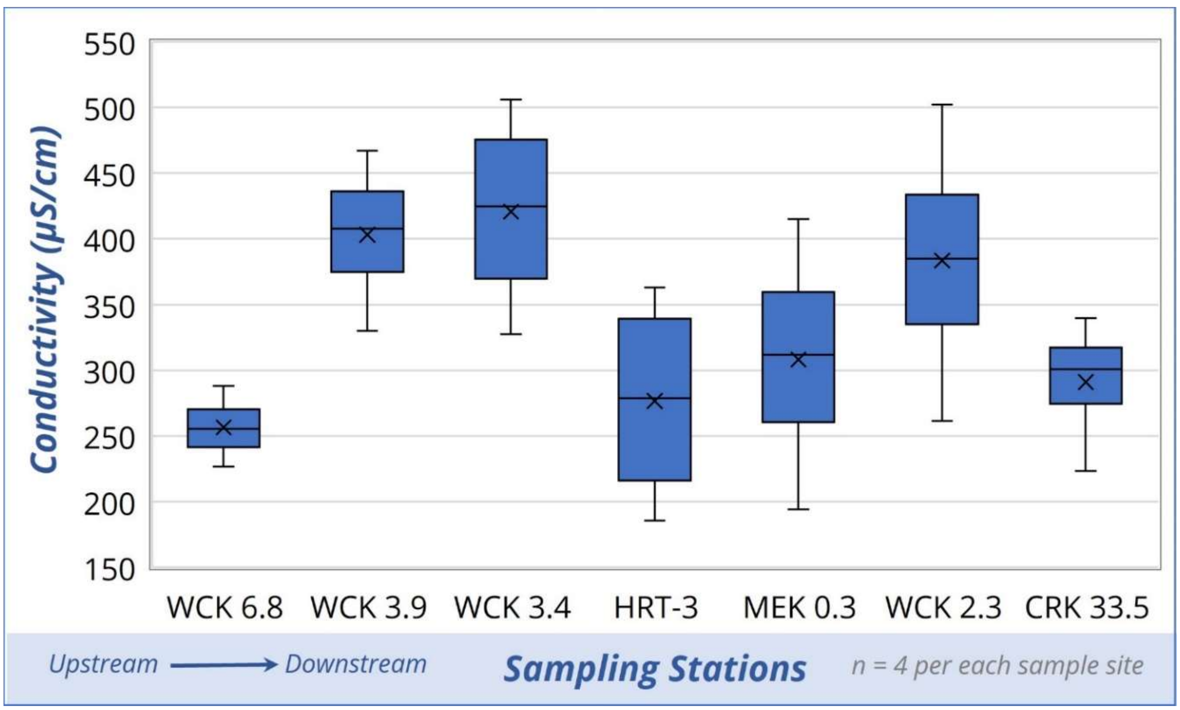


Figure 7.3.7.4: Specific Conductivity Box Plot Per Sampling Station

Surface Water Analytical Results

This section presents the analytical results of the quarterly surface water sampling events. Analytical testing of surface water revealed that select gamma isotopes (bismuth-214, cesium-137, cobalt-60, europium-154, lead-214, and potassium-40) were infrequently observed, low-levels of isotopic uranium were noted at all sampling stations but the combined activities of uranium-234 and uranium-238 were well below the standard of 30 pCi/L, and elevated strontium-90 activities were observed at WCK 3.9, WCK 3.3, WCK 2.3, HRT-3, MEK 0.3, and CRK 33.5. These analytical data are presented in Table 7.3.7.1 and the Sr-90 data are illustrated in various figures throughout this section. Additionally, a trend analysis was conducted on the entire strontium-90 data set which includes data collected in previous fiscal years. Although WOC is not a designated drinking water source, the EPA derived drinking water standards for beta and photon emitters and the MCL for uranium at mill tailings sites are referenced here solely for comparison purposes.

Table 7.3.7.1: Quarterly Surface Water Analytical Results Summary

Sample Location	Sample Date	Bismuth-214	Cesium-137	Cobalt-60	Europium-154	Lead-214	Plutonium-238	Plutonium-239/240	Potassium-40	Strontium-89	Strontium-90	Uranium-234	Uranium-235	Uranium-238
Derived Standard[1,2]		NE	200	100	60	NE	NE	NE	NE	20	8	30	NE	30
Activities		pCi/L												
WCK 6.8	9/8/2022	15.9±6.2	-	-	-	10.6±6	0.042±0.042	0.008±0.025	-	2.1±1.2	-0.46±0.79	0.132±0.064	0.034±0.038	0.057±0.041
	12/1/2022	18.2±8.3	-	-	-	-	0.02±0.035	0.03±0.039	-	-0.04±1.2	0.55±0.7	0.163±0.067	0.024±0.032	0.07±0.043
	3/21/2023	-	-	-	-	-	-0.006±0.022	0.006±0.018	-	0.5±1.3	-0.15±0.88	0.139±0.063	0.034±0.035	0.07±0.044
	6/26/2023	-	-1.38±3.29	-0.64±2.99	0.58±11.92	-	-0.01±0.04	0.01±0.04	-	-	0.27±0.28	0.24±0.18	0.07±0.1	0.17±0.14
WCK 3.9	9/8/2022	28.7±8.5	-	-	-	15±6.5	0.006±0.02	0.013±0.029	-	1±1.7	**27±19**	0.48±0.12	0.021±0.028	0.181±0.07
	12/1/2022	-	-	-	-	-	0.004±0.3	-0.014±0.31	-	-2.2±1.6	**40±15**	2.09±0.32	0.065±0.052	0.36±0.11
	3/21/2023	-	-	-	-	-	0.03±0.041	0.023±0.035	49±26	-0.8±1.7	**70±28**	3.71±0.48	0.091±0.056	0.277±0.088
	6/26/2023	-	2.66±3.17	-1±3.1	6.38±11	-	-0.01±0.03	0.03±0.05	-	-	2.59±0.56	0.58±0.26	-0.01±0.07	0.13±0.13
WCK 3.4	9/8/2022	-	-	-	-	-	0.016±0.04	0.034±0.043	-	0.1±1.3	**33±14**	2.1±0.31	0.022±0.028	0.193±0.074
	12/1/2022	-	-	-	-	-	0.012±0.034	-0.006±0.022	-	-0.5±1.7	**41±19**	2.53±0.35	0.091±0.054	0.37±0.1
	3/21/2023	-	-	-	-	-	-0.009±0.021	0.015±0.026	-	-2±1.7	**58±22**	2.72±0.38	0.095±0.056	0.336±0.099
	6/26/2023	-	2.33±3.31	4.15±3.36	-3.1±11.3	-	0.04±0.05	-0.02±0.03	-	-	2.16±0.5	1.8±0.48	0.1±0.13	0.29±0.18
HRT-3	9/8/2022	9.1±6.3	-	-	-	-	0.023±0.03	0.003±0.028	-	-6±2.8	**138±53**	0.156±0.069	0.029±0.036	0.106±0.057
	12/1/2022	10.3±7.4	-	-	-	-	0.027±0.042	0±0.028	40±24	-4.7±2.7	**104±43**	0.199±0.084	0.073±0.057	0.083±0.054
	3/21/2023	-	-	-	-	10.3±5.9	0.017±0.029	0.014±0.024	-	14±27	**69±61**	0.075±0.046	0.014±0.03	0.075±0.046
	6/26/2023	-	0.41±3.63	2.38±3.61	0.42±10.65	-	0.04±0.06	0±0.05	-	-	**11.59±1.72**	0.25±0.17	0.09±0.12	0.11±0.12
MEK 0.3	9/8/2022	27.7±8	-	-	-	18.2±7.3	0.02±0.03	0.008±0.025	-	-0.4±1.3	**20.9±8.6**	0.162±0.075	0.019±0.032	0.069±0.049
	12/1/2022	13.6±5.7	-	-	-	-	-0.018±0.026	0.01±0.029	-	-2.2±1.8	**30±13**	0.178±0.076	0.018±0.033	0.126±0.064
	3/21/2023	23.6±7.8	-	-	-	-	0.088±0.058	0.009±0.026	-	1±12	**13±14**	0.34±0.1	0.035±0.038	0.103±0.055
	6/26/2023	-	1.7±5.43	-0.38±5.12	4.12±10.55	-	0.01±0.04	0±0.05	-	-	2.86±0.55	0.16±0.14	0.03±0.06	0.07±0.09
WCK 2.3	9/8/2022	11.1±7	-	-	-	-	0.018±0.031	0.028±0.036	-	3.1±2.3	**45±36**	1.9±0.29	0.039±0.038	0.182±0.07
	12/1/2022	-	-	-	-	-	-0.027±0.03	0.019±0.05	-	-1.6±2	**67±30**	1.78±0.31	0.067±0.058	0.34±0.12
	3/21/2023	-	-	-	-	-	0.048±0.044	0.006±0.019	-	-4.7±2.2	**89±34**	2.36±0.35	0.038±0.039	0.257±0.089
	6/26/2023	-	0.58±3.68	1.77±4.06	0.59±7.51	-	0.06±0.06	0.03±0.05	-	-	4.9±0.85	0.98±0.35	0.03±0.07	0.25±0.17
CRK 33.5	9/8/2022	-	-	-	-	-	0.007±0.022	0.036±0.035	-	-0.7±1.3	**25±10**	0.7±0.14	0.034±0.033	0.198±0.071
	12/1/2022	-	-	-	-	-	0.004±0.058	0.12±0.082	49.6±24.7	-1.4±1.6	**35±16**	1.28±0.22	0.05±0.043	0.254±0.086
	3/21/2023	-	-	-	-	-	0.016±0.027	0.117±0.069	52±26	13±20	**37±34**	1.61±0.27	0.062±0.049	0.147±0.072
	6/26/2023	-	13.87±6.59	0.6±5.36	4.99±10.76	-	0.03±0.05	0.08±0.08	-	-	1.56±0.44	0.5±0.24	0.06±0.1	0.14±0.14

Notes:

***Bolded** values exceed the derived drinking water standard.*

CSU = 1-sigma combined standard uncertainty reported as ± with analytical result

1 = Derived MCL of beta and photon emitters in drinking water taken from NBS Handbook 69.

2 = EPA isotopic uranium standards taken for uranium mill tailing sites (uranium-234 and -238 combined).

NE = No drinking water standard established.

- = not detected

pCi/L = picocurie per liter

As illustrated in Figure 7.3.7.5, elevated activities of Sr-90 were observed in surface water samples collected from six (6) of the seven (7) sampling stations. During the first three quarters, all the results for the six (6) sampling stations exceeded the derived drinking water standard of 8 pCi/L. However, during the fourth quarter, only HRT-3 had a Sr-90 activity that exceeded this standard. All fourth quarter Sr-90 activities were significantly lower at all sample locations. A significant rain event had occurred prior to the Q4 sampling event and higher flows were noted at all sample locations. These lower activities were likely a result of increased surface runoff within these streams due to the heavy precipitation event.

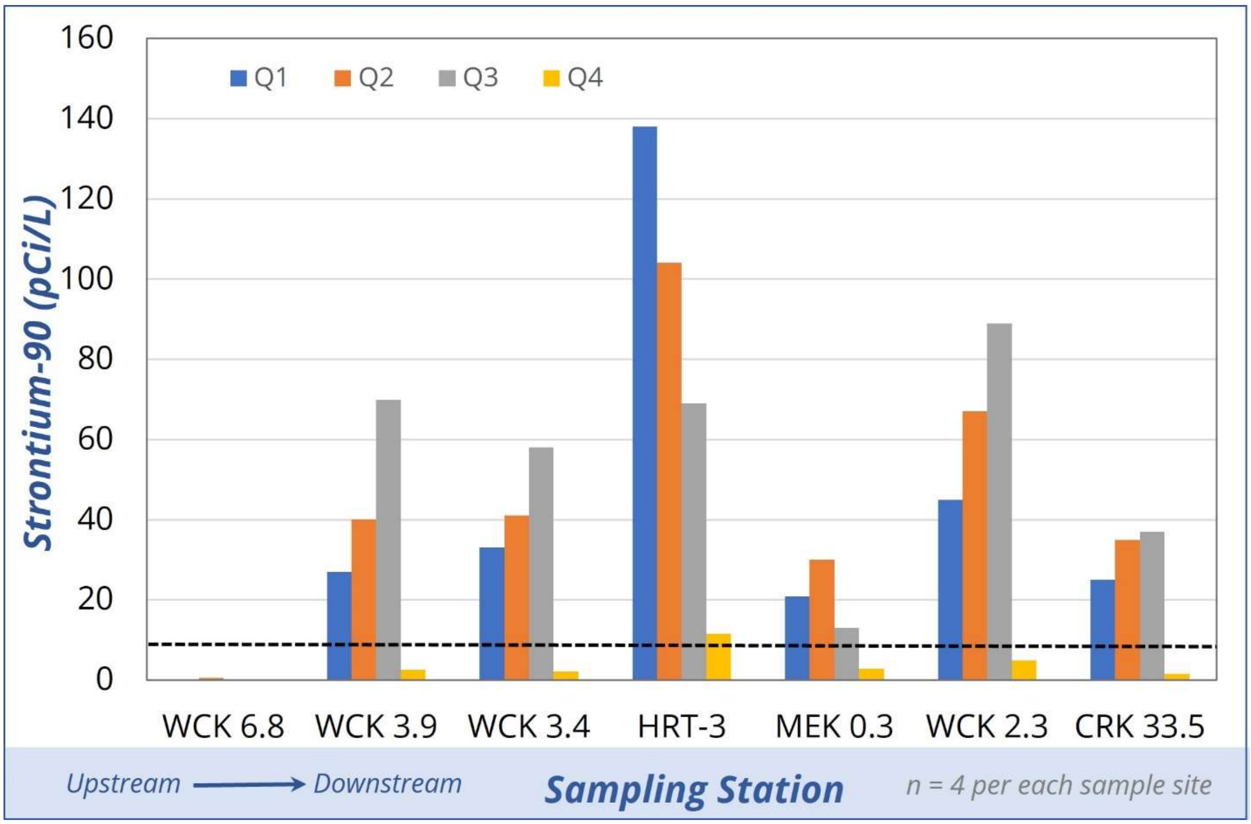


Figure 7.3.7.5: Quarterly Strontium-90 Activity Per Sampling Station

The mean Sr-90 activities were much higher at WCK 3.9, WCK 3.3, HRT-3, MEK 0.3, WCK 2.3, and CRK 33.5, compared to WCK 6.8 (Table 7.3.7.2). As evident in Figure 7.3.7.5 and Table 7.3.7.2, Sr-90 values generally increase as you move downstream, and it appears that HRT-3 is a big contributor of Sr-90 in WOC. Comparatively, the Sr-90 activities measured at WCK 6.8 are much lower because this sample site is located upstream of the main ORNL campus.

Table 7.3.7.2 Mean Strontium-90 Results

Sample Location	Mean Strontium-90
Derived Standard	8
Activity	pCi/L
WCK 6.8	0.5
WCK 3.9	34.9
WCK 3.4	38.8
HRT-3	80.6
MEK 0.3	16.7
WCK 2.3	58.5
CRK 33.5	34.7

A box plot illustrating Sr-90 data collected between June 2019 and June 2023 is provided as Figure 7.3.7.6. The trend between sampling stations over this four (4) year period was consistent with respect to the quarterly data collected during FY23.

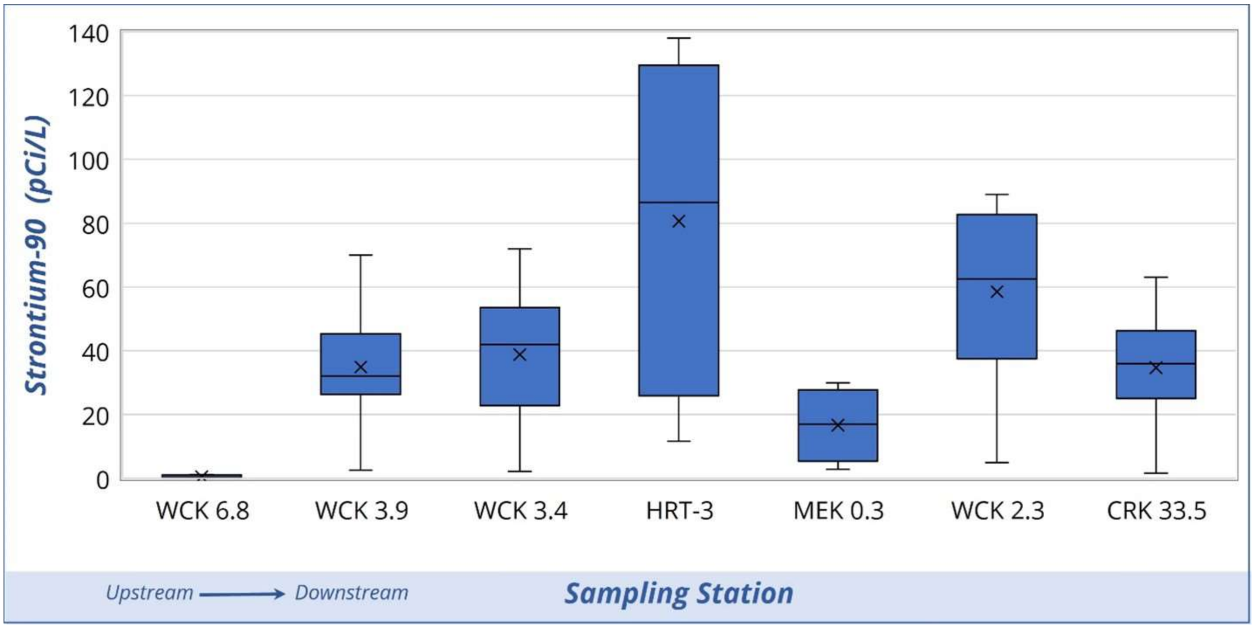


Figure 7.3.7.6 Strontium-90 Box Plot Per Sampling Station (June 2019-June 2023)

Trend Analysis

A time series illustrating a trend of Sr-90 activities from June 2019 through June 2023 at each of the seven (7) sampling stations is provided as Figure 7.3.7.7. A trend analysis was performed to determine if Sr-90 activities are increasing or decreasing over time.

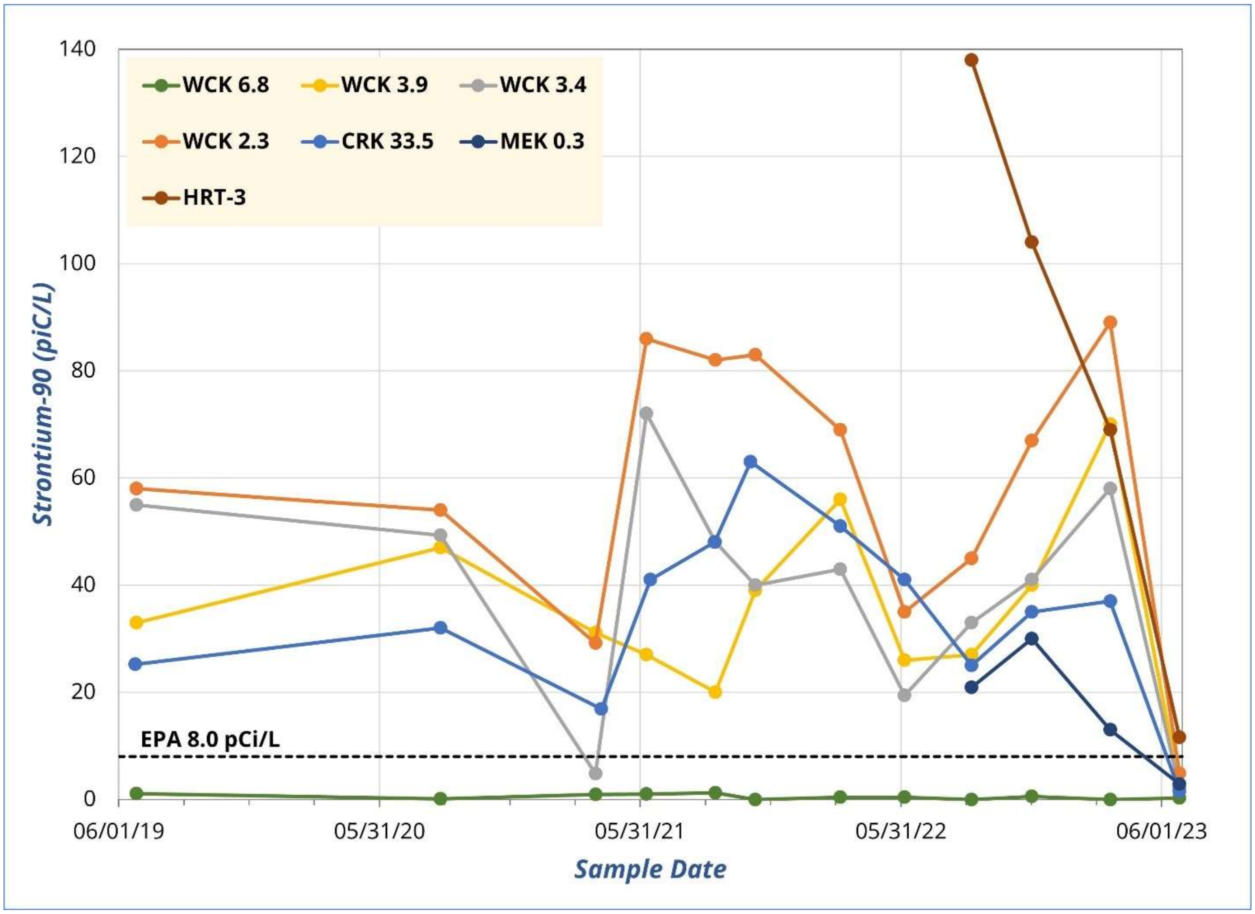


Figure 7.3.7.7. Strontium-90 Time Series

The *Mann-Kendall Trend Test* was performed using EPA's ProUCL software (version 6.2.0). The negative Sr-90 results for WCK 6.8 were set to zero for statistical analysis. Results for six (6) out of seven (7) stations indicated no trend. The one exception, site HRT-3, showed evidence indicating a statistically significant (p=0.05) *decreasing trend*. The HRT-3 data set only covers one year of sampling, as such, further sampling is needed to confirm this trend.

7.3.8 Conclusion

In conclusion, analytical testing of surface water (WCK 6.8, WCK 3.9, WCK 3.3, HRT-3, MEK 0.3, WCK 2.3, CRK 33.5) revealed the following:

1) Surface water sampling at all locations showed that levels of gamma isotopes and uranium isotopes are below EPA drinking water standards.
2) Elevated Sr-90 activities at levels greater than the EPA derived drinking water standard of 8 pCi/L were observed at six (6) stations: WCK 3.9, WCK 3.3, HRT-3, MEK 0.3, WCK 2.3, and CRK 33.5.
3) The absence of elevated levels of radiological contaminants in surface water at

WCK 6.8 was most likely due to this sample location being located upstream from the ORNL campus.

4) Sr-90 activities increased from upstream (WCK 6.8) to downstream (WCK 2.3) locations along WOC and HRT-3 appears to be a big contributor of Sr-90 to WOC.
5) Except for HRT-3, there was insufficient evidence to identify a significant trend in Sr-90 activities. Additional samples need to be collected at HRT-3 to confirm a decreasing Sr-90 trend.

7.3.9 Recommendations

DoR-OR recommends the continuation of monitoring for radiological COCs along WOC, its tributaries and its confluence into the CR. These data results supplement DOE's ongoing investigations of Sr-90 migration and CR monitoring and is important because Sr-90 is entering the CR via WOC. Additionally, due to the upcoming D&D of Building 3042 in Bethel Valley and the planned cessation and removal of its groundwater sump pump, DoR-OR recommends adding a sample location along Fifth Creek (Figure 7.3.8.1). Turning off the sump pump could result in contaminated groundwater impacting surface water in Fifth Creek.

7.3.10 References

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7.4 Wetland at the Filled Coal Ash Pond (FCAP)

7.4.1 Background

The wetland at the FCAP site located near Chestnut Ridge is used as a passive treatment system to treat leachate from the coal ash retention pond through a subsurface drainage system. This wetland, located at the base of the dam that was constructed to create the pond, discharges to Upper McCoy Branch and Rogers Quarry.

The *2016 Five Year Review* identified reduced arsenic uptake through the wetland system due to channelization around the edges of the wetland and invasive plants displacing the cattails which are utilized for the uptake of arsenic and other metals. Work was concluded in 2019 to restore the flow in the wetland and the cattail community.

7.4.2 Problems Statements

Stream flow continues to carry contaminants downstream from the FCAP site. These contaminants can be hazardous to aquatic life, especially fish species. Arsenic is the primary wetland COC and cattails within the wetland are prone to uptake this carcinogen. Currently, no water sampling is being conducted near the weir/outfall of the wetland treatment system, nor is there any vegetation or sediment sampling occurring within the wetland. Without sampling, there is no way of knowing whether additional COC removal via wetland/vegetation maintenance would benefit the downstream communities.

7.4.3 Goals

The goal of this project is to monitor levels of COCs within the wetland vegetation, sediments, and water at the FCAP site to determine if there are seasonal changes in COCs. This project will help to determine if seasonal uptake of contaminants increases during the growing season, then decreases and releases COCs with die off in the colder months. The decomposing plant materials, or lack of active uptake during seasonal vegetation die off, could be increasing the COC loading within the wetland and ultimately to downstream locations.

This project will help to determine if seasonal cattail die offs have been increasing overall COC loading within the wetland, and ultimately to downstream locations.

7.4.4 Scope

This project includes collecting vegetation (cattails), sediment, and surface water samples within the FCAP wetland to sample for coal combustion residual COCs. Sampling will occur twice per year: once during the growing season and once after the vegetation has died off. These sample results will be analyzed to examine wetland uptake efficiency.

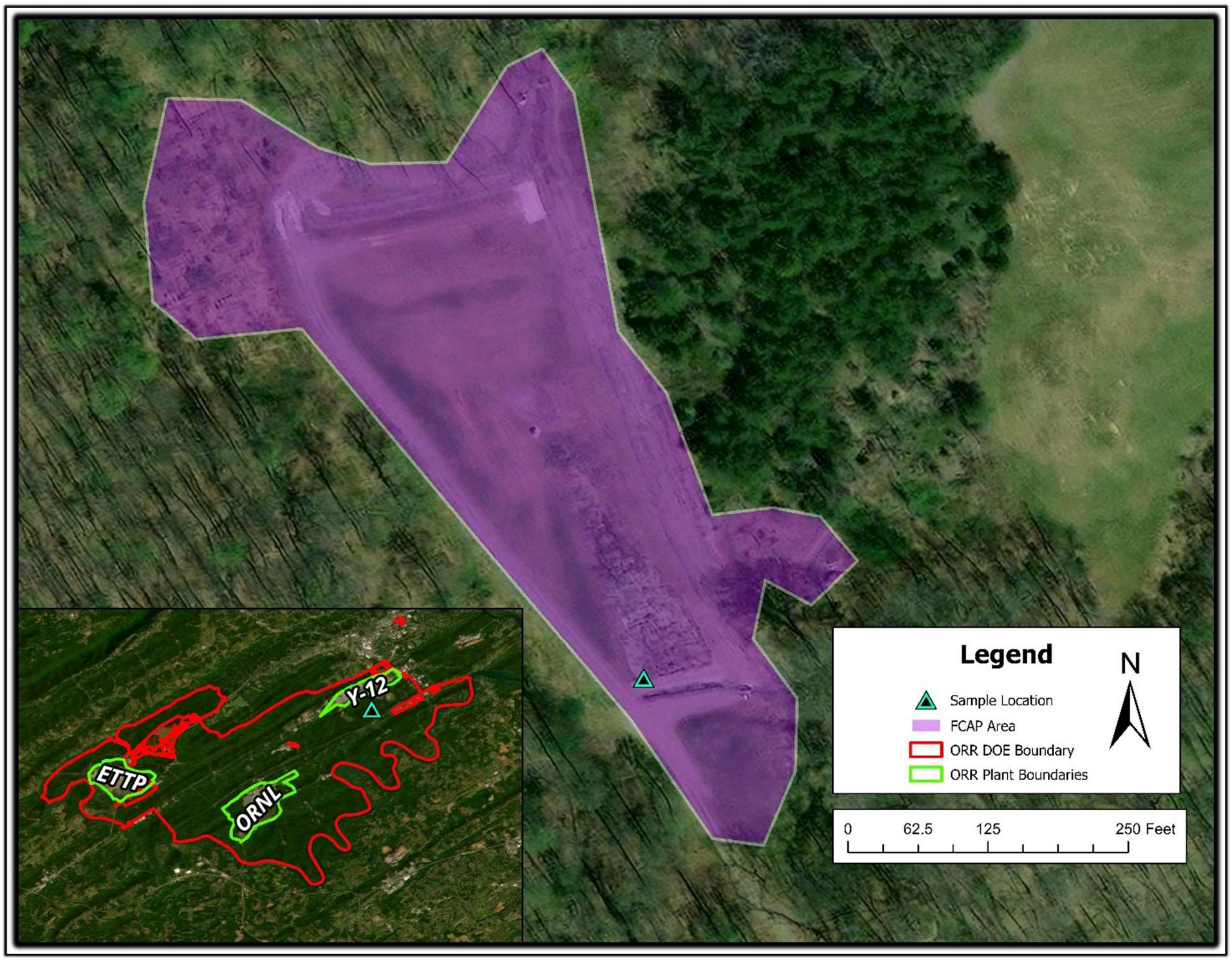

Figure 7.4.4.1: FCAP Sampling Location

7.4.5 Methods, Materials, Metrics

Vegetation, sediment, and water samples will be collected twice a year within the FCAP wetland. Results from samples collected during the growing season will be compared to those collected during the late fall vegetation die off. Each sample was shipped and analyzed for 15 contaminants of concern. These COCs are listed in Table 7.4.7.1 along with the analytical results.

7.4.6 Deviations from the Plan

Deviations occurred during this project. Due to laboratory issues, the following samples did not receive the full regiment of analyses requested.:

1) October 2022 – water samples were not analyzed for fluoride and mercury, sediment was not analyzed for beryllium and fluoride, and vegetation was not analyzed for molybdenum
2) March 2023 – sediment and vegetation were not analyzed for fluoride

7.4.7 Results and Analysis

Table 7.4.7.1: FCAP COCs Analyzed (FY23)

	10/26/2022			3/7/2023		
	Water	Sediment	Vegetation	Water	Sediment	Vegetation
1. Antimony	x	x	x	x	x	x
2. Arsenic	x	x	x	x	x	x
3. Barium	x	x	x	x	x	x
4. **Beryllium**	x		x	x	x	x
5. Cadmium	x	x	x	x	x	x
6. Chromium	x	x	x	x	x	x
7. Cobalt	x	x	x	x	x	x
8. **Fluoride**			x	x		
9. Lead	x	x	x	x	x	x
10. Lithium	x	x	x	x	x	x
11. **Mercury**		x	x	x	x	x
12. **Molybdenum**	x	x		x	x	x
13. Selenium	x	x	x	x	x	x
14. Thallium	x	x	x	x	x	x
15. Radium 226/ 228	x	x	x	x	x	X
Bolded *COCs were not analyzed in 1 or more samples.*						

The following table contains the COC concentrations for each of the six (6) sampling sets. As previously stated, the primary COC at FCAP is arsenic, and the main goal of this project was to determine whether seasonal changes (i.e. cattails' spring growth versus fall die off) affected Arsenic concentrations. Additionally, analyses for other coal combustion residual COCs in the sediment and water were requested.

Table 7.4.7.2. FCAP COCs Results

Sample Dates	Media	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Fluoride	Lead	Lithium	Mercury	Molybdenum	Radium-226	Radium-228	Selenium	Thallium
10/26/22	V	0.027 U	*4.51*	18.9	0.0249 J	0.013 J	0.718 J	0.843	0.198	0.534	1.77	0.004 J, HR		0.31	0.75	2.57	0.056 U
	S	0.183	*12.6 D*	9.17 D		0.235	14.3 D, U	2.01 D, U		15	6.02 D, U	0.123	1.67	0.5	0.36	5.89	0.390
	W	0.287 U	*17*	56.3	0.123 U	0.095 U	1.5 U	0.717 J		0.294 J	41.9		3.06	1.3 Lo Rec	0	1.88 U	0.579 U
03/07/23	V	0.029 U	*0.164 J*	27.9	0.012 U	0.015 J	0.152 U	0.081 J		0.301	0.499	0.005 U, H	2.05	0.006	0.024	1.43	0.059 U
	S	0.106	*87.5 D*	41.9	1.2 D, U	0.203	16.2 D, J	30.3 D		36.3	13.9 D	0.136 H	2.97 D	0.53	0.37	10.5 D	0.370
	W	0.287 U	*9.72*	68.7	0.123 U	0.095 U	1.5 U	0.369 J	0.113	0.288 U	32.9	0.044 U	2.44	0.15	0	3.33 J	0.579 U

V *= Vegetation Units: mg/kg* ***Qualifiers =*** *D: Dilution required* *J: Result <MDL but >MQL* *MDL: Method Detection Limit*
S *= Sediment Units: mg/kg* *H: Holding time exceeded* *U: Result <MDL* *MQL: Method Quantitation Limit*
W *= Surface Water Units: µg/L* *HR: Sample Received OOH*

Arsenic results show that concentrations within the vegetation decreased by 96% from the growing season to the dormant season. Water sample concentrations (17 µg/L) exceeded TDEC's *General Water Quality Criteria Chapter 0400-40-03-.03* Ambient Water Quality Criteria (AWQC) of 10 µg/L during the growing season. While water concentrations decreased by 42% from the growing season to the off season, sediment concentrations increased 594%.

Other notable observations include:

- Sediment concentrations shifted from growing season to dormant season for barium (357% increase), cobalt (1,407% increase), lead (142% increase), lithium (131% increase), and selenium (78% increase).
- Vegetation concentrations decreased in the dormant season for cobalt (90% decrease), lead (44% decrease), lithium (72% decrease), and selenium (44% decrease).
- Surface water sample concentrations decreased in cobalt by 49% and radium-226 by 88% but increased in selenium by 82% in the dormant season. Sample results increased for barium in the winter months (dormant season) for all samples (vegetation by 48%, sediment by 357%, and surface water by 24%). It is important to note that these comparisons may change from year to year as they are based on a single sample collected in each season.

Table 7.4.7.3. Percent (%) Increase / Decrease from Growing Season to Dormant Season by Media

	Arsenic +/- %	Barium +/- %	Cobalt +/- %	Lead +/- %	Lithium +/- %	Selenium +/- %	Radium-226 +/- %
Vegetation	-96	+48	-90	-44	-72	-44	
Sediment	+594	+357	+1407	+142	+131	+78	
Surface Water	-42	+24	-49			+82	-88

Red - # = decreased percentage
Black +# = increased percentage

Certain COC's show elevated concentrations in the cattails in the growing months, decreasing after the die off. Sediment concentrations show an increase in the winter months after the cattails have died off for the season.

7.4.8 Conclusions

The cattails exhibited elevated concentrations of arsenic during the growing season. In the fall, as the cattails died off, arsenic and other COCs were seen at higher levels in the sediment and surface water. This shift may be a result of the dying cattail stalks releasing the arsenic and some other COCs into the sediment and surface water, or it may be that the cattails were no longer actively sequestering contaminants during the dormant season. Overall, this small dataset may indicate seasonal fluctuations in arsenic and other COCs within the wetland media that could contribute to seasonal flux of discharge to Rogers Quarry.

7.4.9 Recommendations

The presented data suggest that removing dead or dying cattails could help improve the performance of the wetland to manage arsenic and other coal ash contaminants. While the only AWQC exceedance for water occurred in the October sample, annual harvesting of cattails could remove COCs stored in the plant tissue and decrease contaminant loading back into the sediment. This plant removal could ultimately affect downstream locations and improve the overall health of the system. Because these results represent a small dataset and limited sampling, TDEC recommends that additional sampling be considered to create a more robust dataset to better determine if the wetland management plans could be adjusted to improve performance.

7.4.10 References

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8.0 Holistic Watershed Monitoring

8.1 Bear Creek Assessment Project (BCAP) – Phase 4

8.1.1 Background

This phase of the BCAP was a follow-up evaluation of the overall health of the Bear Creek Watershed. The focus was to provide new sampling data to fill in data gaps left from *Phase 2.* New data for toxicity and/or biomonitoring of surface water and sediment was obtained to fill those gaps.

8.1.2 Problem Statements

1) DOE has yet to conduct a comprehensive assessment of Bear Creek at BCK 3.3 or at any other reaches further downstream. Bear Creek is an ORR exit-pathway stream that should be monitored to prevent any potential migration of contaminants downstream.
2) Construction of the EMDF Landfill is scheduled to begin in early 2024 and this landfill will sit alongside a section of Bear Creek. A portion of the creek may need to be rerouted around the construction site footprint.

8.1.3 Goals

The two (2) main goals of this project were:

1) To provide a water quality parameter baseline for Bear Creek prior to construction of the EMDF Landfill.
2) To assure the public that recreation areas along Bear Creek, located in the downstream reaches, do not pose any health risks to the public.

8.1.4 Scope

The scope of the BCAP Phase 4 project includes an environmental assessment of this watershed through the sampling and testing of the following media:

1) surface water
2) sediment
3) soil
4) biota
    1. benthic macroinvertebrates
    2. songbird eggs
    3. nocturnal flying insects
    4. spiders
    5. surface water toxicity
        1) water flea (survival and reproduction)

2) fathead minnow (survival and growth)

The stream reach being assessed goes from the mouth of Bear Creek (BCK 0.0) at EFPC (EFK 2.2) to BCK 12.3. The sampling locations along this reach are listed below in Table 8.1.4.1 and are mapped out in Figure 8.1.4.1.

Table 8.1.4.1: BCAP Sampling Sites

Site Description	Name	Latitude	Longitude
Bear Creek kilometer 3.3	BCK 3.3	35.94354	-84.34911
Bear Creek kilometer 4.5	BCK 4.5	35.93731	-84.34013
Bear Creek kilometer 7.6	BCK 7.6	35.95096	-84.31395
Bear Creek kilometer 7.87	BCK 7.87	35.950622	-84.313795
Bear Creek kilometer 9.6	BCK 9.6	35.96032	-84.29741
North Tributary 5 of Bear Creek	NT-5	35.96603	-84.29024
Bear Creek kilometer 11.97	BCK 11.97	35.971489	-84.279735
Bear Creek kilometer 12.3	BCK 12.3	35.973	-84.27814
East Fork Poplar Creek kilometer 2.2	EFK 2.2	35.95169	-84.3716
Emory Background Site	EMORY	36.02698	-84.19983
Hinds Creek kilometer 20.6	HCK 20.6	36.15797	-83.99944
Mill Branch kilometer 1.6	MBK 1.6	35.98886	-84.28935
Pinhook Branch kilometer 1.6	PBK 1.6	35.963495	-84.326492

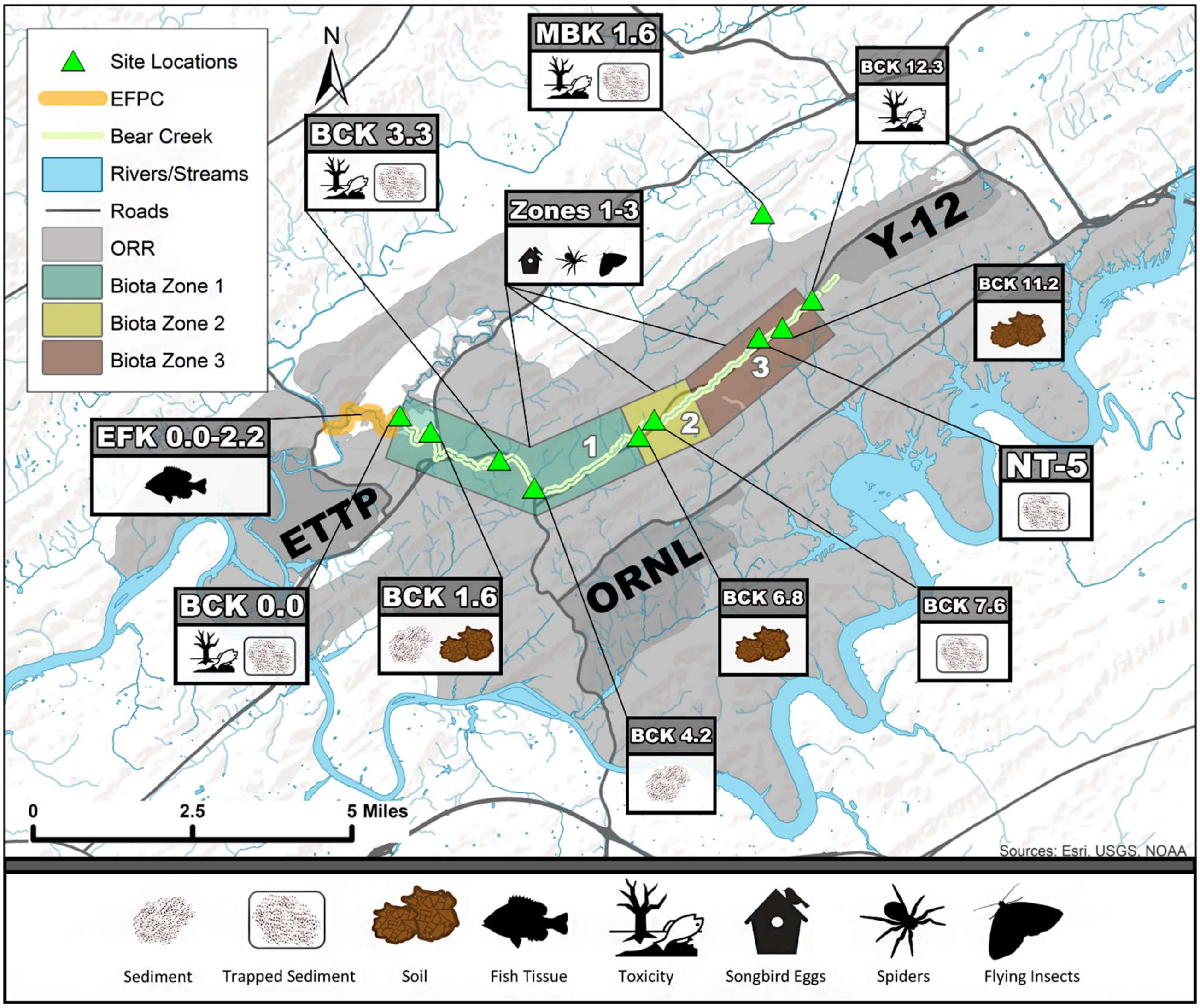

Figure 8.1.4.1: Map of the BCAP sampling locations

8.1.5 Methods, Materials, Metrics

Sediment

Sediment sampling was performed at four (4) locations twice during this fiscal year, on November 10, 2022, and June 15, 2023. These sampling locations were NT-5, BCK 7.6, BCK 3.3, and MBK 1.6. Suspended sediment samples were obtained using fixed sediment collection devices (traps). These traps were installed in the stream bed and placed in a position where considerable flow through the body of the trap occurs. Suitable sites are often limited in a stream and careful consideration must be given to selecting installation locations for the sediment traps.

Following a sampling period of approximately five (5) months, the collected sediment was emptied from a sediment trap and transferred to a clean bucket where the sediment was allowed to settle for three (3) days. After the sediment settled, the supernatant water was carefully drawn off the sample with a peristaltic pump. Sediment samples were then spooned from the bucket into sample containers. Sediment samples were analyzed for gross alpha, gross beta, strontium 89 and 90 (Sr-89/90), isotopic uranium, and metals including cadmium (Cd), mercury (Hg), and uranium (U). The sediment samples were sent to Pace Analytical for analysis.

Toxicity/biomonitoring

Toxicity and biomonitoring sampling was conducted in the fall of 2022 at BCK 12.3 and BCK 3.3, and MBK 1.6, the background site. Toxicity and biomonitoring sampling requires the collection of surface water samples three times during the week that the testing occurs (Monday, Wednesday, and Friday). Surface water samples were sent each sampling day by courier to Pace Analytical Laboratories for analysis. Analyses included survival and reproduction of water fleas (*Ceriodaphnia dubia)* and survival and growth for fathead minnows (*Pimephales promelas*). Biomonitoring analytes included cadmium, mercury, nitrate, gross beta, PCBs, and uranium. This sampling project was performed by Civil and Environmental Consultants, Inc. (CEC) with assistance from TDEC DoR-OR.

A second round of toxicity and biomonitoring sampling was originally planned for June 2023, but was delayed due to the enaction of temporary administrative controls on the ORR resulting in a work pause. This sampling was completed in July 2023, but the results have not yet been received from PACE.

BIOTA

Please see the *Mercury Uptake in Biota Project* report in this EMR for information about BCAP biota sampling and analysis during FY23.

PREVIOUS BCAP REPORTS

For information about sampling results for the Bear Creek Valley from previous years, please refer to the following documents:

1) Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office, Environmental Monitoring Report for Work Performed July 1, 2020, through June 30, 2021. August 2022.

2) Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office, Environmental Monitoring Report for Work Performed July 1, 2021, through June 30, 2022. October 2023.
3) TDEC Division of Remediation – Oak Ridge Office, Bear Creek Assessment Project (BCAP) Final Report (Phases 1-4). August 2023.

8.1.6 Deviations from the Plan

Additional sampling projects were added to the original plan when CEC was contracted to conduct toxicity/biomonitoring sampling in the fall of 2022. Also, additional suspended sediment sampling was completed in fall 2022 and spring 2023 by TDEC DoR-OR.

8.1.7 Results and Analysis

The project team visited the suspended sediment sampling locations at NT-5, BCK 7.6, BCK 3.3, and MBK 1.6. (Table 8.1.4.1) to collect suspended sediment samples on November 10, 2022, and again on June 15, 2023. Unfortunately, the results from the June 15, 2023, collection is not included in this report as data has not yet been received.

Mercury

The suspended sediment mercury results are graphed in Figure 8.1.7.1. These data are compared to EPA risk-based Screening Levels (SLs). SLs are risk-based chemical concentrations that correspond to fixed levels of risk in soil, air, and water. These concentrations are derived from standardized equations combining exposure information assumptions with EPA toxicity data. SLs are protective of human health over a lifetime, but do not address ecological impacts (EPA 2022). SLs are not cleanup standards, but are used to identify areas, contaminants, and conditions that require attention at a site (EPA 2022).

The suspended sediment results from the Bear Creek and NT-5 sampling sites were well below the mercury SL, Total Hazard Index (THI)=1, Resident Soil (10.9 mg/kg). In noncarcinogenic risk equations, the target hazard quotient (THQ) is used for individual substances or for exposure routes like ingestion, dermal, and inhalation. The hazard quotient (HQ) is the ratio of the potential exposure to the substance and the level at which no adverse effects are expected. A hazard quotient of 1.0 or less is not likely to result in adverse noncancer effects. HQs greater than one do not statistically predict adverse noncancer harm, but simply state how much the exposure concentration exceeds the reference dose or reference concentration (RAIS, n.d.).

A HQ above 1.0 signifies an increased likelihood of an adverse response (Hertzberg and

Teuschler 2002), such as a rash or hair loss. The THI is the target across multiple substances or exposure routes (EPA 2022). The Bear Creek Valley Watershed Remedial Action Report Comprehensive Monitoring Plan specifies the use of Risk-Based Concentrations of a TR of 1E-5 and THI=1 for residential receptors for Zones 1 and 2 and industrial receptors in Zone 3 (DOE 2019). The boundary between Zones 2 and 3 is at BCK 9.2.

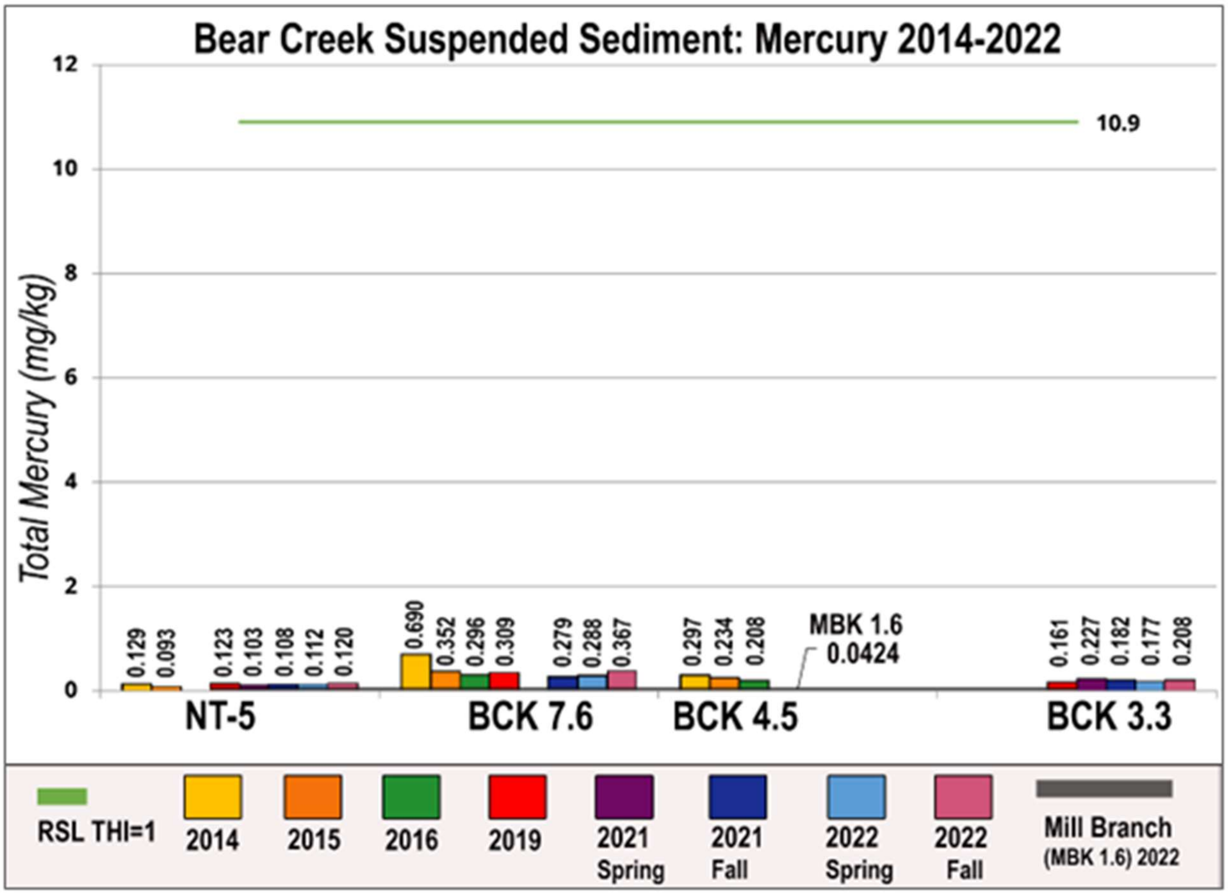

Figure 8.1.7.1: Bear Creek Suspended Sediment: Mercury Results

URANIUM

Sediment uranium results were lower than the Resident Soil RSL (THI=1) of 15.6 mg/kg, except for BCK 7.6 (Figure 8.1.7.2). The greatest concentration of sediment uranium was collected from the sediment trap at BCK 7.6 in June 2022; this sampling station is downstream of all Bear Creek disposal facilities and is just downstream of NT-8, a tributary that transports considerable amounts of uranium from the BCBGs.

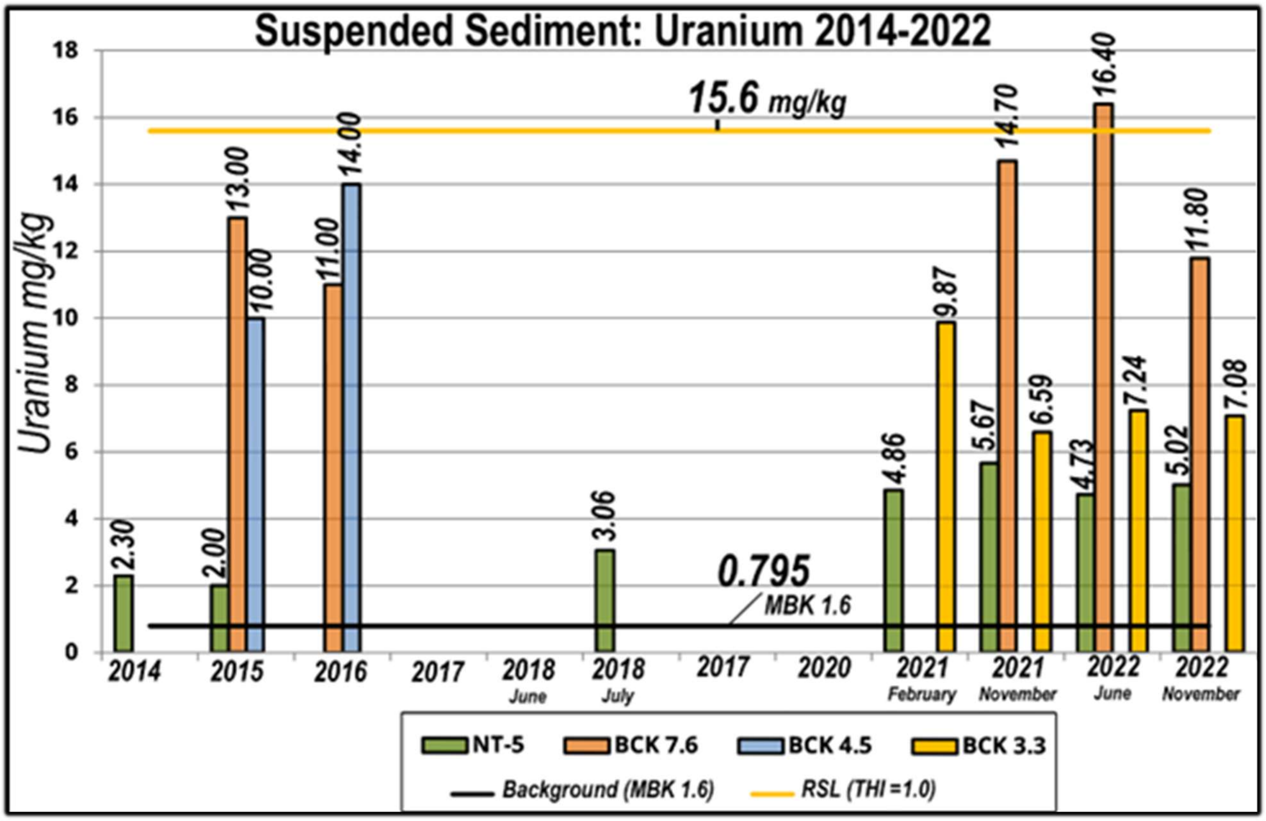

Figure 8.1.7.2 Bear Creek Suspended Sediment: Uranium Results

CADMIUM

Cadmium results were all either J values, meaning that the results were estimated by the laboratory, or non-detects. The sites with J values had data that were much lower than the Resident SL of 8.14 mg/kg.

PCBS

Analysis for PCBs was also conducted on the sediment samples. Only one detection was above the minimum detection limit (MDL). Aroclor 1260 was detected at BCK 7.6 at 0.276 mg/kg in November 2022. This concentration is less than the Resident SL TR=1E-5 of 2.4 mg/kg. The screening level TR=1E-5 indicates the chemical concentration that corresponds to a one-in-one hundred thousand risk of cancer (EPA 2022).

GROSS ALPHA

The gross alpha suspended sediment results from 2014 to 2022 are presented in Figure 8.1.7.3. The NT-5 data have a downward trend through February 2021, dipping below background in 2019 and winter 2021. Since the winter of 2021, the NT-5 gross alpha data has been *increasing* with a high of 11.6 pCi/g in November 2022. There are currently no EPA screening levels for gross alpha in soil/sediment for comparison.

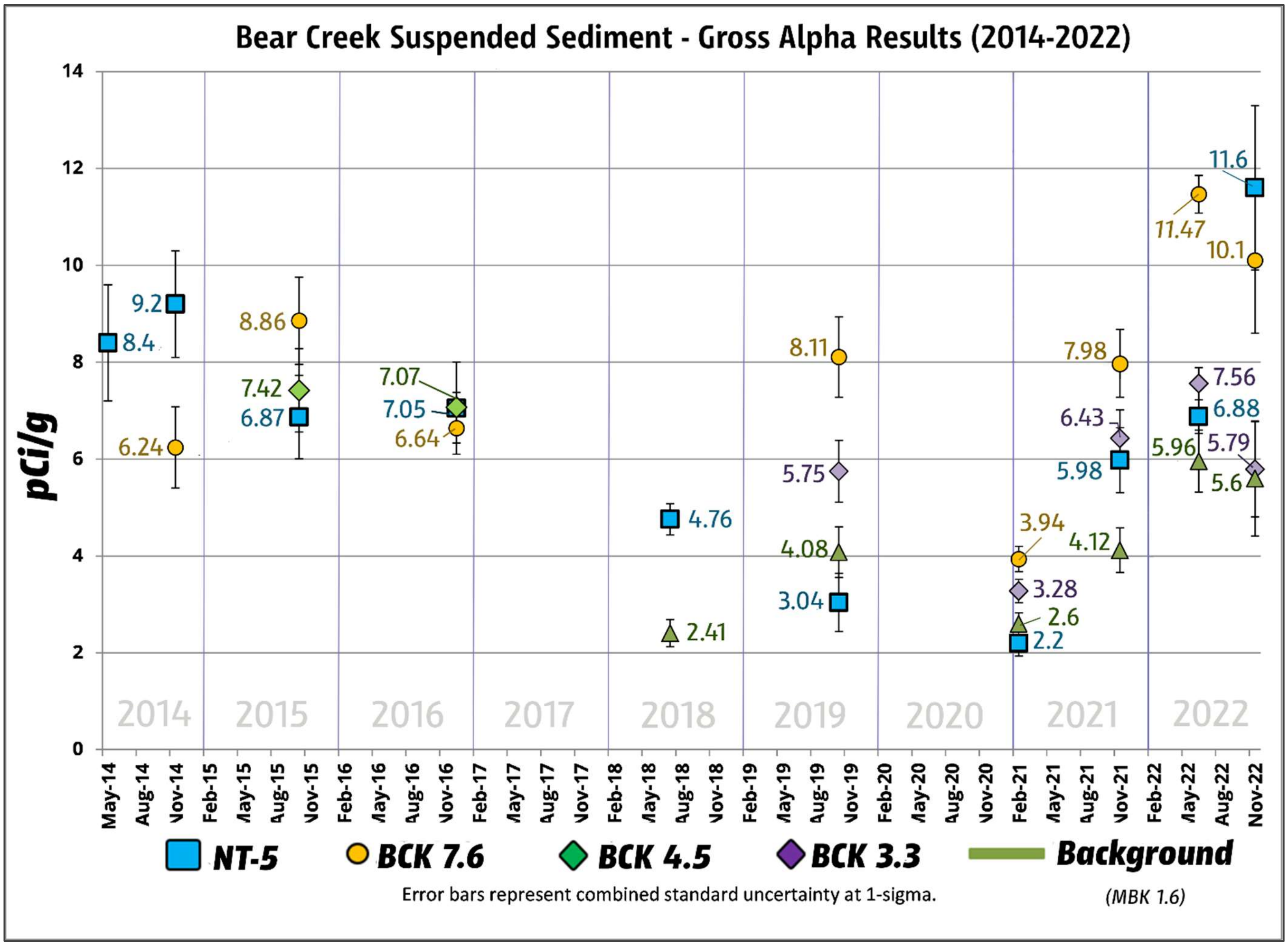

Figure 8.1.7.3: Bear Creek Suspended Sediment: Gross Alpha Results

GROSS BETA

Gross beta activities were greatest at the NT-5 suspended sediment site (Figure 8.1.7.4). The reason for this elevated gross beta activity may be an artifact of the disposal of Tc-99 containing waste from ETTP in recent years at the EMWMF. Gross beta activities at BCK 7.6 and BCK 3.3 have been fairly consistent over the years that have been sampled. All of the gross beta results are above those seen at the background location (MBK 1.6). There are currently no EPA screening levels for gross beta in soil/sediment for comparison.

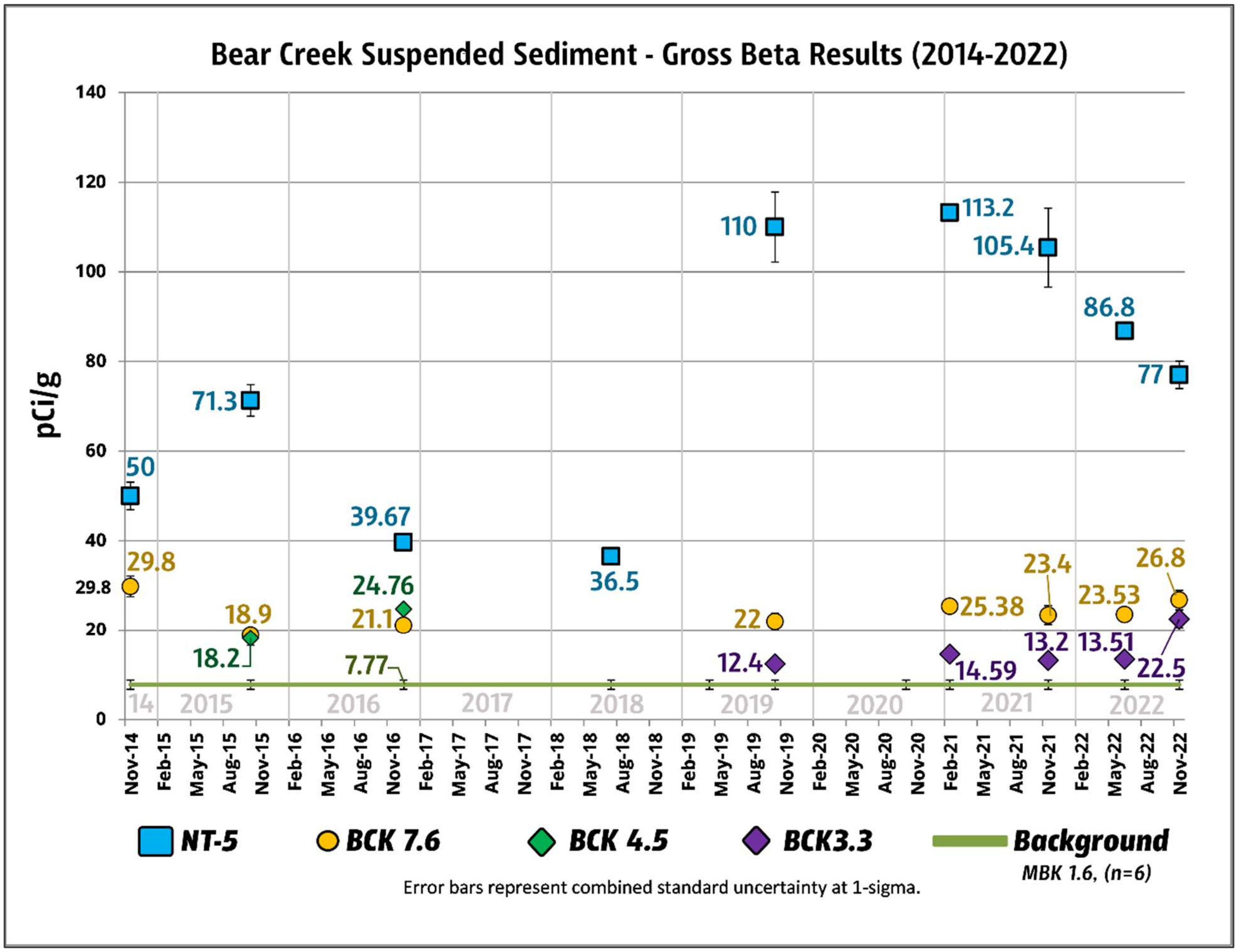

Figure 8.1.7.4: Bear Creek Suspended Sediment: Gross Beta Results

ISOTOPIC URANIUM

Isotopic uranium analysis was conducted on suspended sediment samples for Bear Creek sites in 2014-2016 and 2021-2022 (Figure 8.1.7.5). The only exceedances of the EPA Resident soil SLs were at NT-5 for uranium-233/234 in 2014 and 2015. All of the uranium-235 data were non-detects or very low values with high combined standard uncertainties, so these data were not used or graphed in Figure 8.1.7.5.

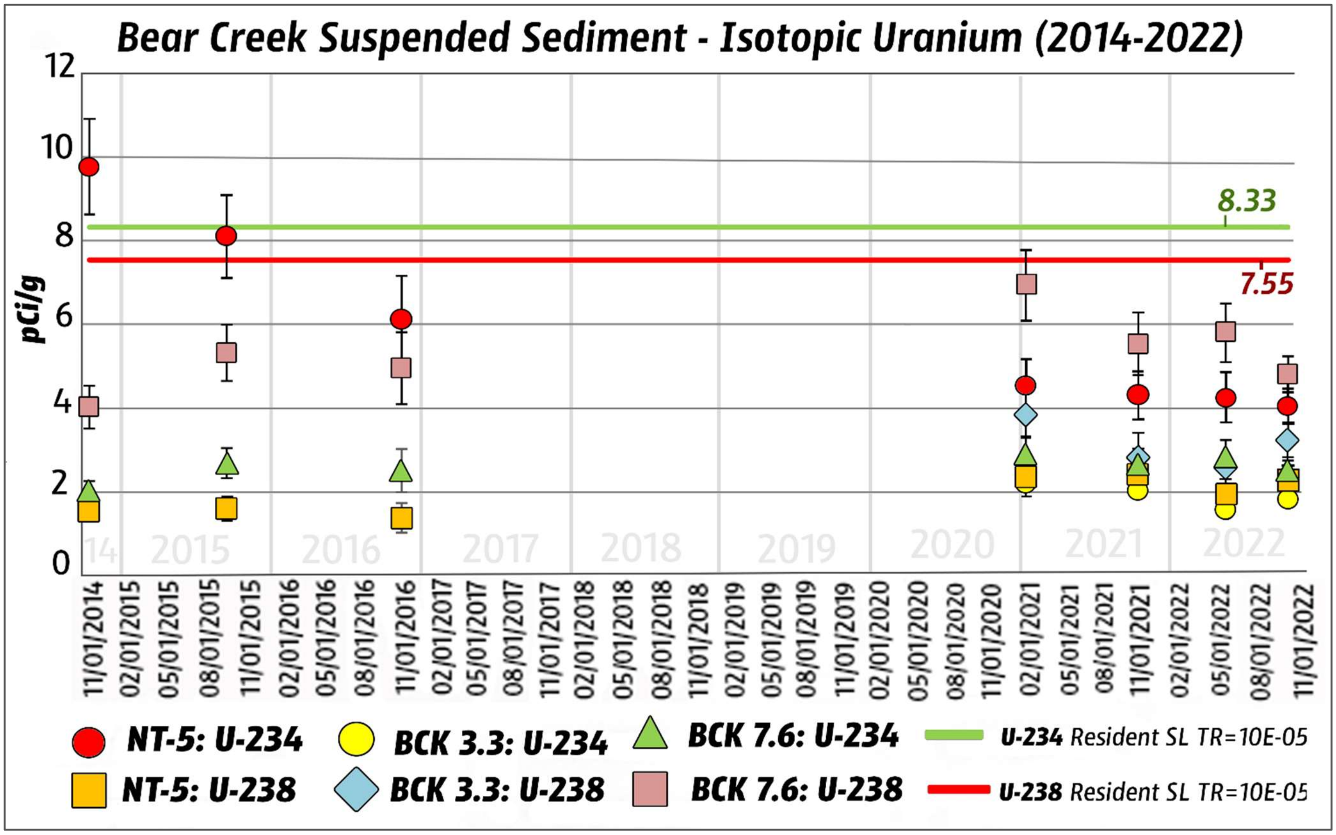

Figure 8.1.7.5: Bear Creek Suspended Sediment: Isotopic Uranium Results

STRONTIUM 89/90

Strontium-89/90 data were non-detects or very low values with high combined standard uncertainties; these data were not used.

TOXICITY

<u>*Ceriodaphnia dubia* (water flea):</u>

Sampling of surface water for toxicity testing was conducted at three (3) locations during the week of October 16, 2022, by CEC with assistance from TDEC DoR-OR staff. The sample locations were BCK 12.3, BCK 3.3, and MBK 1.6 (Table 8.1.4.1). Sites were chosen to verify scores from previous testing done in 2020 and 2021. To determine if *water or effluent* is causing acute or chronic toxicity, the IC25 value was used. The IC25 value is a statistical calculation of the effluent concentration which causes a 25% reduction in survival, growth, *or* reproduction of test organisms.

Ceriodaphnia dubia (water flea) reproduction inhibition was demonstrated at BCK 12.3 during testing conducted in fall 2020, spring 2021, and fall 2022 (Figure 8.1.7.6) but was not inhibited in Spring 2022. On the other hand, survival was not affected by toxicity at any of the sample sites. Tennessee Macroinvertebrates Index (TMI) scores at BCK 12.3 have been consistently low and have not attained bio-criteria guidelines (TMI>32) in the last ten (10) years. TMI scores have ranged from 10 (2022) to 18 (2020). These low TMI scores are attributed to poor habitat (channelized stream section and hardpan clay substrate). In addition, this section of Bear Creek is impacted by the influx of contaminated groundwater during low flow periods.

Using the Linear Interpolation Method, the IC25 was calculated for these 4 sampling events. In fall 2020, the IC25 for survival was reported as being greater than (>) 100% effluent and reproduction as 26.8% effluent. The combined IC25 is reported as the lesser of the two values (i.e. 26.8% effluent). Since the IC25 results were less than 100% effluent, the effluent was toxic to water flea reproduction at BCK 12.3 in fall 2020. On a second testing event in spring 2021, BCK 12.3 had an IC25 score of 77.3%, still exhibiting inhibition of reproduction. Alternatively, Spring 2022 testing had an IC25 score of >100, representing a passing score with no toxicity demonstrated. Unfortunately, in the fall of 2022, BCK 12.3 had a lower IC25 score of 68.1%, again showing toxicity to water flea. Beginning in spring 2022, surface water samples were collected for cadmium, mercury, nitrate, and PCBs on each sampling day. In Figure 8.1.7.6, recent nitrate data suggest that high nitrate concentrations may be contributing to reproduction inhibition at BCK 12.3. Nitrate monitoring concurrent with toxicity sampling was not conducted in 2020 or 2021.

Table 8.1.8.1: Toxicity Results: Reproduction Inhibition in *Ceriodaphnia dubia* at BCK 12.3

BCK 12.3	**IC25**			
Season Sampled	**Survival**	**Reproduction**	**Overall**	**Toxicity**
Fall 2020	>100% Effluent	26.8% Effluent	26.8% Effluent	Reproduction
Spring 2021		77.3% Effluent	77.3% Effluent	Reproduction
Spring 2022		>100% Effluent	>100% Effluent	Not Toxic
Fall 2022		68.1% Effluent	68.1% Effluent	Reproduction

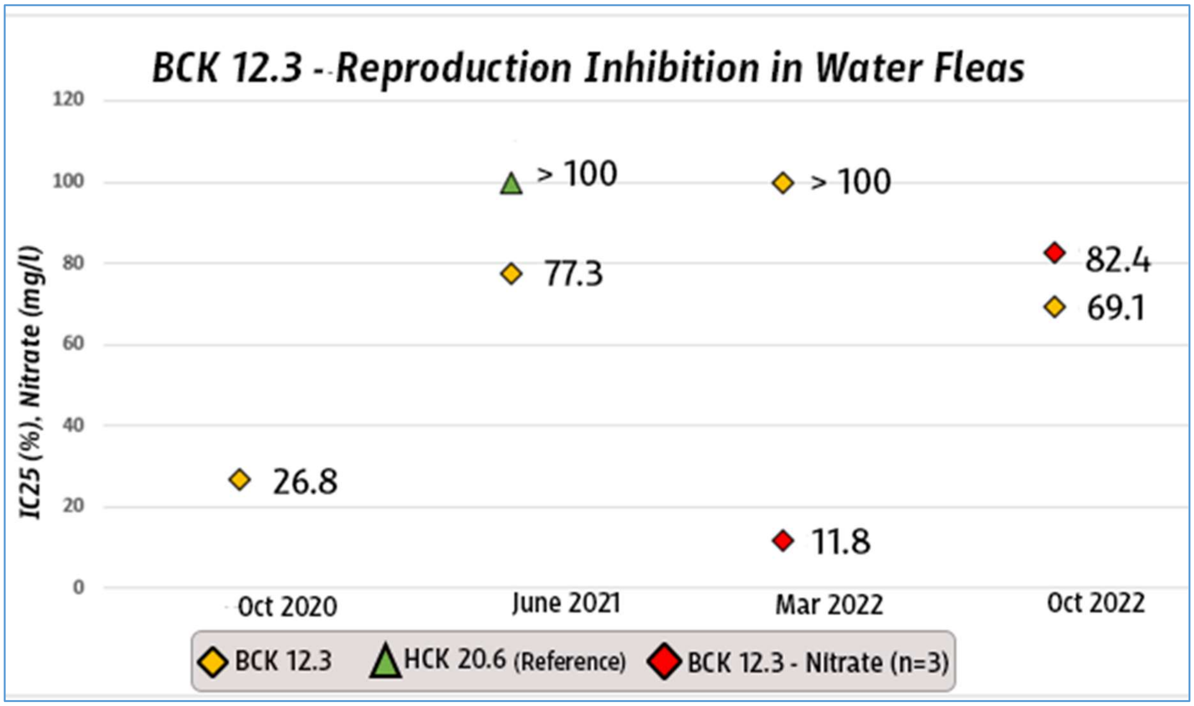

Figure 8.1.7.6: Reproduction Inhibition of *Ceriodaphnia dubia* (water flea) at BCK 12.3 (2020-2022)

Pimephales promelas (fathead minnow):

Inhibition of growth of *Pimephales promelas* (fathead minnow) was demonstrated at BCK 3.3 (Figure 8.1.7.7). At BCK 3.3, the fall 2020 IC25 growth was 87%; the spring 2021 IC25 (growth) was 39.3%. In spring 2022, BCK 3.3 had an IC25 score of >100%, indicating no toxicity was observed. Fall of 2022 toxicity testing resulted in an IC25 score of 10.8%, again showing toxicity to fathead minnow. In Figure 8.1.7.7, nitrate does not appear to impair fathead minnow growth based on a limited dataset. Uranium in Bear Creek surface water at BCK 3.3 (Figure 8.1.7.7) does not appear to be contributing to the inhibition of minnow growth either; in October of 2022, the uranium concentration was 0.01 mg/L (n=3) and the IC25 score was 10.8%, while in March of 2022, the uranium concentration was 16 mg/L (n=3) and the IC25 score was >100%.

In contrast, benthic macroinvertebrate TMI scores for BCK 3.3 are consistently above bio-criteria guidelines (>32), Indicating that BCK 3.3 is fully supporting for benthic macroinvertebrate communities.

Table 8.1.8.2: Toxicity Results: Growth Inhibition in *Pimephales promelas* at BCK 3.3

BCK 12.3	IC25			Toxicity
Season Sampled	**Survival**	**Growth**	**Overall**	
Fall 2020	>100% Effluent	87% Effluent	87% Effluent	Growth
Spring 2021		39.3% Effluent	39.3% Effluent	Growth
Spring 2022		>100% Effluent	>100% Effluent	Not Toxic
Fall 2022		10.8% Effluent	10.8% Effluent	Growth

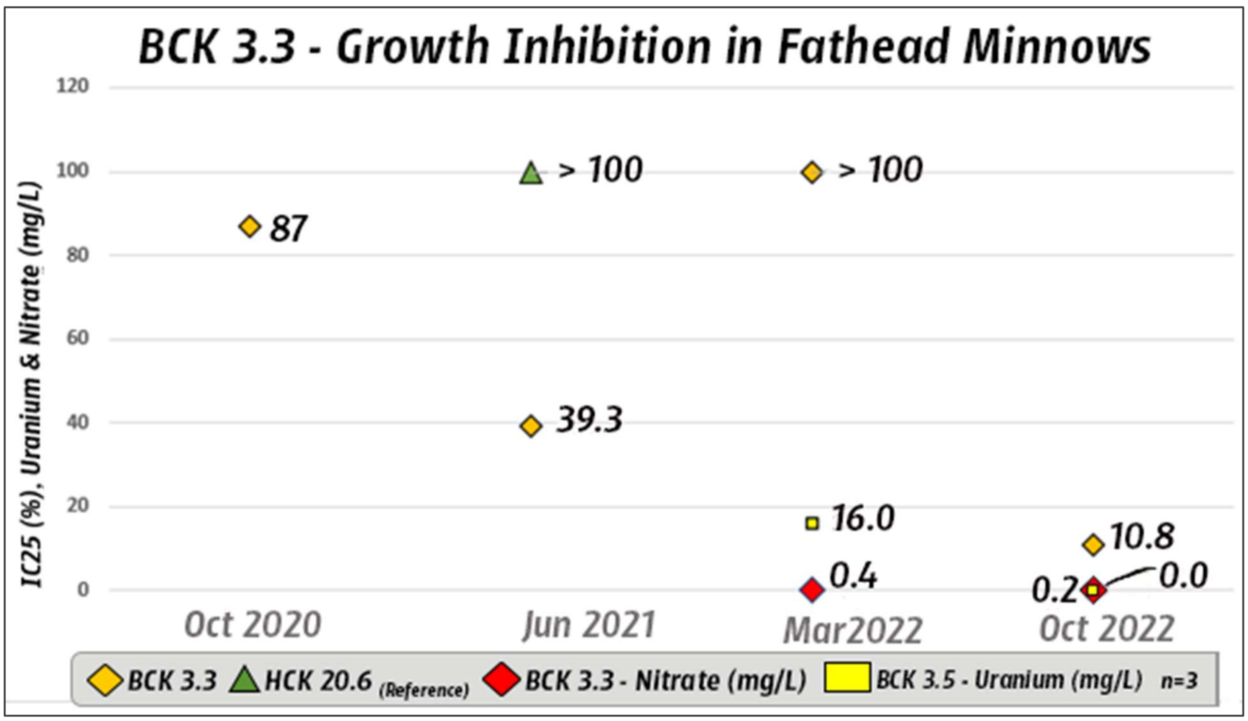

Figure 8.1.7.7: Growth Inhibition of *Pimephales promelas* (fathead minnow) at BCK 3.3 (2020-2022)

BIOMONITORING

Mercury, cadmium, and PCBs were not detected in any of the surface water samples. The nitrate MCL (10,000 µg/L) was exceeded only at BCK 12.3. The nitrate concentrations at BCK 12.3 from fall 2022 were around eight times the MCL (Figure 8.1.7.8). TDEC quarterly surface water sampling from FY23 found the average nitrate concentration at BCK 12.3 to exceed the MCL at 10,045 µg/L (n=4). In addition, uranium concentrations at BCK 12.3 were much greater than the MCL (30 µg/L) in both spring and fall of 2022 (Figure 8.1.7.9). Quarterly TDEC surface water sampling at BCK 12.3 in FY23 also found the annual average concentration of uranium to exceed the MCL at 115.98 µg/L (n=4). Analysis for gross beta was conducted in fall of 2022 in conjunction with the toxicity testing. BCK 12.3 gross beta results from the week of 10/16/2022 had a mean (n=3) of 290.3 ± 8.97 pCi/L, exceeding the EPA 50 pCi/L screening level for community water systems determined to be vulnerable by the State (EPA 2000). Although Bear Creek is not a drinking water source, the screening level is used as a reference.

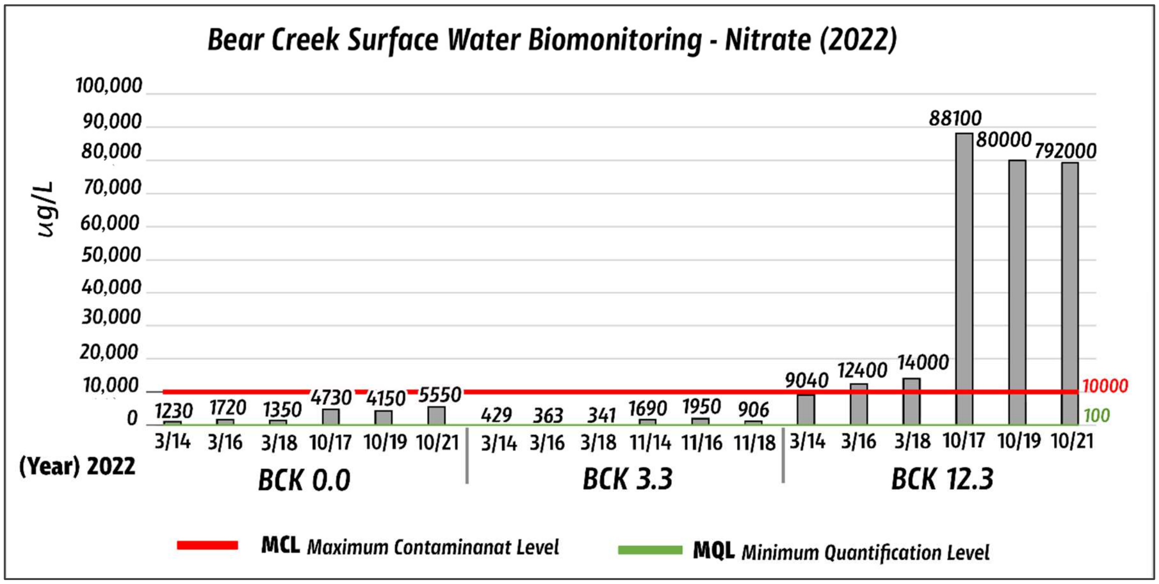

Figure 8.1.7.8: Nitrate Biomonitoring Results from Bear Creek Sites

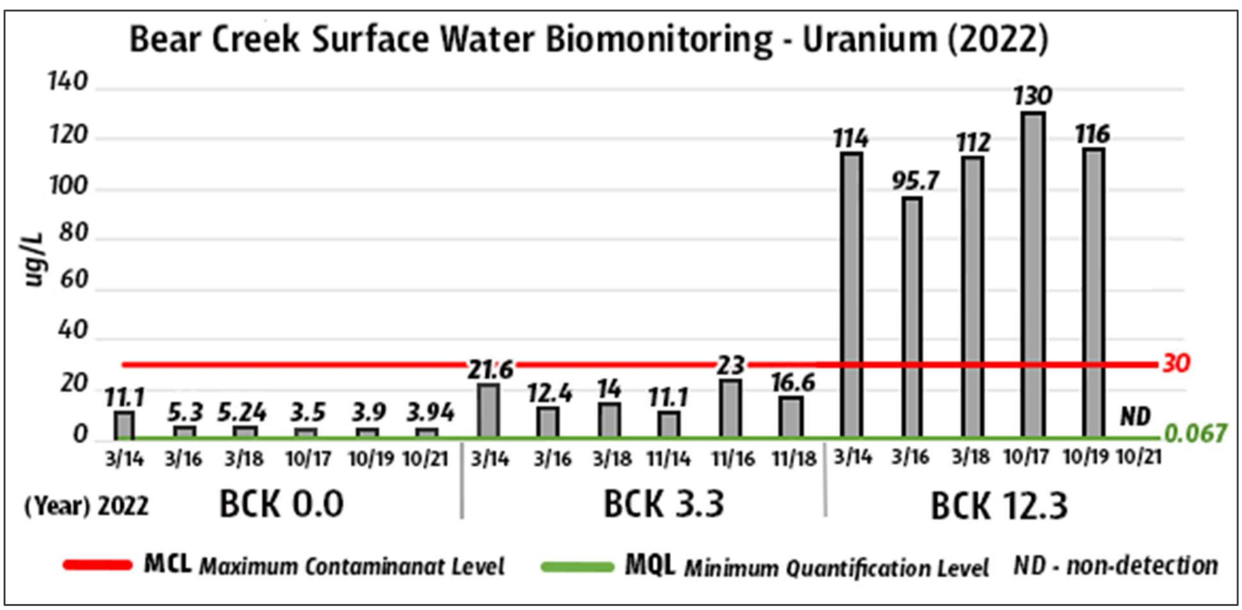

Figure 8.1.7.9: Uranium Biomonitoring Results from Bear Creek Sites

8.1.8 Conclusions

Although mercury is present in Bear Creek sediments, the concentrations do not exceed human health risk levels. Bear Creek sediments do not present a human health risk because the mercury levels are much lower than 10.9 mg/kg, which is the risk-based screening level for a resident scenario at THI=1.

Uranium sediment concentrations exceeded the resident soil SL THI=1 (15.6 mg/kg) at BCK 7.6 in June 2022 only. Since the uranium concentration at BCK 7.6 (16.4 mg/kg) exceeds the resident soil THI=1 SL, this indicates that further evaluation of the potential risks by uranium in sediment is appropriate.

PCB concentrations were below detection limits in the suspended sediment samples except for BCK 7.6. In November 2022, Aroclor 1260 was detected at BCK 7.6 at 0.276 mg/kg, which is less than the resident SL TR=1E-5 of 2.4 mg/kg.

Surface water toxicity testing results from March of 2022 showed no toxicity or inhibition of reproduction (*C. dubia*) or growth (*P. promelas*) at any of the sampling locations. This contrasts with the results obtained from other sampling events. Toxicity testing conducted in fall 2020, spring 2021, and fall 2022 reported inhibition at BCK 12.3 (water flea) and BCK 3.3 (fathead minnow). All of the toxicity testing was conducted by Pace Analytical Laboratories with the exception of the March 2022 sampling event, which was conducted by Waypoint Analytical.

In spring and fall of 2022, uranium biomonitoring surface water samples had concentrations of uranium three to four times greater than the MCL at BCK 12.3. Nitrate concentrations at BCK 12.3 were also high, especially in fall 2022, when they were about eight times the MCL.

8.1.9 Recommendations

Considering the concentrations of uranium and the presence of mercury and PCBs in the soils and sediments of the Bear Creek Valley, this project team recommends repeating this soil sampling on a regular basis to monitor for these COCs.

One concern is that future remedial actions and construction of the EMDF in Bear Creek Valley may result in the release of legacy contaminants into the watershed. With each flooding event, deposition of new layers of sediment on soils will continue, possibly increasing the contaminant content of the soils. The increase in contamination of the floodplain soils could result in elevated human risk and ecological impacts. To remediate against this potential contaminant migration, the project team recommends that soil sampling be conducted every three (3) to five (5) years. Since changes in soils occur slowly, sampling need not be on a yearly basis. Of course, in the event of a major release or spill upstream in the BCV watershed, soil sampling will be performed again and on a more frequent basis in the short term.

Suspended sediment sampling is recommended twice a year since this sediment shows changes in direct response to environmental contaminant discharges. These sampling results could potentially give us a better idea of how contaminants migrate in the ORR.

Toxicity/biomonitoring testing should be repeated until a clear picture of the in-stream habitat is obtained. Additional toxicity testing is planned for July of 2023.

8.1.10 References

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8.2 East Fork Poplar Creek Assessment Project (EFPCAP) – Phase 2

8.2.1 Background

The ORR resides in the Valley and Ridge physiographic province. This province is distinguished by series of northeast-southwest trending ridges and interceding valleys (Figure 1.3.1.1) (Miller, 1974).

The headwaters of EFPC are located within the Y-12 NSC where the primary COCs are mercury and uranium. The EFPCAP involves a comprehensive evaluation of the ecological health of this entire watershed and will focus on mercury and uranium monitoring. To accomplish this holistic assessment, the EFPCAP has been organized into several progressive phases.

1) **Phase 1** Researched historical data and compiled existing data.
    a. Data acquisition, reviewed, summarized, and interpreted historical data for upper and lower EFPC.
    b. Examined and compiled available types of environmental data including: (1) surface water, (2) groundwater, (3) sediment, (4) soils, (5) toxicity/biomonitoring, (6) fish tissue, (7) benthic macroinvertebrates, (8) terrestrial biota [bird eggs, spiders, flying insects, ground beetles].
2) **Phase 2** This phase included new sampling and subsequent analysis of monitoring data collected in Phase 1. In Phase 2, the above-mentioned projects (1.b.) focused on the EFPC sampling. In addition, mercury uptake sampling also included ground beetle monitoring.
3) **Phase 3** will use the analytical data obtained from Phases 1 and 2 to produce a comprehensive report. If data gaps are present after Phase 2, there will be further sampling and analysis.
4) **Phase 4** will address any areas requiring additional field sampling for a more comprehensive analysis and interpretation of all watershed data.

As stated above, in FY23 DoR-OR researched legacy contamination and historical events that potentially impacted EFPC. Relevant FY23 sampling data from other projects has been compiled in this EMR report.

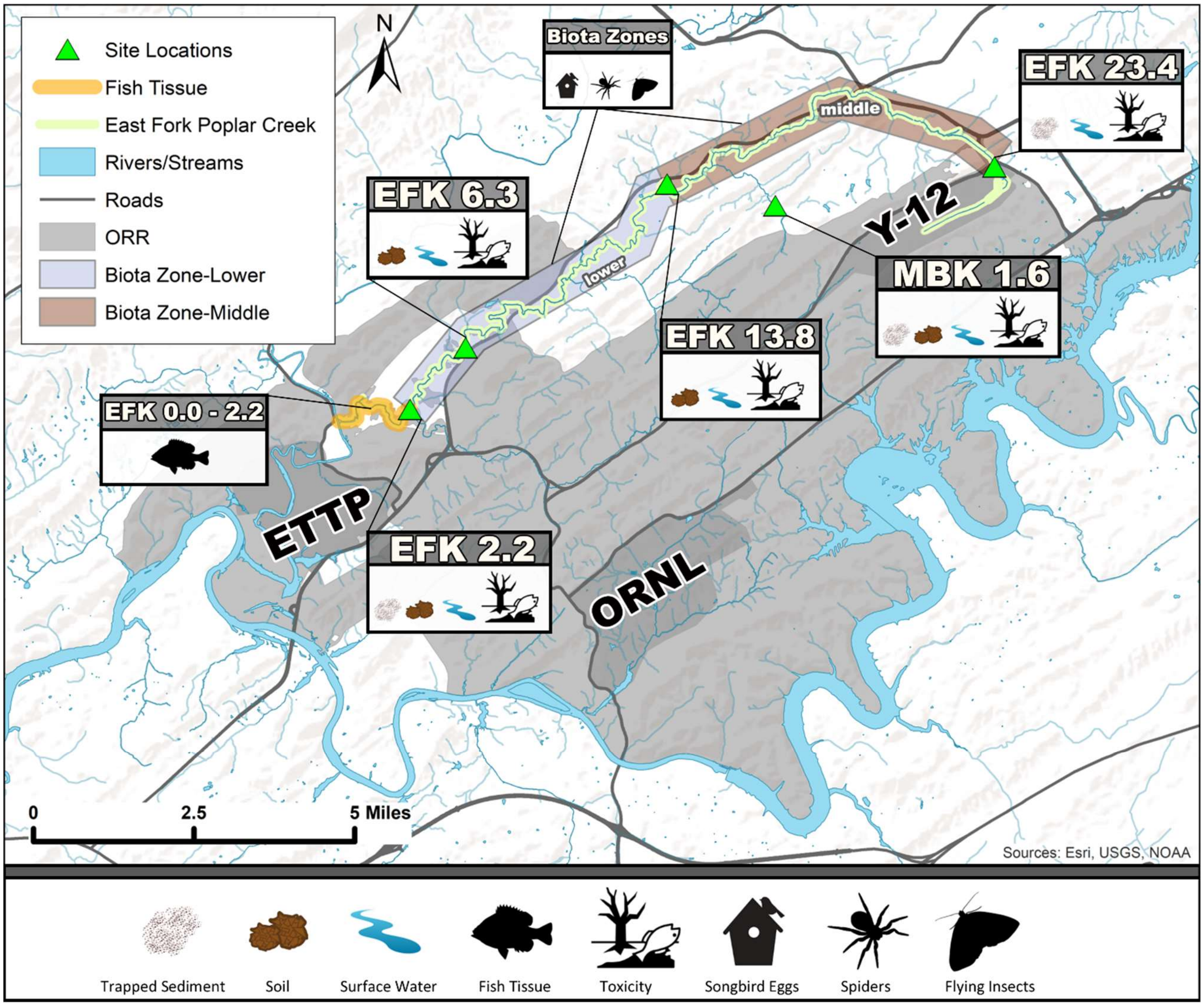

Figure 8.2.1.1: EFPCAP Sampling Sites

8.2.2 Problem Statements

In the years from 1950 to 1963, an estimated 100 metric tons of elemental mercury were released into EFPC from Y-12 (Turner and Southworth 1999). Mercury continues to leak into EFPC from Y-12 subsurface drains, contaminated building foundations, and soils. It is estimated that EFPC discharges approximately 0.2 metric tons of mercury to the Clinch River every year (DOE 1992). This mercury has migrated into soils in the floodplain and into the food web. Although mercury concentrations in EFPC water have decreased 85% from the 1980s, methylmercury concentrations in water and fish have not declined, even with efforts to improve water quality (Brooks and Southworth 2011). In addition to mercury, uranium is also a contaminant of concern in EFPC. Uranium was released from Y-12 into the air from vents and stacks and into surface water via Upper EFPC.

8.2.3 Goals

1) Holistic assessment of ORR contaminants and the quantification of the risk to wildlife in the EFPC watershed.
2) Provide an environmental assessment benchmark to gauge the effects of future DOE remediation activities in the EFPC watershed, including the Y-12 Mercury Treatment Facility and changes to the nearby Outfall 200 area (OF 200 MTF).

8.2.4 Scope

Phase 2 of the EFPCAP included the reach from the mouth of EFPC (EFK 0.0) to Station 17 (EFK 23.3), which is the integration point for EFPC at the DOE Y-12 NSC. The sampling sites are listed in Table 8.2.4.1 and include reference stream sites (CCK 1.6, MBK 1.6, HCK 20.6).

Table 8.2.4.1 EFPCAP Sampling Sites

Site Description	Name	Latitude	Longitude
E. Fork Poplar Creek km 23.4	EFK 23.4	35.99596	-84.24
E. Fork Poplar Creek km 13.8	EFK 13.8	35.99283	-84.3137
E. Fork Poplar Creek km 6.3	EFK 6.3	35.96293	-84.3591
E. Fork Poplar Creek km 2.2	EFK 2.2	35.95169	-84.3716
Clear Creek km 1.6	CCK 1.6	36.21346	-84.0598
Hinds Creek km 20.6	HCK 20.6	35.15797	-83.9994
Mill Branch Mile 1.0	MBK 1.6	35.98886	-84.2894

8.2.5 Methods, Materials, Metrics

Toxicity/biomonitoring

Toxicity and biomonitoring tests were conducted at all four (4) EFK sites and at MBK 1.6. *Ceriodaphnia dubia* (water flea) were used for testing survival and reproduction in EFPC effluent. *Pimephales promelas* (fathead minnow) were used for testing survival and growth for the same sampling sites.

In addition, surface water samples were collected during each sampling day for cadmium, mercury, nitrate, gross beta, and uranium analysis. Low-level mercury (EPA Method 1631E) analysis was added to the biomonitoring plan in winter 2023; mercury by EPA method 7470A was used previously. Surface water samples were collected three (3) times during the work week on Mondays, Wednesdays, and Fridays. Samples were promptly sent to the laboratory for testing. Each sampling set was conducted quarterly in FY23 by CEC.

Surface Water

Please refer to the *Ambient Surface Water Project* section of this EMR for information about methods, materials, and metrics for surface water sampling and processing.

Soil

Soil samples were collected at the three (3) lower sites on EFPC (i.e., EFK 13.8, 6.3, and 2.2) and at one (1) background location, Clear Creek (CCK 1.6). Sample locations were in the flood plain adjacent to each water sampling site. Each soil sample collected by CEC used the *Incremental Sampling Methodology* (ISM) and a grid of 30, 1-meter square cells.

Since the samples were to be analyzed for per- and polyfluoroalkyl substances (PFAS), special care was taken to prevent the contamination of the samples inadvertently. Staff used the guidelines from *PFAS Soil Sampling Guidance* issued by the Michigan Department of Environmental Quality (November 2018). This guide outlined the required sampling technique in detail. For example, the project team was instructed on how to choose PFAS-free clothing and footwear for the field sampling (MDEQ 2018).

Overall, sampling was conducted in accordance with the Interstate Technology Regulatory Council (ITRC) ISM that was published in February 2012 and the updated version released in October 2020. Incremental sampling uses a normalized composite sampling and processing approach to reduce variability. ISM provides a relatively unbiased representation of the average constituent concentration in the sample material and over the assessed area. This approach leads to more consistent and reproducible results that are more representative of the assessed area.

This method of soil collection involved staking out a sample grid at each of the four (4) EFPC sample locations. The result was a 30-point bulk sample for laboratory processing and subsampling. Soil sampling equipment consisted of nickel-plated metal sampling tubes were purchased new from *JMC Soil* for the sampling events. Sampling tubes were first washed with a solution of *ThermoFisher Scientific* certified PFAS-free water and *Alconox*, then rinsed with PFAS-free water. The PFAS-free water used for equipment decontamination was *Optima-LCMS Grade Water*. After cleaning, the sampling tubes were left to air dry and then placed into gallon-size Ziploc brand bags. Soil samples were placed directly into laboratory-provided PFAS-free containers. Equipment and sample containers were shuttled to and from the sample locations in food-grade 5-gallon buckets that had been washed by the same method as the sampling tubes (CEC 2023).

Sample increments were collected using a *JCM Backsaver Handle* outfitted with a dedicated 1.25-inch inside diameter by 8-inch-long core barrel that had been marked with a metal file for sampling to a depth of 6 inches. New core sampler barrels were purchased for each site and pre-cleaned using the same cleaning method as above.

Beginning with the grid cell designated as cell 1, an approximately 6-inch-deep soil increment was collected from a random quadrant as determined using a random number generator tool in *Microsoft Excel*. Random secondary, tertiary, and quaternary quadrant selections were also available in case a full increment could not be collected from a cell due to obstructions such as roots or rocks. Sample increments were removed from the soil corer with a gloved hand and placed directly into a labeled, laboratory-provided PFAS-free bulk container (*QEC* 64 oz. HDPE wide-mouth containers). At locations where a field duplicate or matrix spike/matrix spike duplicate sample was being collected, additional increments were subsequently collected from the same quadrant and placed into the respective containers. After all increments had been collected from cell 1, this process was repeated in each subsequent cell until 30 increments had been collected (CEC 2023).

The soil samples were processed by Pace Analytical Laboratory according to strict ISM protocols and were analyzed for metals (arsenic, cadmium, mercury, and uranium), radionuclides (gross alpha/beta, gamma spectroscopy, and uranium isotopic), and organics (PCBs and PFAS) (CEC 2023).

Soil and sediment data were compared to EPA risk-based screening levels (SLs). SLs are risk-based chemical concentrations that correspond to fixed levels of risk in soil, air, and water. These concentrations are derived from standardized equations combining exposure information assumptions with EPA toxicity data. SLs are protective of human health over a lifetime, but do not address ecological impacts (EPA 2022). SLs are not cleanup standards, but are used to identify areas, contaminants, and conditions that require attention at a site (EPA 2022).

SEDIMENT

Sediment traps (Phillips et al. 2000) were deployed in streams for the purpose of sampling suspended sediment at EFK 23.3, EFK 2.2, and MBK 1.6 for approximately five (5) months before sample collection. The suspended sediment trap samples were collected in five-gallon buckets which were stored on ice in coolers. The samples were allowed to settle for approximately 72 hours. The ice in the coolers was replenished every 12 hours during this settling period. After the settling period, the supernatant water of the sediment samples was removed with a peristaltic pump. Subsequently, the remaining sediment for each sample was stirred thoroughly and spooned into sample containers, labeled, and sent to the laboratory for analysis. The analyses included all the same tests as the soil samples except for PFAS. Sampling was conducted in November 2022 and in June 2023.

BENTHIC MACROINVERTEBRATES

Please refer to the *Benthic Community Health Project* section of this EMR for information about methods, materials, and metrics for benthic macroinvertebrate sampling and processing.

BIOTA

Please refer to the *Mercury Uptake in Biota Project* section of this EMR for information about methods, materials, and metrics for biota sampling and processing.

FISH

To assess for risk associated with mercury and other potential COCs in the food web, fish tissue analysis was conducted on fish samples collected by CEC using electrofishing techniques in the stream reach from EFK 0.0 to EFK 2.2. The whole-body fish analysis was conducted on a composite sample of golden redhorse (*Moxostoma erythrurum*). Samples were analyzed for gross alpha, gross beta, gamma radionuclides, Sr-89,90, isotopic Uranium, isotopic Pu, Pu-241, C-14, Po-210, Tc-99, mercury, arsenic, cadmium, uranium, and PCBs.

8.2.6 DEVIATIONS FROM THE PLAN

CEC staff were unable to capture central stonerollers in the stream reach from EFK 0.0 to EFK 2.2, as specified in the EMP. Golden redhorse (*Moxostoma erythrurum*) were captured and analyzed instead.

8.2.7 RESULTS AND ANALYSIS

TOXICITY/BIOMONITORING:

Collection of surface water samples for toxicity/biomonitoring testing was conducted on Mondays, Wednesdays, and Fridays of each sampling week. Water samples were collected for analysis of toxicity for *Ceriodaphnia dubia* (water flea) and *Pimephales promelas* (fathead minnow). The biomonitoring analysis of surface water included nitrate, mercury, cadmium, uranium, gross beta, and PCBs. Gross alpha analysis was added to the analyte suite in winter 2023.

The sampling was conducted at five (5) locations by CEC with assistance from DoR-OR staff. The locations included the four (4) EFPC sites and MBK 1.6. (Table 8.2.4.1). To determine whether surface water or effluent was causing acute or chronic toxicity, the IC25 value was used. The IC25 value is a statistical calculation of the effluent concentration which causes a 25% reduction in survival, growth, or reproduction of test organisms.

<u>Ceriodaphnia dubia (water flea):</u>

TOXICITY

Water flea reproductive inhibition was demonstrated at EFK 23.3 during testing conducted in fall 2022 (Figure 8.2.7.1). Using the *Linear Interpolation Method*, the IC25 was reported as being greater than (>) 100% effluent for survival and equal to 19.4% effluent for reproduction for the fall 2022 testing. The overall IC25 is reported as the lesser of the two values (19.4% effluent). Since the IC25 result of 19.4% effluent was less than 100% effluent, this effluent was toxic to water flea reproduction at EFK 23.3 in fall 2022. In summer 2022 and winter 2023, EFK 23.3 had an IC25 score of >100% (no toxicity observed). Toxicity sampling was conducted during the week of spring 2023 with an IC25 score of 5.91%, again showing toxicity to water fleas.

Inhibition of water flea reproduction (IC25 = 89.6%) was observed in the summer 2023 sampling event at EFK 2.2. This was the only instance of water flea toxicity other than that observed at EFK 23.3.

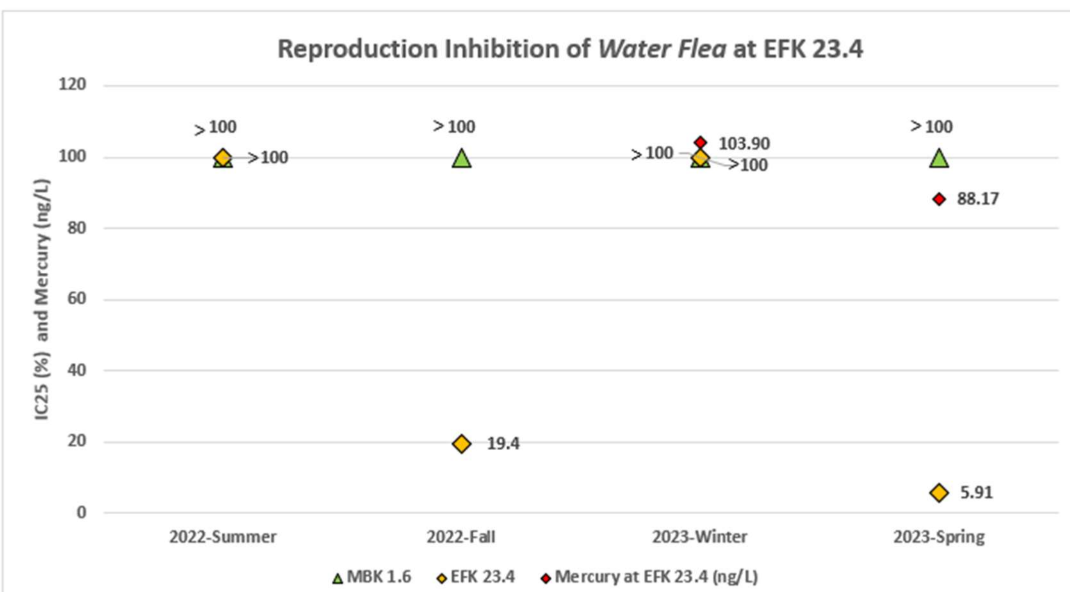

Figure 8.2.7.1: Inhibition of Reproduction of *Ceriodaphnia dubia* (water flea) at EFK 23.3 (2022-2023)

EFK 23.3

Uranium

Uranium data from the biomonitoring surface water samples was compared to the EPA Drinking Water MCL of 30 µg/L. EFPC is not used for drinking water; therefore, the MCL is used only as a reference. There was only one (1) exceedance of this criterion for FY23: EFK 23.3 had a uranium concentration of 44.6 µg/L on 3/3/2023.

Metals and Organics

Cadmium and PCBs were not detected in any of the surface water samples.

Mercury

Low-level mercury (EPA Method 1631E) analysis was added to the biomonitoring plan in winter 2023; mercury by EPA method 7470A was used previously. In the winter 2023 and spring 2023 samples, mercury concentrations in EFK 23.3 surface water samples exceeded the *Tennessee Recreation – Organisms Only* water quality criterion of 51 ng/L for mercury.

Nitrate

Nitrate was detected at very low concentrations in EFPC, much less than the MCL (10 mg/L).

***Pimephales promelas* (fathead minnow):**

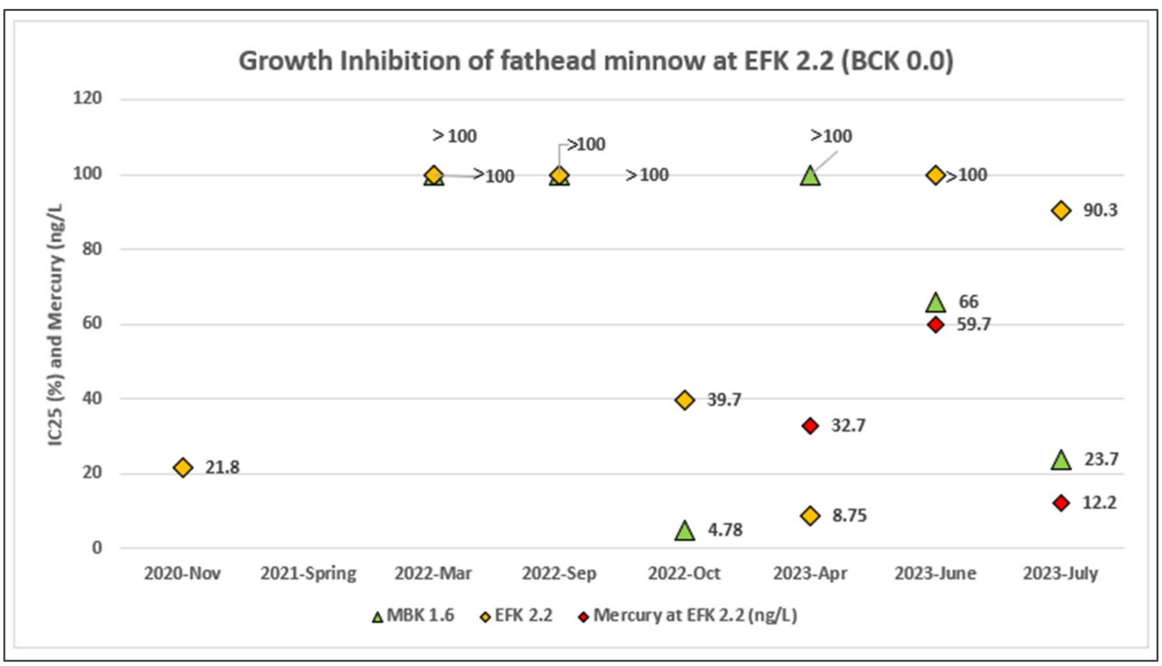

Figure 8.2.7.2 Inhibition of Growth of *Pimephales promelas* (fathead minnow) at EFK 2.2 (2020-2023)

EFK 2.2

Inhibition of the fathead minnow was demonstrated at EFK 2.2 (Figure 8.2.7.2). At EFK 2.2, the fall 2022 IC25 (growth) was 21.8%. In spring and summer of 2022, EFK 2.2 had an IC25 score of >100%, indicating no toxicity was observed. Fall of 2022 and spring of 2023 toxicity testing resulted in IC25 scores of 39.7% and 8.75%, respectively. The IC25 was >100% in the summer 2023 sampling event.

URANIUM AND NITRATE

Uranium was at low concentrations in the EFK 2.2 surface water samples collected, much lower than the MCL. Also, nitrate was consistently low in all the EFPC surface water samples.

MERCURY

Mercury exceeded the TDEC's *General Water Quality Criteria Chapter 0400-40-03-.03 Tennessee Recreation Organisms-Only* limit of 51 ng/L in summer 2023 at EFK 2.2.

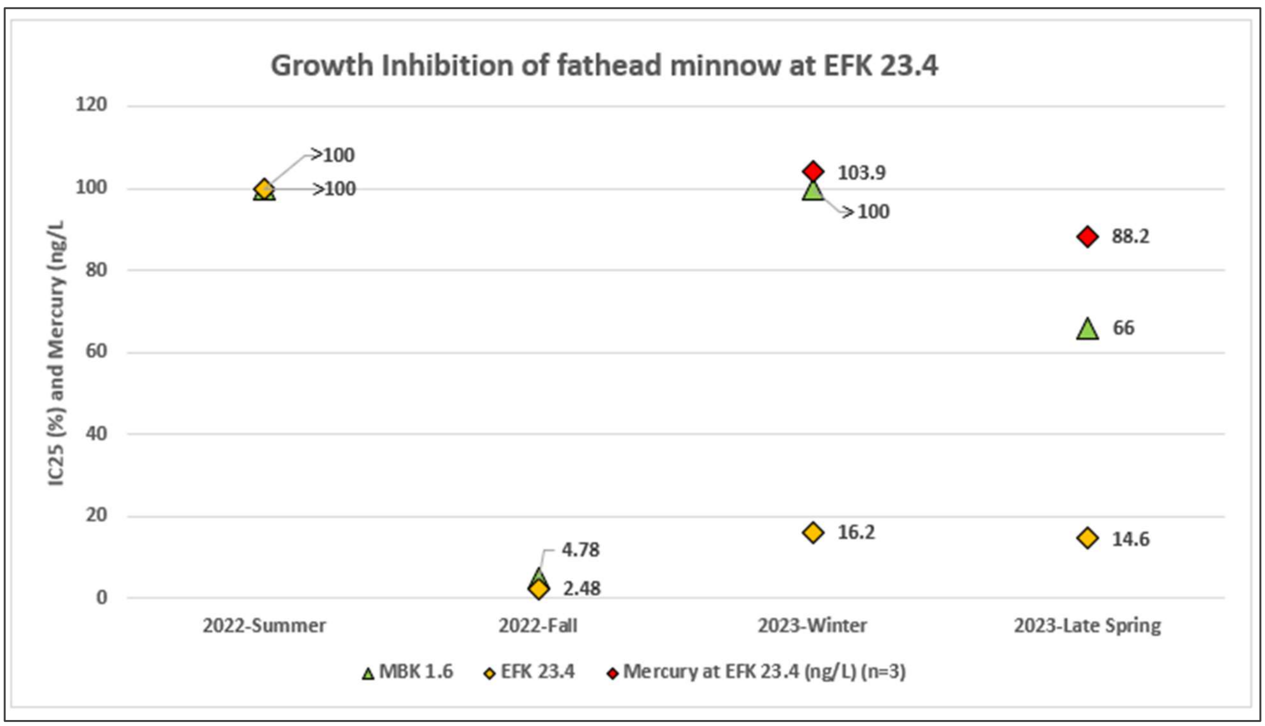

Figure 8.2.7.3: Inhibition of Growth of *Pimephales promelas* (fathead minnow) at EFK 23.3 (2022-2023)

EFK 23.3

At EFK 23.3, growth inhibition of fathead minnow was observed in the Fall 2022, winter, and late spring 2023 toxicity sampling event results (Figure 8.2.7.3). The background site, MBK

1.6 also had a low IC25 score in Fall 2022.

Mercury and Uranium

Mercury results from winter and late spring 2023 were greater than the *Tennessee Recreation Organisms-Only* limit of 51 ng/L (Figure 8.2.7.3). The uranium results from 3/3/2023 in winter 2023 (44.6 µg/L) exceeded the MCL of 30 µg/L.

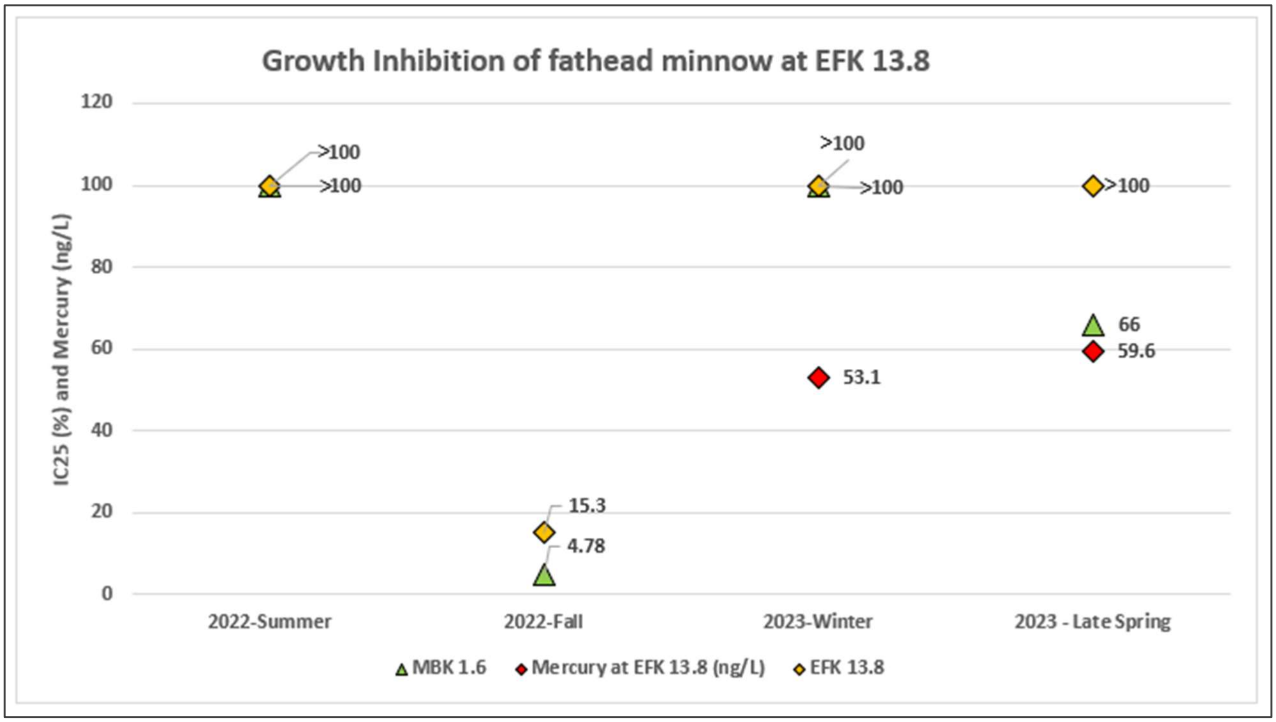

Figure 8.2.7.4: Inhibition of Growth of *Pimephales promelas* (fathead minnow) at EFK 13.8 (2022-2023)

EFK 13.8

Growth inhibition was observed at EFK 13.8 from the results of the Fall 2022 toxicity sampling event. All the other toxicity tests had IC 25 values of >100%.

Mercury

The mercury data from winter and late spring 2023 exceed TDEC's *General Water Quality Criteria Chapter 0400-40-03-.03* for *Recreation Organisms-Only* limit of 51 ng/L (Figure 8.2.7.4).

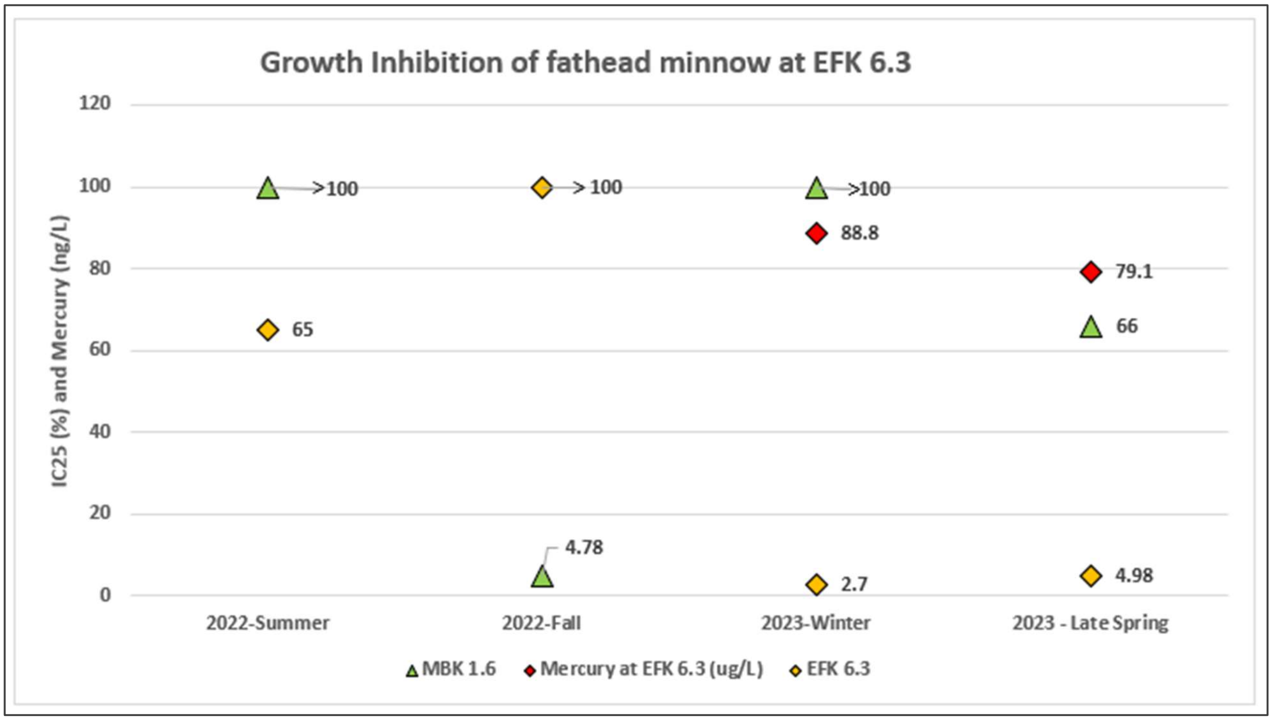

Figure 8.2.7.5: Inhibition of Growth of *Pimephales promelas* (fathead minnow) at EFK 6.3 (2022-2023)

EFK 6.3

EFK 6.3 toxicity testing resulted in three (3) out of four (4) instances of observed toxicity for fathead minnow. Fall of 2022 was the only time this site had a passing score of >100%.

Mercury and Uranium

In winter and late spring of 2023, mercury exceeded TDEC's *General Water Quality Criteria Chapter 0400-40-03-.03 Tennessee Recreation Organisms-Only* limit of 51 ng/L (Figure 8.2.7.5). Uranium concentrations ranged from 2.55 µg/L to 4.96 µg/L and were less than the MCL of 30 µg/L.

Gross Alpha and Beta

Gross alpha activity was higher than the background site with a mean of 6.2 pCi/L (n=12) for all the EFPC sites. The background site, MBK 1.6, had a gross alpha mean (n=3) of 1.2 pCi/L. Gross alpha activities generally decrease from EFK 23.3 downstream. There were no exceedances of the EPA drinking water MCL for gross alpha (15 pCi/L).

The mean of EFPC gross beta activity (n=24) was 5.9 pCi/L. MBK 1.6 had a gross beta mean (n=6) of 2.7 pCi/L. The drinking water MCL for gross beta is based on dose and is 4 mrem/year to the total body or any critical organ. A total of 179 individual beta particle and photon emitters may be used to calculate compliance with the MCL. The EFPC gross beta data did not exceed EPA's 50 pCi/L screening level for community water systems determined to be vulnerable by the State (EPA 2000). Although EFPC is not a drinking water source, the screening level is used as a reference.

SOILS:

No PCBs were quantified in the sample from near Clear Creek; however, Aroclor 1260 was quantified in each of the samples from the floodplains near EFPC sites and were at concentrations less than the EPA risk-based SLs for residential soil under direct contact exposure (Figure 8.2.7.7).

PFAS compounds perfluorobutanoic acid (PFBA) and perfluorooctanesulfonic acid (PFOS) were quantified at low levels from each soil sampling location. Estimated concentrations of up to seven (7) additional PFAS compounds were reported in the three (3) samples from the EFPC locations. EPA risk-based SLs for residential soil have been established for six (6) of the PFAS compounds analyzed. Where SLs do exist, the quantified concentrations are reported below the established SLs.

Arsenic, cadmium, mercury, and uranium were quantified in each of the samples. Arsenic levels were highest at CCK 1.6, with the concentration of 12.2 mg/kg reported above the SL of 6.77 mg/kg. Arsenic in the remaining samples were quantified below the SL. Mercury at EFK 13.8 (60.2 mg/kg) and EFK 6.3 (26.4 mg/kg) were reported above the SL of 10.9 mg/kg. Cadmium and uranium were reported below the SLs at all locations.

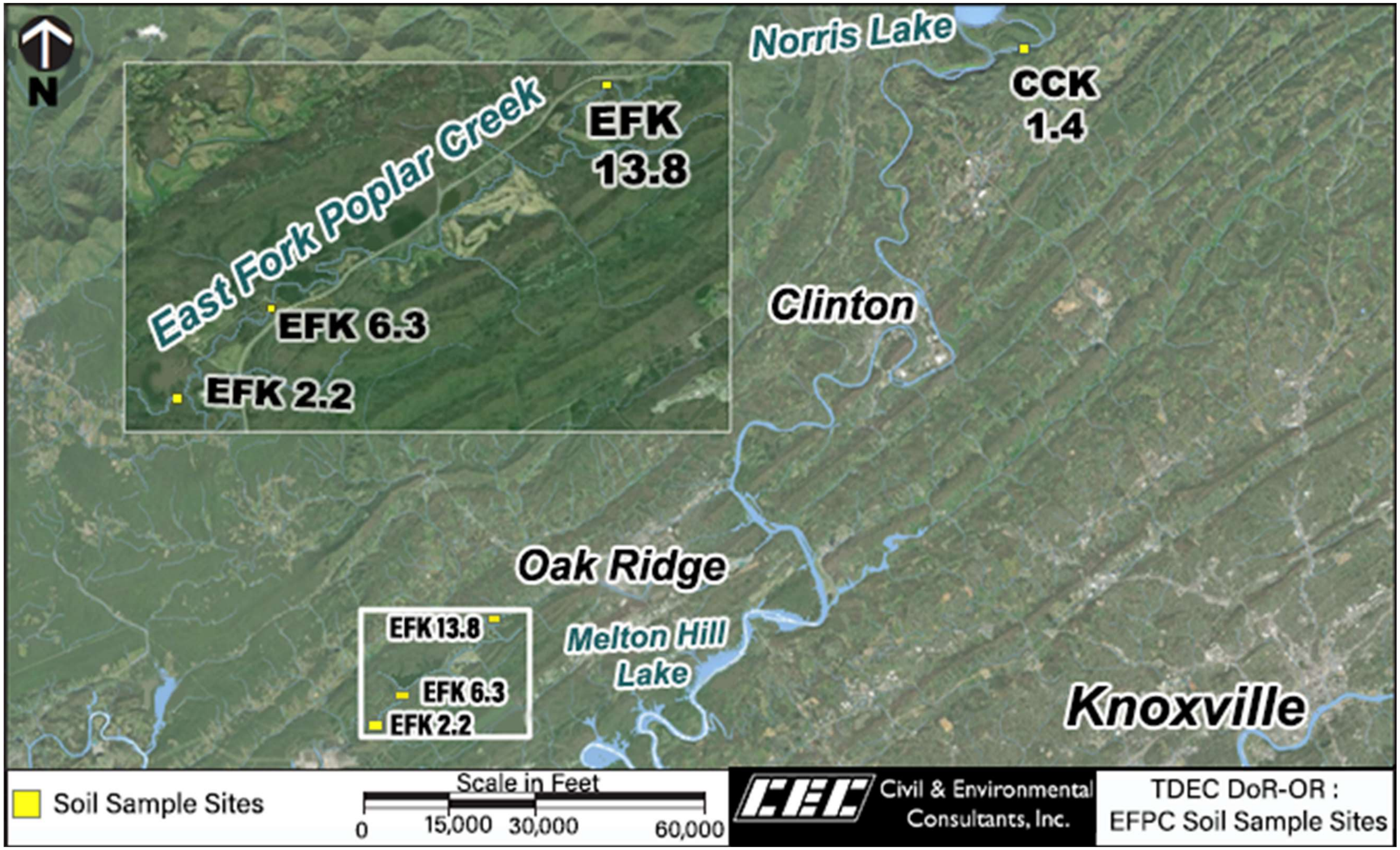

Figure 8.2.7.6: Map of Soil Sampling Locations (CEC 2023)

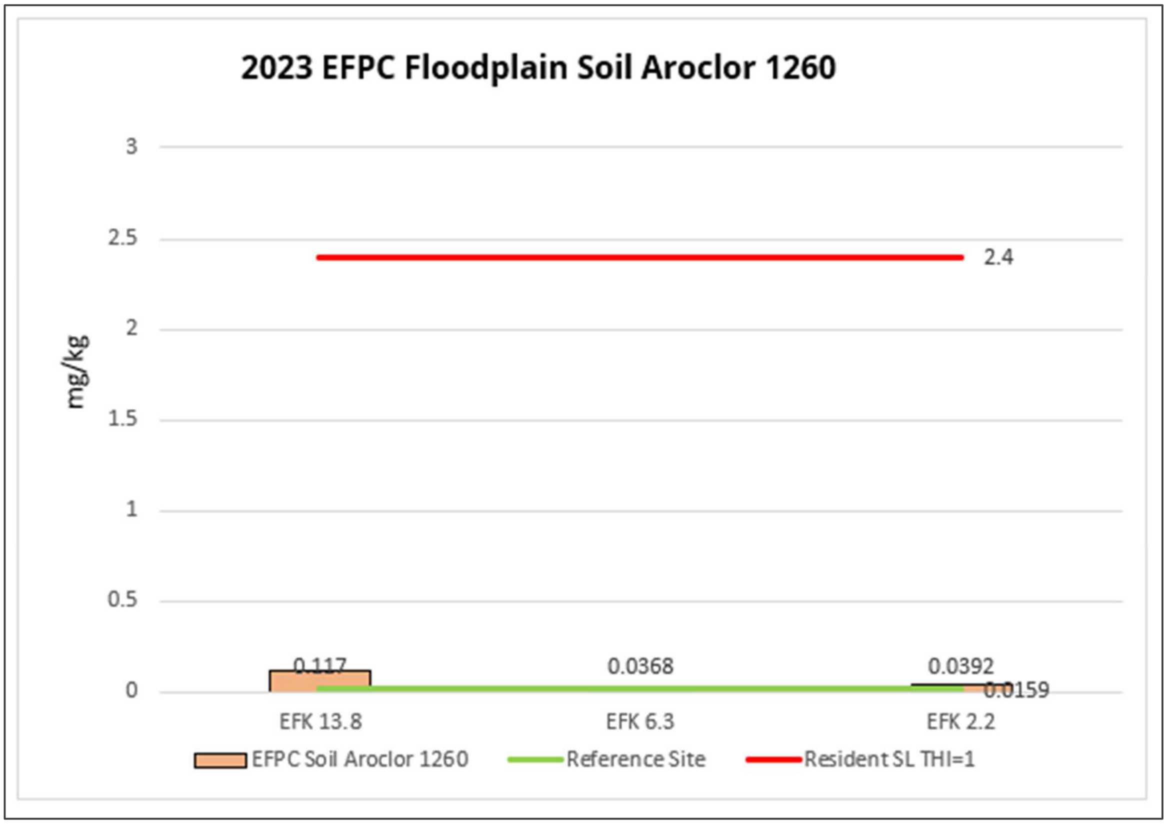

Figure 8.2.7.7: EFPC Floodplain Soil Aroclor 1260 (FY23)

Aroclor 1260 was detected at each of the EFPC sites at concentrations well below the EPA resident SL. Aroclor 1260 was the only PCB compound detected at the sampling sites.

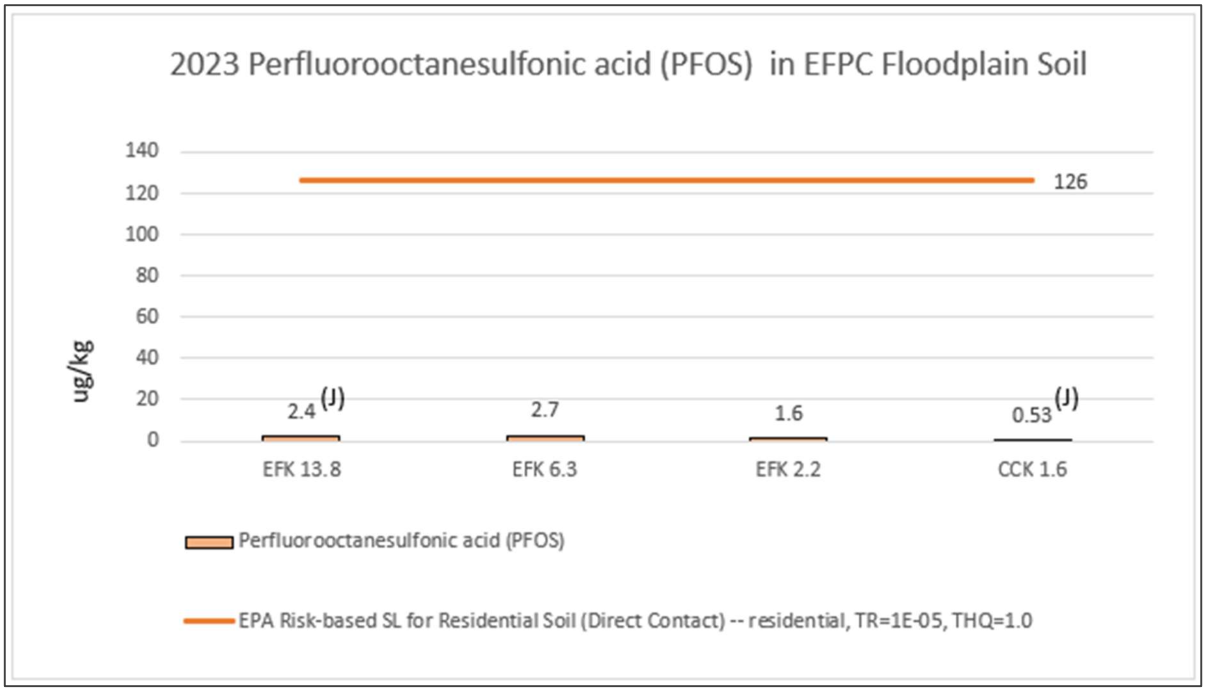

Figure 8.2.7.8: 2023 EFPC Floodplain Soil PFOS

PFOS were detected in low concentrations in EFPC soils, well below the EPA SL.

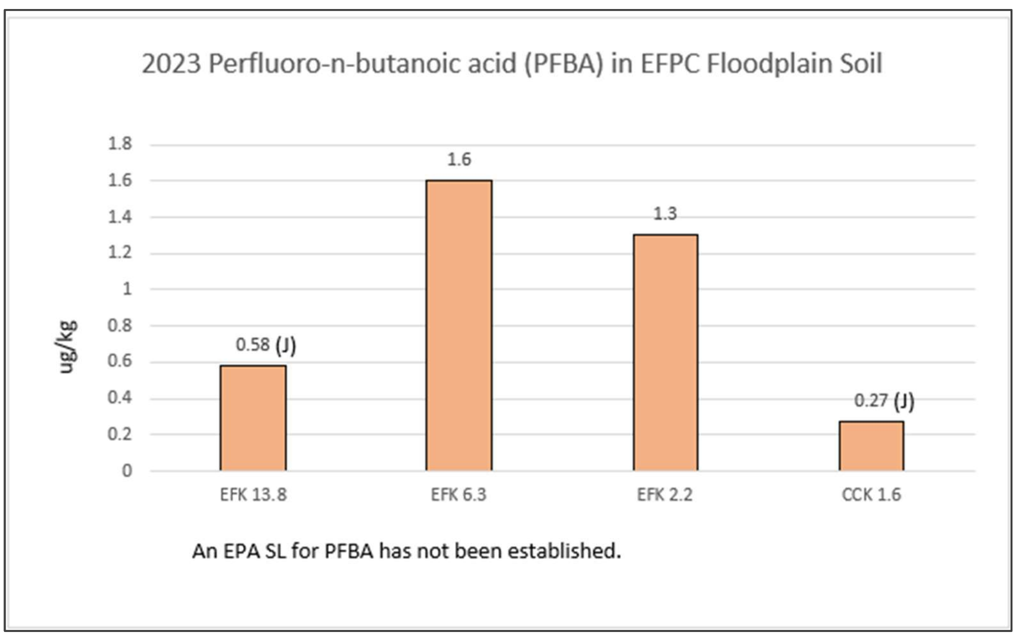

Figure 8.2.7.9: 2023 EFPC Floodplain Soil PFBA

PFBA was detected in all of the sampling sites. At the time of data collection, no EPA SLs for PFBA have been promulgated.

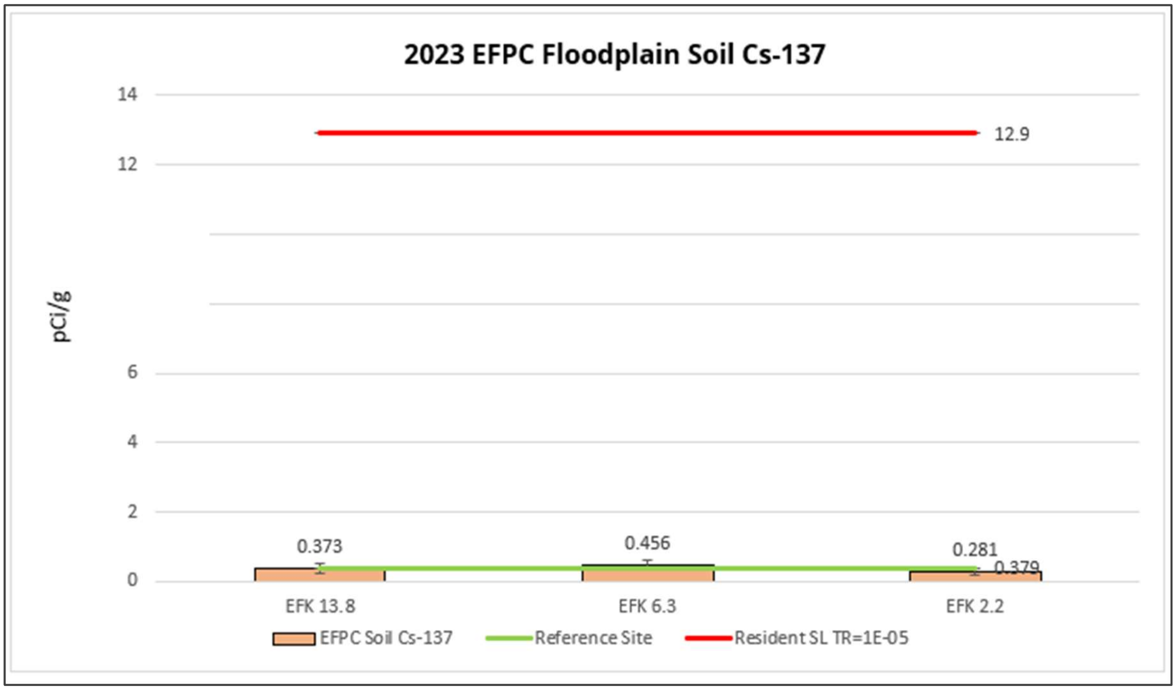

Figure 8.2.7.10: 2023 EFPC Floodplain Soil Cs-137

Cs-137 is present at all the sites, but at activities well below the SL.

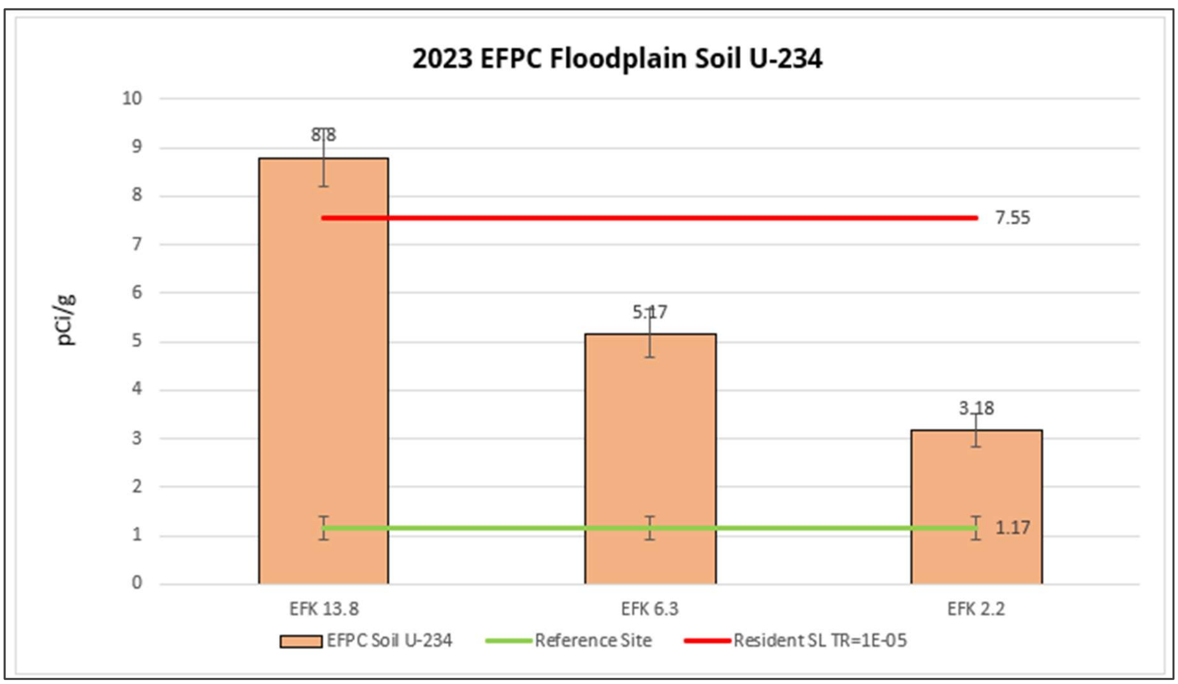

Figure 8.2.7.11: 2023 EFPC Floodplain Soil U-234

U-234 was detected at all the sites with only EFK 13.8 exceeding the EPA Resident SL.

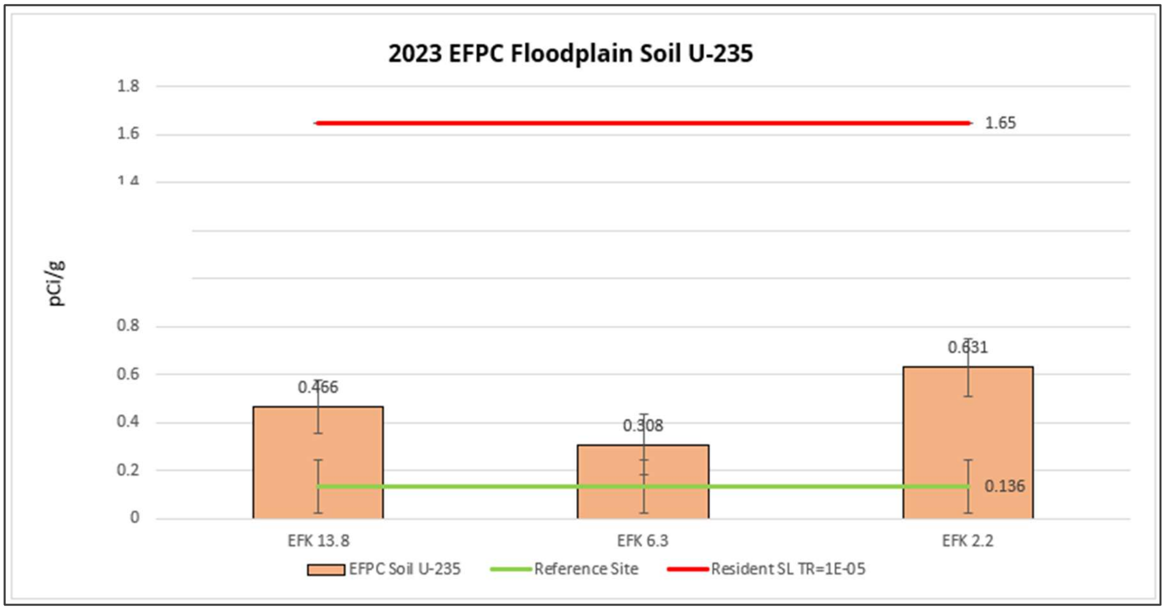

Figure 8.2.7.12: 2023 EFPC Floodplain Soil U-235

U-235 was found at each of the sampling sites at levels below the EPA Resident SL.

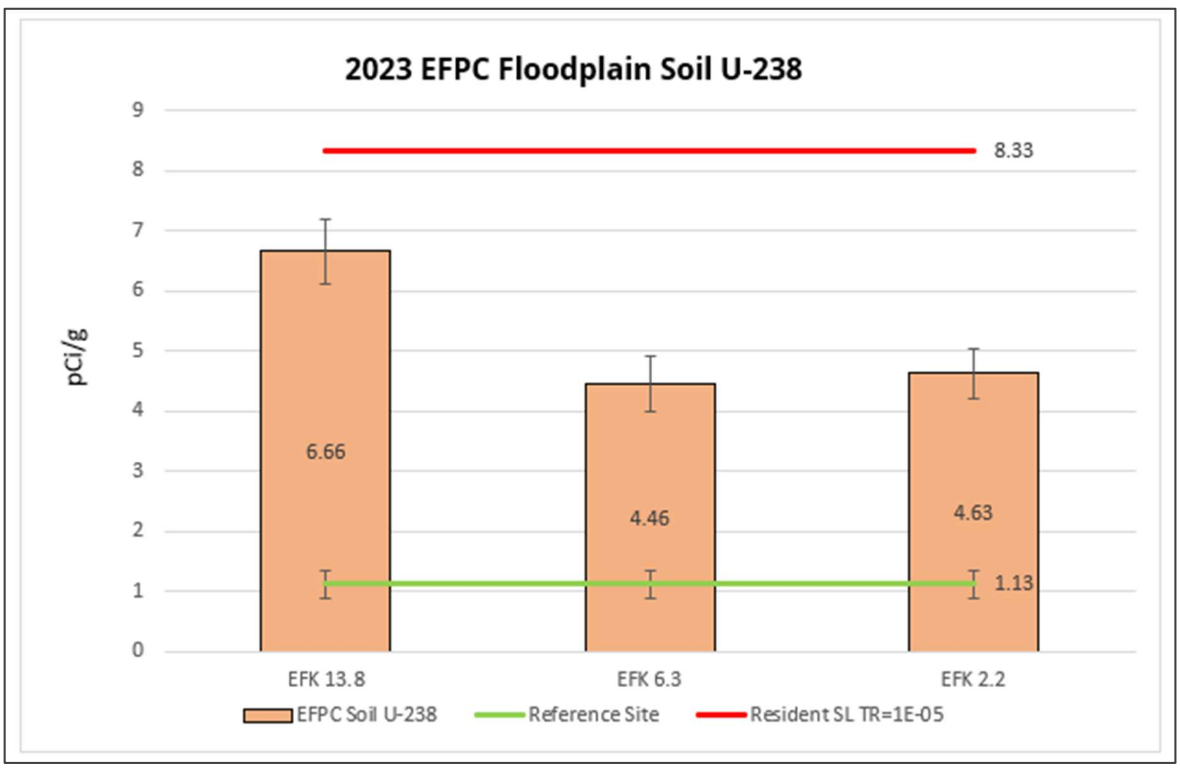

Figure 8.2.7.13: 2023 EFPC Floodplain Soil U-238

The levels of U-238 found at the sampling sites are less than the EPA Resident SL.

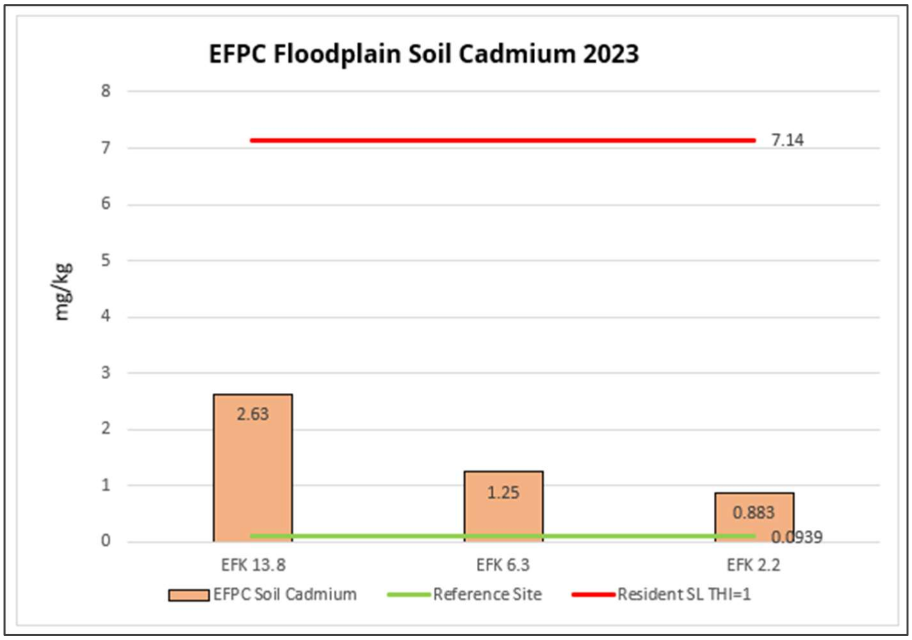

Figure 8.2.7.14: 2023 EFPC Floodplain Soil Cadmium

Cadmium soil concentrations decrease downstream of EFK 13.8. The results are less than the EPA Resident SL.

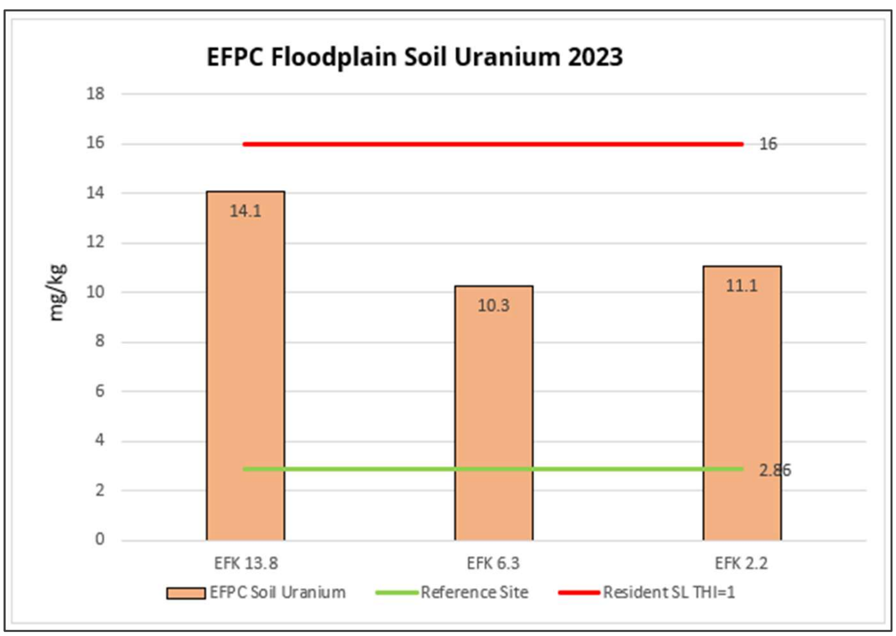

Figure 8.2.7.15: 2023 EFPC Floodplain Soil Uranium

Soil uranium metal concentrations are elevated at EFPC sampling sites and, at EFK 13.8, approach the EPA Resident SL.

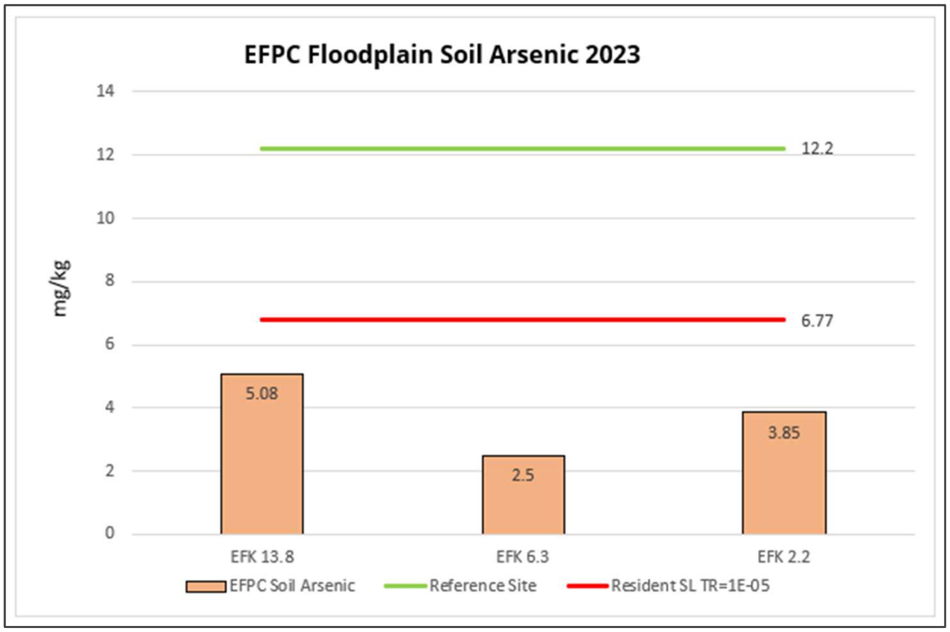

Figure 8.2.7.16: *2023* EFPC Floodplain Soil Arsenic

The arsenic concentration at the background site, CCK 1.6, exceeded the EPA Resident SL TR=1E-05 (6.77 mg/kg). It is unclear why the background site had such an elevated concentration of arsenic. The EFPC soils had arsenic concentrations less than the SL.

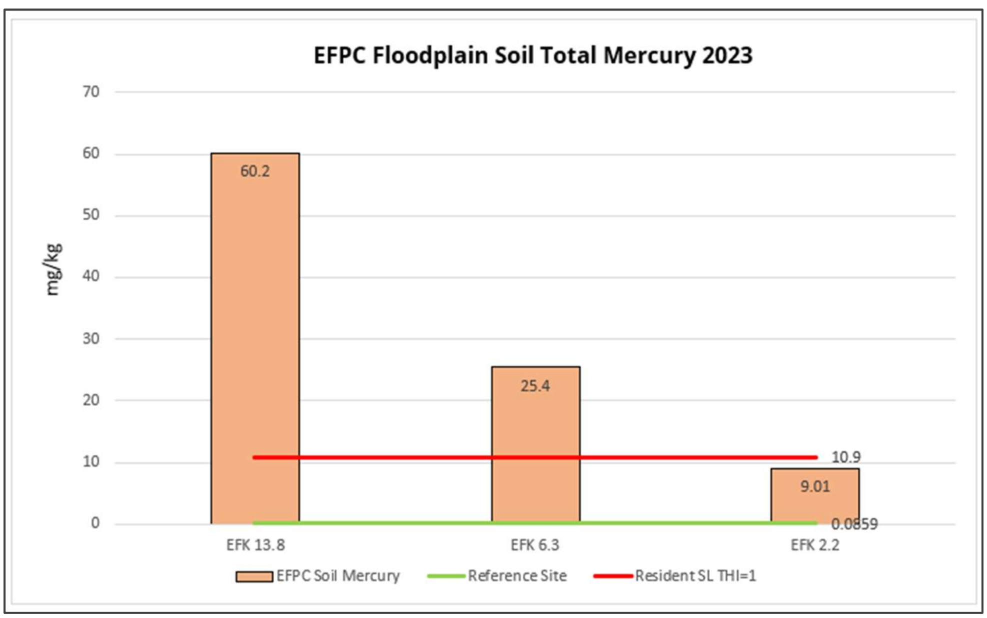

Figure 8.2.7.17: *2023* EFPC Floodplain Soil Mercury

The EPA Resident SL for mercury was exceeded at EFK 13.8 and EFK 6.3.

AMBIENT SURFACE WATER:

Please refer to the *Ambient Surface Water Project* section of this EMR.

SUSPENDED SEDIMENT:

Project staff conducted suspended sediment sampling at EFK 23.3, EFK 2.2 (BCK 0.0), and MBK 1.6. (Table 8.2.7.2) on November 10, 2022, and on June 15, 2023. The results from the June 15, 2023, sampling event have not yet been reported.

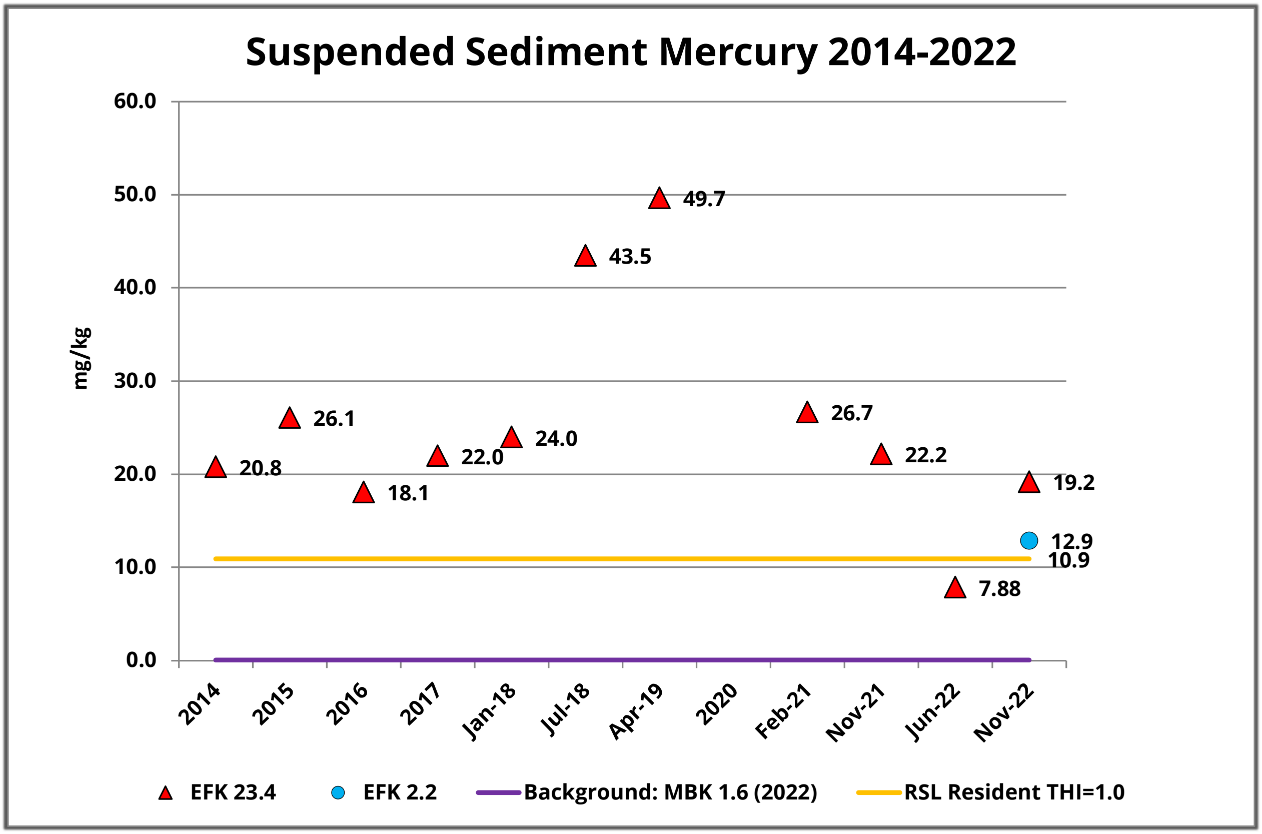

Figure 8.2.7.18 Mercury in EFPC Suspended Sediment (2014-2022)

The suspended sediment mercury results are graphed in Figure 8.2.7.18. These data are compared to EPA SLs. Except for June 2022, the suspended sediment results from the EFPC sampling sites were greater than the mercury SL; THI=1, Resident Soil 10.9 mg/kg.

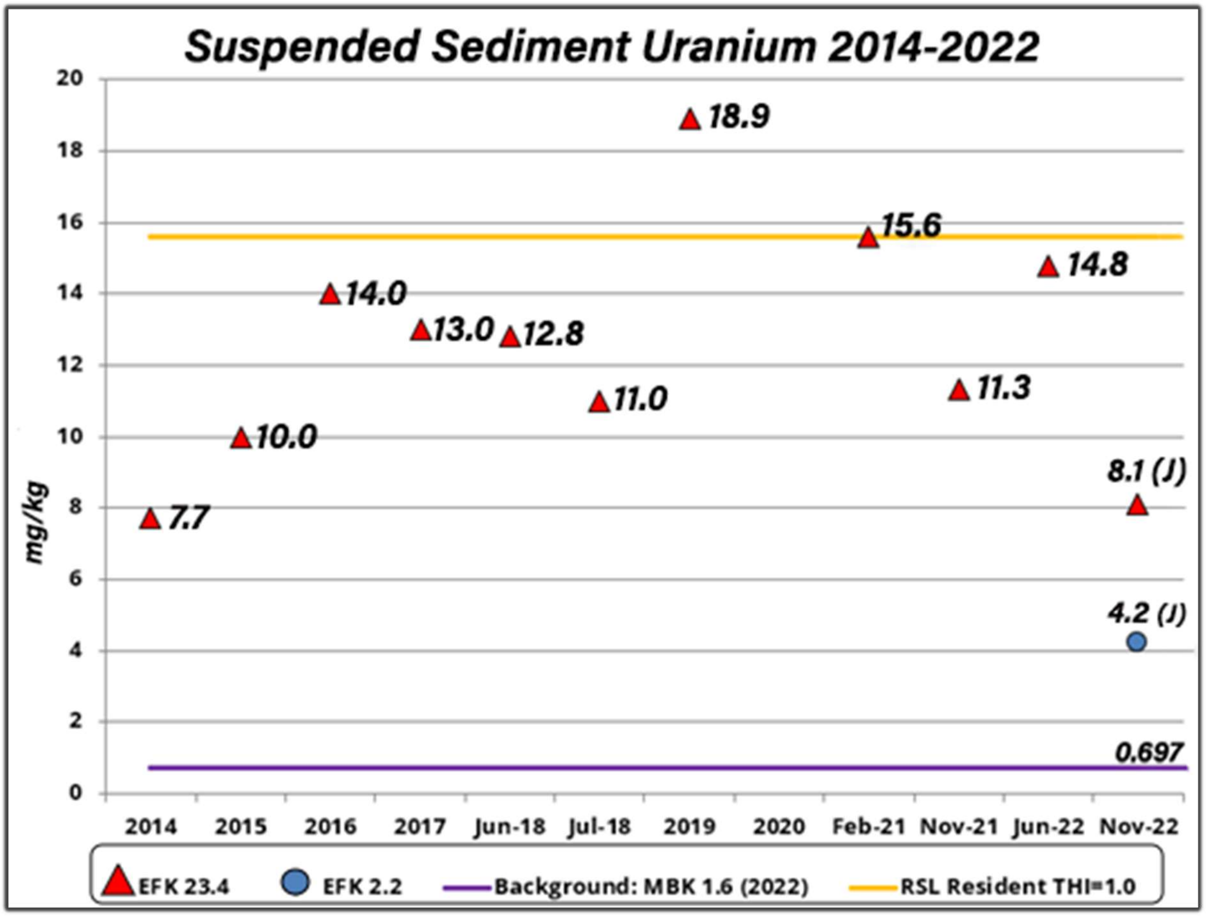

Figure 8.2.7.19: Uranium in EFPC Suspended Sediment (2014-2022)

Sediment uranium results from EFK 23.3 were lower than the Resident Soil SL (THI=1) of 15.6 mg/kg in most suspended sediment samples except in 2019 and February 2021 (Figure 8.2.7.19). Uranium was detected and given estimated (J) values in the November 2022 sediment samples from EFK 23.3 and EFK 2.2. Pace Analytical was contacted about these (J) values and their high RDLs for uranium in the November 2022 samples and responded that the samples had low Total Solids percentages and that adjusted the RDLs much higher than what they would be with 100% solids. Prior to November 2022, sediment samples were analyzed by the TDH-NEL with EPA method 200.8. The November 2022 samples were analyzed by Pace Analytical Laboratories using EPA method 6020. EFK 2.2 was sampled for the first time in November 2022.

Cadmium results at EFK 23.3 and EFK 2.2 were (J) values. These (J) values were much lower than the Resident SL of 8.14 mg/kg.

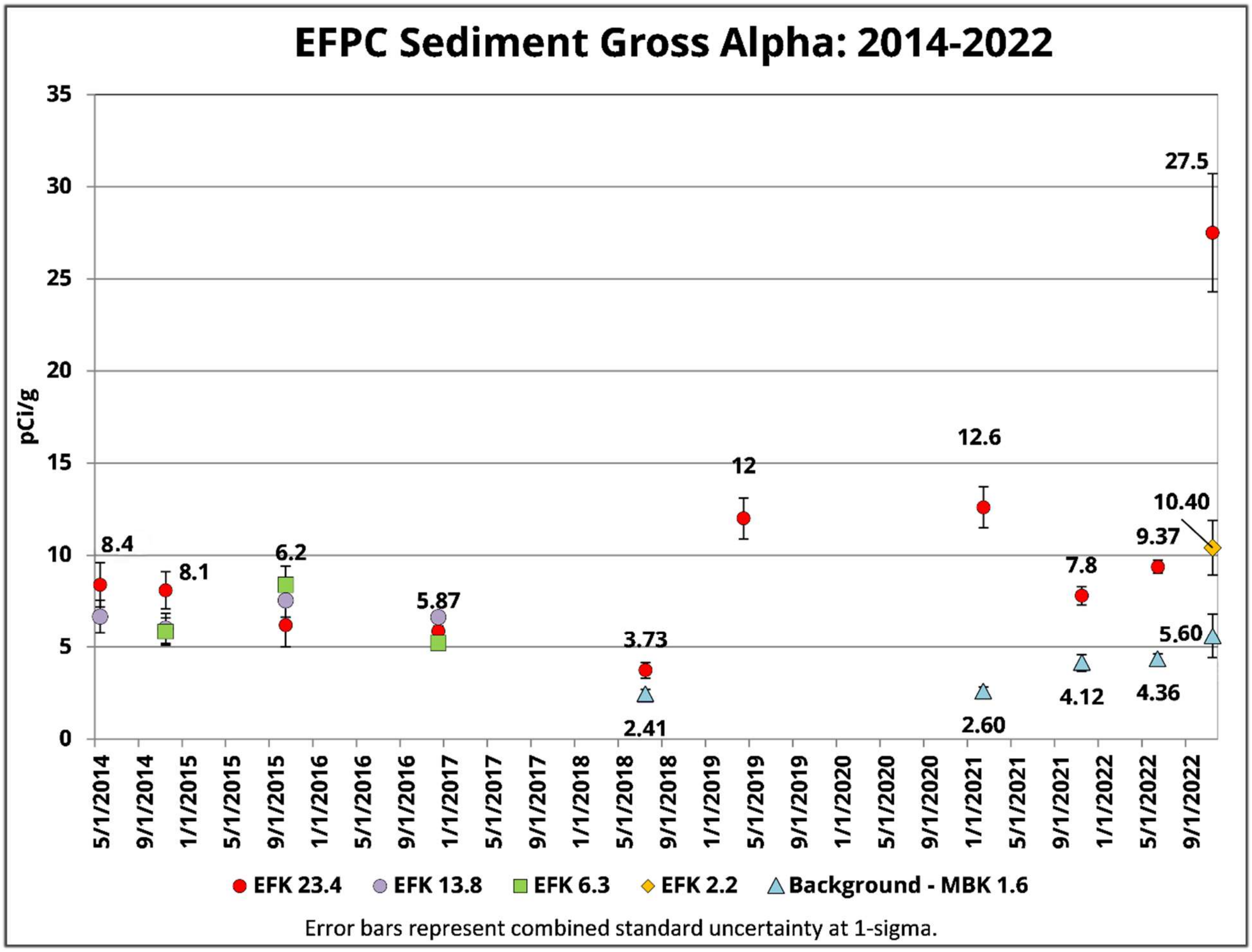

Figure 8.2.7.20: Gross Alpha in EFPC Suspended Sediment (2014-2022)

Gross alpha activities were greater than background (MBK 1.6) in all cases (Figure 8.2.7.20). MBK 1.6 suspended sediment sampling was initiated in 2018. In November of 2022, gross alpha activity (27.5 pCi/g) was the highest yet recorded at EFK 23.3. Suspended sediment sampling at EFK 2.2 began in November 2022. There are no EPA screening levels for gross alpha in soils or sediments. Uranium in the suspended sediment samples (Figure 8.2.7.20) may be the source of the slightly elevated gross alpha activity in EFPC. Although the uranium concentration for November 2022 (Figure 8.2.7.18) was a J value, there was a change in laboratory used and the analytical method (EPA 6020) used to analyze the sediment sample. Based on past uranium results at EFK 23.3, the uranium concentration may have been higher had the previous analytical method (EPA 200.8) been used.

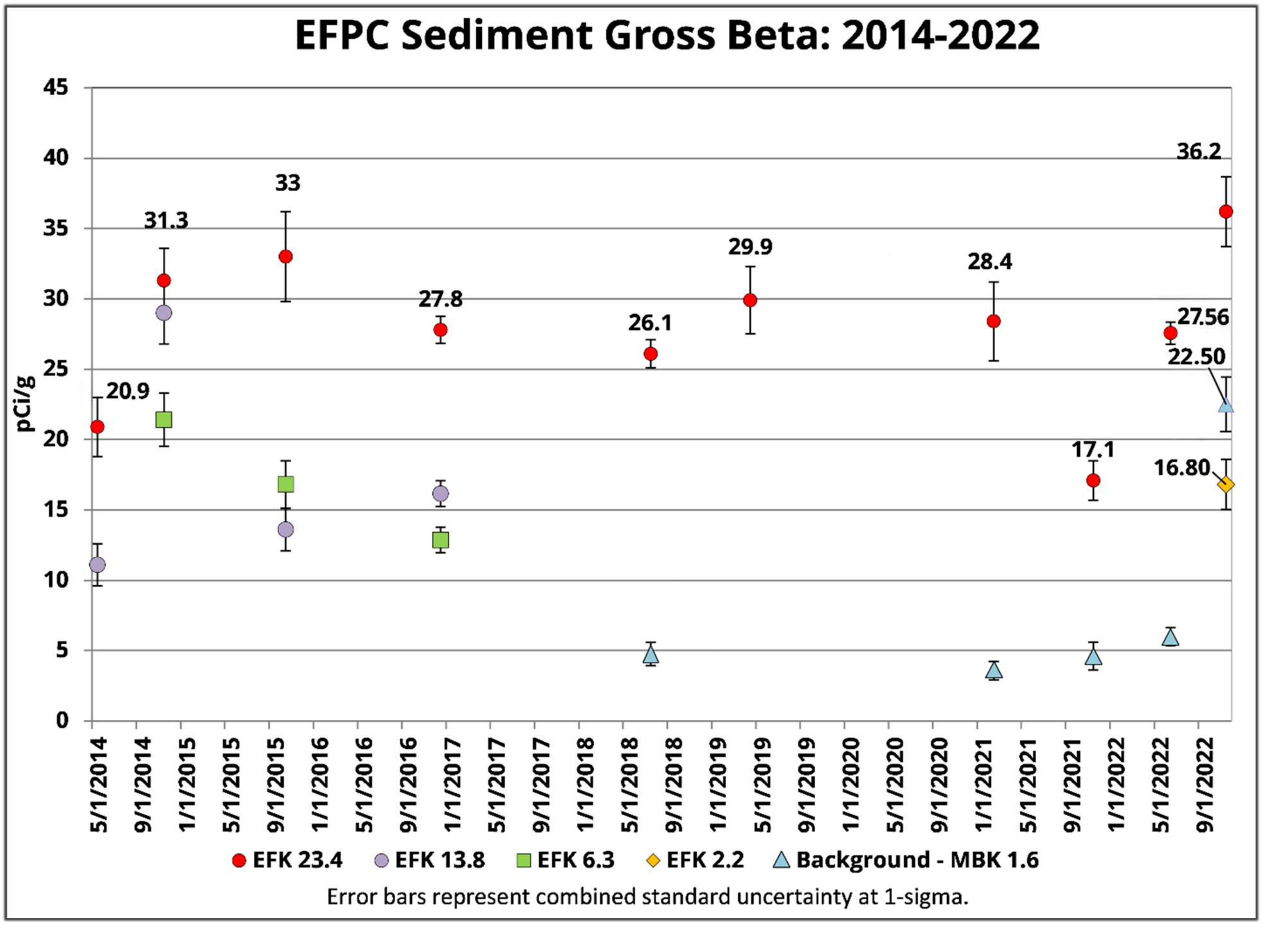

Figure 8.2.7.21: Gross Beta in EFPC Suspended Sediment (2014-2022)

Gross beta activity was greater than background in the EFK 23.3 suspended sediment samples (Figure 8.2.7.21). Both the U-238 and U-235 decay series produce several beta-emitting daughter nuclides with very short half-lives, (e.g., bismuth-214 and lead-214) and may be causing the elevated beta radioactivity in suspended sediment at EFK 23.3. The June 2023 results have not yet been received from the laboratory. There are no EPA screening levels for gross beta in soils or sediments.

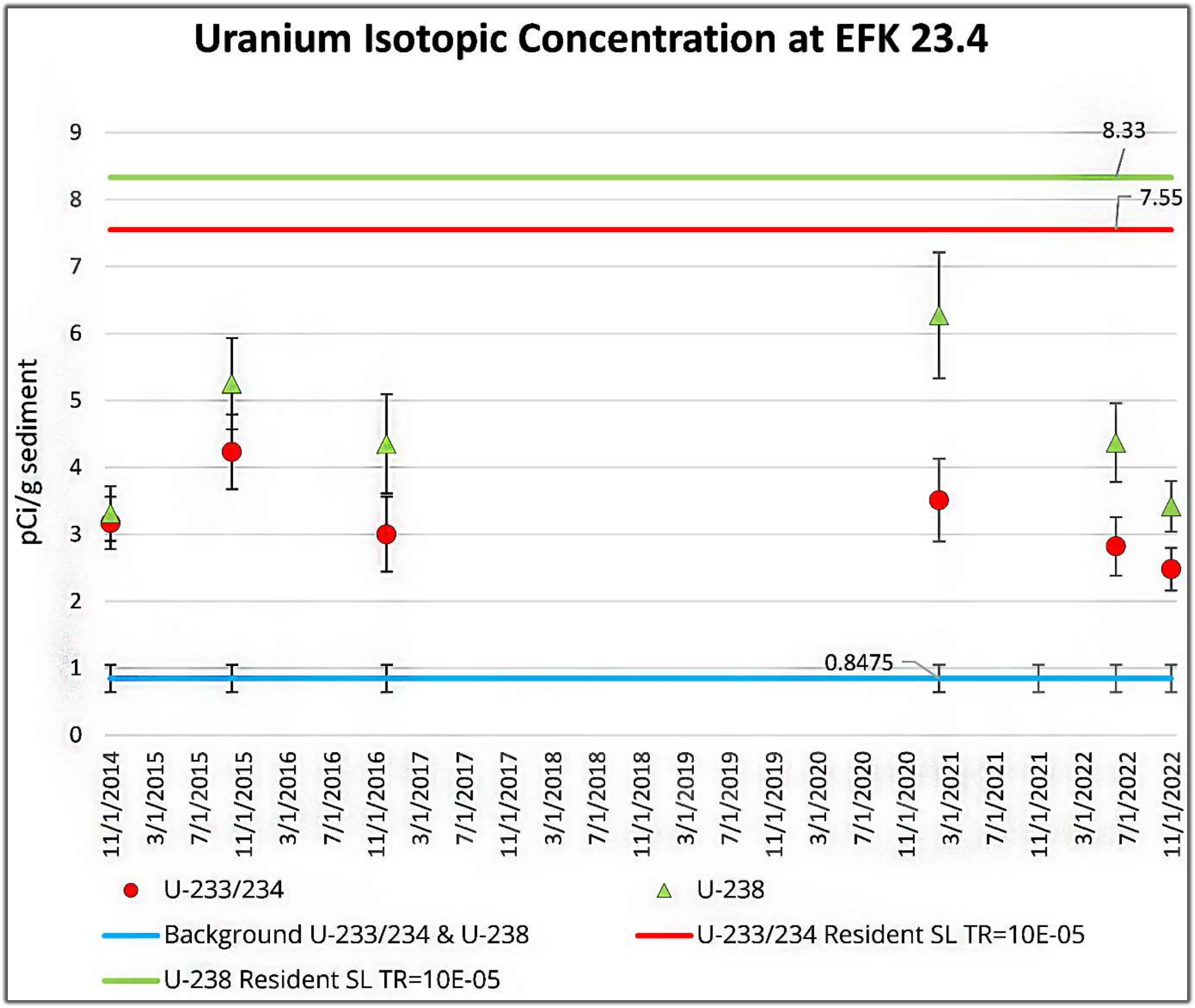

Figure 8.2.7.22: Uranium Isotopic Concentration in EFK 23.3 Suspended Sediment (2014-2022)

Uranium isotopic data show that EFK 23.3 results for both U-233/234 and U-238 are below the EPA Resident SLs (Figure 8.2.7.22). U-235 activities were very low and could not be quantified due to high combined standard uncertainties. EFK 2.2 suspended sediment was first sampled in November of 2022 and had activities of 1.68 ± 0.333 pCi/g for U-234 and 2.70 ± 0.400 pCi/g for U-238. Strontium-89/90 analysis for the November 2022 suspended sediment samples produced non-detects and one J value with a high combined standard uncertainty.

BENTHIC MACROINVERTEBRATES:

Please refer to the *Benthic Community Health* section of this EMR for information about EFPC benthic communities.

FISH:

The golden redhorse (*Moxostoma erythrurum*) is a bottom-feeder that consumes microcrustaceans, aquatic insects, detritus, algae, and small mollusks. This species is a member of the sucker family, *Catostomidae*, and a game fish. Surprisingly, this sucker is not commonly pursued by anglers. The substitution of the central stoneroller with the golden redhorse may seem unusual because they belong to different families. However, both species fill similar niches and have similar dietary habits.

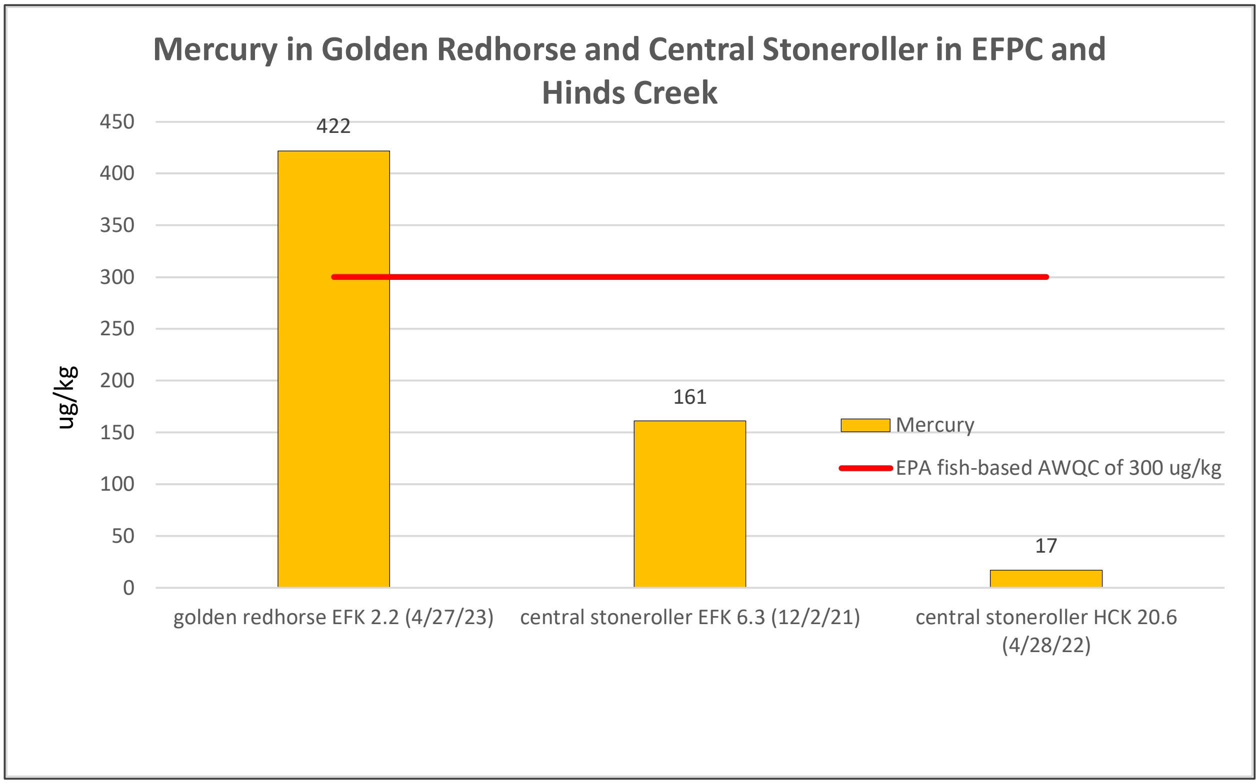

Figure 8.2.7.23 Total Mercury in EFPC Golden Redhorse and Central Stoneroller (2021-2023)

The golden redhorse data were compared to central stoneroller data obtained from DOE's OREIS database (Figure 9.8.2.23). Due to the absence of historical data on the golden redhorse, this other data set was used. Due to these limitations, EFK 6.3 data was used for comparison because of its proximity to EFK 2.2.

Central stoneroller data from Hinds Creek (HCK 20.6) (4/28/2022) were used for reference. The golden redhorse at EFK 2.2 had mercury concentrations greater than the EPA fish based AWQC of 300 ug/kg for fillets (DOE 2022 RER). Arsenic, cadmium, and uranium were not detected in golden redhorse from this sampling event.

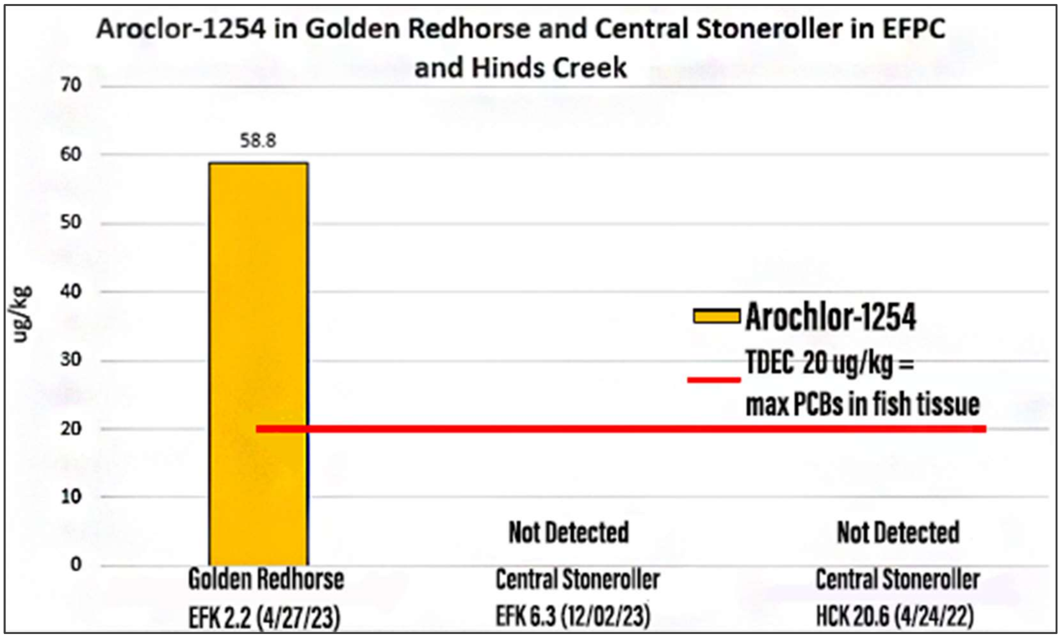

Figure 8.2.7.2 Aroclor-1254 in EFPC Golden Redhorse and Central Stoneroller (2021-2023)

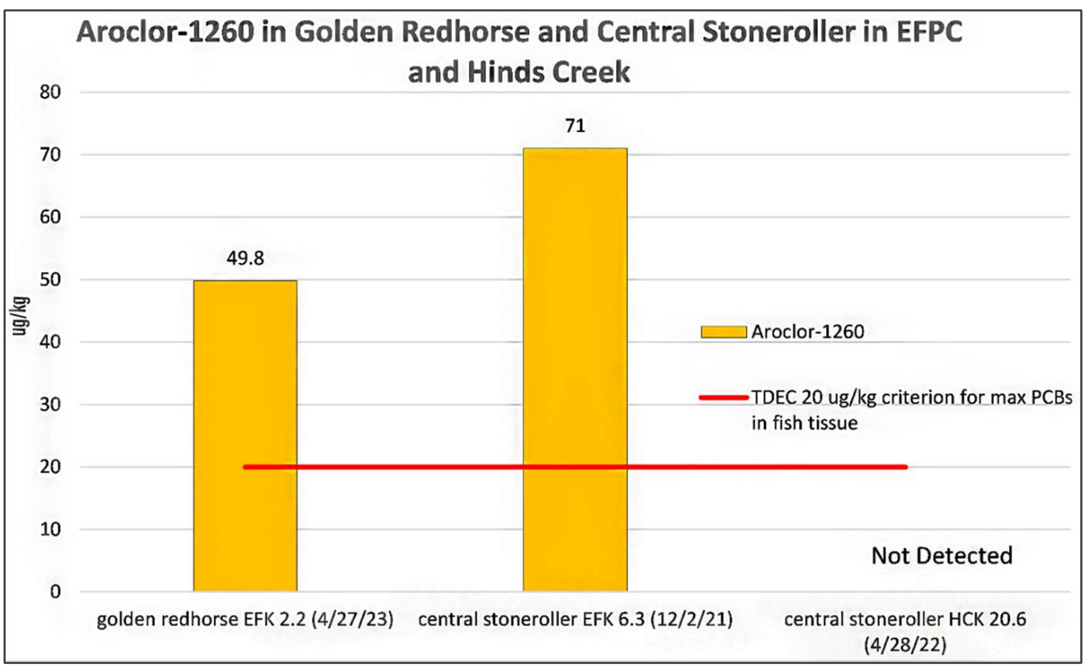

Figure 8.2.7.25 Aroclor-1260 in EFPC Golden Redhorse and Central Stoneroller (2021-2023)

Aroclor-1254 and Aroclor-1260 were the only PCB compounds detected in the golden redhorse tissue. Aroclor-1254 was not detected in central stoneroller at EFK 6.3 or HCK 20.6 (Figure 9.8.2.23). Aroclor-1260 was detected in central stoneroller at EFK 6.3, but not at HCK 20.6 (Figure 9.8.2.24). Where these Aroclors were detected, concentrations were greater than the TDEC 20 ug/kg criterion for maximum PCBs in fish tissue (DOE 2022 RER).

Table 8.2.7.1: Analytes Not Detected in Golden Redhorse

Analytes Not Detected in Golden Redhorse				
Actinium-228	Cerium-141	Iron-59	PCB-1248	Strontium-90
Alpha activity	Cerium-144	Lead-210	PCB-1262	Technetium-99
Americium-241	Cesium-134	Lead-212	PCB-1268	Thallium-208
Antimony-124	Cesium-136	Lead-214	Plutonium-238	Thorium-234
Antimony-125	Cesium-137	Manganese-54	Plutonium-239/240	Tin-113
Arsenic	Chromium-51	Mercury-203	Plutonium-241	Uranium
Barium-133	Cobalt-56	Neodymium-147	Polonium-210	Uranium-233/234
Barium-140	Cobalt-57	Neptunium-239	Promethium-144	Uranium-235
Beryllium-7	Cobalt-58	Niobium-94	Promethium-146	Uranium-235/236
Bismuth-212	Cobalt-60	Niobium-95	Radium-228	Uranium-238
Bismuth-214	Europium-152	PCB-1016	Ruthenium-106	Uranium-238
Cadmium	Europium-154	PCB-1221	Silver-110m	Yttrium-88
Carbon-14	Europium-155	PCB-1232	Sodium-22	Zinc-65
Cerium-139	Iridium-192	PCB-1242	Strontium-89	Zirconium-95

Many analytes were not detected in golden redhorse tissue (Table 8.2.7.1). Beta activity (2.82 pCi/g) and Potassium-40 (3.61 pCi/g) were detected at very low concentrations. Radiological contamination of golden redhorse has not been observed in these data.

BIOTA:

Please refer to the *Mercury Uptake in Biota Project* section of this EMR.

Holistic Results for Phase 2 - FY23:

Table 8.2.7.2: Holistic EFPC Results

Media	*Parameter*	*EFK 23.3*	*EFK 13.8*	*EFK 6.3*	*EFK 2.2*	*MBK 1.6*	*CCK 1.6*	*HCK 20.6*
1. ASW	*							
2. GW	FY24							
3. Sediment	Mercury Uranium Cadmium	**> SL J**			**> SL** J J			
	Gross Alpha Gross Beta Isotopic U	**> BG** **> BG** < SL	**> BG** **> BG** < SL	**> BG** **> BG** < SL	**> BG** **> BG** < SL			
4. Soils	Aroclor 1260 PFBA PFOS Arsenic Mercury U-234 U-235 U-238 U metal	< SL **Present** **Present**	< SL J **Present** < SL **> SL** **> SL** < SL < SL **= SL**	< SL **Highest** **Highest** < SL **> SL** < SL < SL < SL < SL	 < SL < SL < SL < SL < SL < SL		**> SL** J J J	
5. Toxicity & Bio-monitoring	Su22 F22 W23 Sp23 Su23 F23	 **Toxic R & G** **U** **Toxic R & G,** **Hg** **U**	 **Toxic G** **Hg** **Hg**	**Toxic G** **Toxic G,** **Hg** **Toxic G,** **Hg**	 **Toxic G** **Toxic G** **Toxic R,** **Hg**	 **Toxic G**		
6. Fish Tissue	Mercury Aroclor 1254 Aroclor 1260			**<AWQC** J **>AWQC**	**>AWQC** **>AWQC** **>AWQC**			J J J
7. Benthics	**							
8. Hg Uptake	FY24							

1. ASW = ambient surface water Toxic G = Toxic to Growth AWQC = ambient water quality criteria
2. GW = ground water Toxic R = Toxic to Reproduction >BG = above background
3. Sediment = suspended sediment in water column Hg = Mercury J = non-quantifiable
4. Soils = floodplain samples adjacent to stream sites U = Uranium (Isotopes U-234/235/238) SL = Standard Limit

5. Toxicity = impacts to growth & reproduction	*Aroclor 1254, 1260 = PCBs*	*Sp = spring*
6. Fish Tissue = bioaccumulation	*PCBs: polychlorinated biphenyls*	*Su = summer*
7. Benthics = aquatic macroinvertebrates	*PFBAs: perfluoro-n-butanoic acid*	*F = Fall*
8. Mercury (Hg) Uptake = bioaccumulation	*PFOs: Perfluorooctanesulfonic acid*	*W = winter*
** Please refer to the **Ambient Surface Water Project** section of this EMR.*		
*** Please refer to the **Benthic Community Health Project** section of this EMR.*		

8.2.8 CONCLUSIONS

Based on the toxicity results for EFPC, the entire reach of EFPC surveyed had COCs that impacted stream fauna health. For example, all four (4) EFPC sites and at MBK 1.6, water quality was toxic to reproduction (*C. dubia*) and/or growth (*P. promelas*) at least once during sampling. EFK 23.3 had the most frequent toxicity results. Three (3) samples were toxic to growth of the fathead minnow and two (2) showed decreased reproduction for water fleas. Fathead minnow growth inhibition at the other three (3) EFPC sites included one instance at EFK 13.8, one at EFK 6.3, and three (3) such sampling events at EFK 2.2.

During fall 2022, a sampling event was conducted in October, which is historically the driest month of the year. Reduced stream flow will decrease dilution of contaminants, so any COCs present will be found in higher concentrations. Except for EFK 6.3, all the sampling sites had failing (toxic) IC25 scores showing growth inhibition of fathead minnows. Additionally, reproduction inhibition of water fleas also occurred at EFK 23.3.

Biomonitoring of surface water associated with the toxicity sampling indicates that mercury is the primary COC in EFPC. All of the means of each week's low-level mercury data exceed the Tennessee Recreation – Organisms Only water quality criteria of 51 ng/L with the exception of EFK 2.2 in spring 2023. With the exception of uranium, metals other than mercury do not appear to be COCs. Uranium was found to exceed the MCL in only (1) one instance at EFK 23.3 on 3/3/2023. Although EFPC is not used for drinking water, the MCL is used only as a reference. Cadmium was not detected in surface water at any of the sites. Nitrate was in low concentrations at the EFPC sites.

Although gross alpha results (mean of 6.2 pCi/L, n=12) were higher than background at the EFPC sites, the MCL (15 pCi/L) was not exceeded. The background site, MBK 1.6, had a gross alpha mean (n=3) of 1.2 pCi/L. Similarly, gross beta surface water data show that gross beta concentrations are higher than those of the background site, but less than the EPA's 50 pCi/L screening level for community water systems determined to be vulnerable by the State. EFPC is not a community water system; the EPA screening level is used only as a reference.

PCBs were detected in EFPC soil samples and were at concentrations less than the EPA risk-based SLs for residential soil under direct contact exposure. The PFAS compounds PFBA and PFOS were detected in EFPC floodplain soils. The PFBA and PFOS concentrations were very low and do not approach a level of risk.

Arsenic, cadmium, and uranium concentrations in EFPC floodplain soils were less than the SLs at all EFPC soil sampling locations. Mercury concentrations at EFK 13.8 and EFK 6.3 were greater than the SL of 10.9 mg/kg. Mercury contamination in EFPC floodplain soils has been studied extensively by DOE, and these TDEC data reinforce past findings.

Mercury in EFPC suspended sediments was detected and found to be at a level of concern. Suspended sediment mercury results exceed the EPA SL of 10.9 mg/kg for soil, indicating there may be human health risk from mercury in EFPC sediments. Uranium exceeded the SL at EFK 23.3 only one (1) time in 2019. Cadmium and PCBs were not detected in EFPC suspended sediments.

Chemical and radiological whole-body analysis of golden redhorse (*Moxostoma erythrurum*) from EFK 2.2 provided data that show that the fish are contaminated with mercury, Aroclor 1254 and Aroclor 1260. The mercury concentration in the fish tissue sample was greater than the EPA fish based AWQC for fish. PCB (Aroclor 1254 and Aroclor 1260) concentrations were over two (2) times higher than the TDEC 20ug/kg criterion for maximum PCBs in fish tissue. The fish tissue was analyzed for a host of radiochemical analytes and only naturally occurring ones were detected (potassium-40 and gross beta).

In summary, mercury is the primary COC in the EFPC watershed; it exceeds SLs or regulatory limits in soil, sediment, surface water, and fish. Uranium is also a COC that was detected in surface water, soil, and sediment. In a few cases uranium exceeded EPA SLs or the drinking water MCL. Toxicity testing revealed frequent instances of growth inhibition of fathead minnows (*P. promelas*) throughout the length of the stream. Although PCBs are not a concern in soil, sediment, or surface water, they exceed regulatory limits in fish that inhabit EFPC. Radiological contamination is not a concern for fish in the EFPC watershed.

The DWR has posted warning signs at potential access points along EFPC that state “Avoid swimming, wading, or fishing in these waters”. The Tennessee 303d list (2022) includes all of EFPC and lists the following impairment causes: *Escherichia coli* (*E. coli*), mercury, nutrients, PCBs, sedimentation/siltation, and other anthropogenic substrate alterations. All of these impairments, with the exception of mercury and PCBs, are attributed to municipal sources (urbanized high-density area). The sources of impairment for mercury are listed as "industrial point source discharge" and "contaminated sediments". "Contaminated sediments" is listed as the probable cause of impairment for PCBs (TDEC 2022).

8.2.9 Recommendations

Based on the holistic data compilation above plus the upcoming remedial actions at Y-12 there is potential for the release of legacy contaminants from EFPC and COC infiltration into the EFPC that could migrate through the watershed. Future flooding events at remedial and construction sites might deposit new contaminated layers of sediment on top of soils. This deposition could potentially increase COCs in soils. Newly contaminated floodplain soils could result in elevated human risk and ecological impacts. Considering the high concentrations of mercury and the presence of uranium in the surface water, soils, and sediments in the EFPC watershed, holistic environmental sampling is recommended periodically to monitor the EFPC watershed.

8.2.10 References

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APPENDIX A

ADDITIONAL SUPPLEMENTAL SAMPLING /RESULTS

Sampling and monitoring are occasionally conducted in addition to projects planned with in the published EMP by TDEC's contractor. This sampling is conducted in response to new information, to assist in the State's required independent oversight or to evaluate the effectiveness of completed remedies. During FY23 this work included storm drain sampling at the ETTP, treated wastewater sampling for PCBS, and baseline surface water sampling of streams adjacent to the EMDF site. This work scope was reflected in the Contractual Section of the FFA Budget Narrative in the FY23 Annual Grant Application.

Outfall 490 Storm Drain Collection System at ETTP

This collection system was sampled in August 2022 to assist in understanding the sources of various contaminants discharging from Outfall 490 (OF-490).

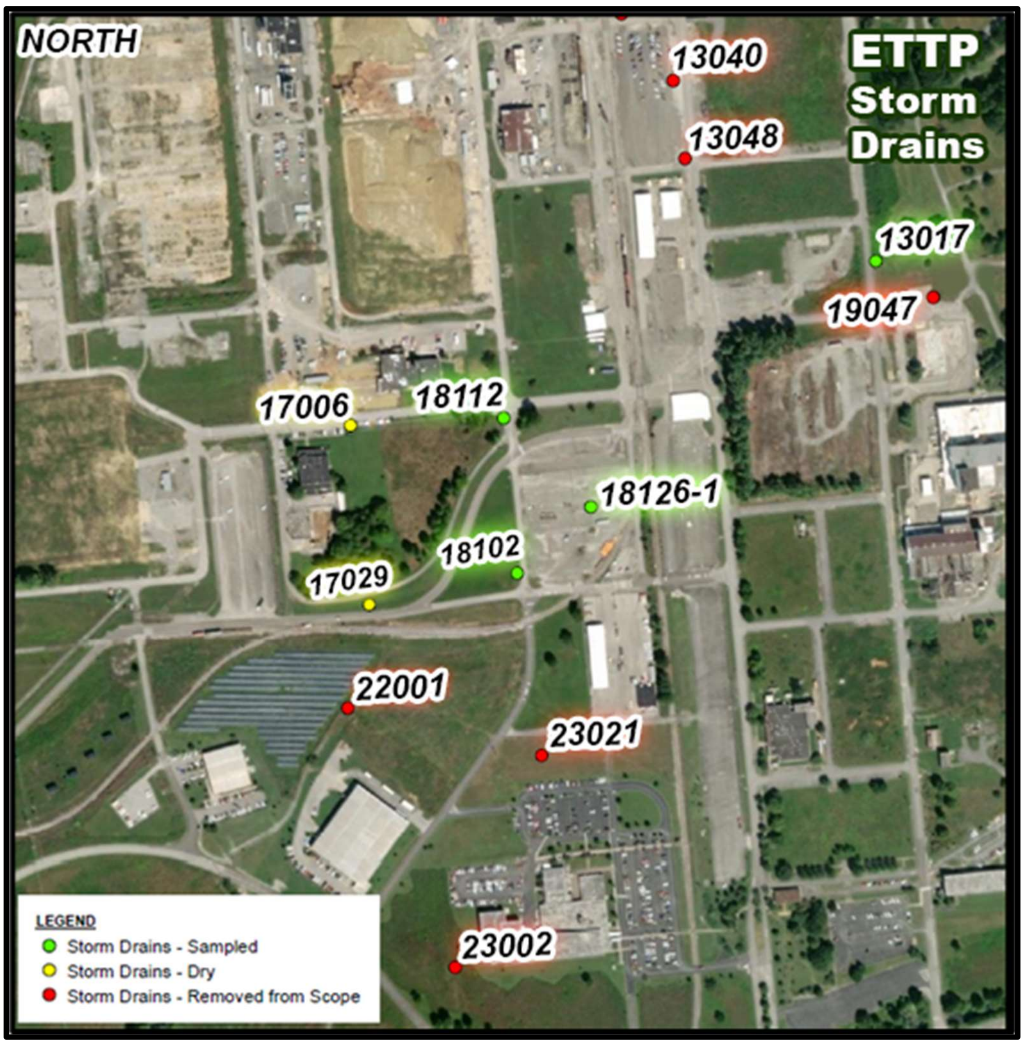

Figure A.1: ETTP OF-490 Storm Drain Sampling Sites

Other than a single Tc-99 detection, the findings were not significant. The tables below summarize the results of this sampling event.

Field parameters

Table A.1. ETTP Outfall (OF-490) Storm Drain Field Parameters

Catch Basin	Conductance (mS/cm)	pH (su)	Temp (º C)	DO (mg/L)	ORP (mV)	Turbidity (NTU)
18112	0.427	8.44	24	6.91	63	146
18126-1	0.458	8.75	25.64	6.46	14	11.3
18102	0.278	8.39	28.11	6.47	65	7.9
13017	0.493	8.2	24.99	6.48	81	1.5

Notes: *mS/cm = milliSiemens per centimeter*
NTU = Nephelometric Turbidity Units
mV = millivolt
mg/L = milligrams per liter
ORP = Oxidation Reduction Potential
DO = Dissolved Oxygen
su = standard units

Laboratory Results

Table A.2. ETTP Outfall 490 (OF-490) Storm Drain Sampling Results

Units	***pCi/L***	***µg/L***									
Catch Basin	**Tc-99**	**Lead**	**Mercury**	**Uranium**	**Aroclor 1016**	**Aroclor 1221**	**Aroclor 1232**	**Aroclor 1242**	**Aroclor 1248**	**Aroclor 1254**	**Aroclor 1260**
18112	1770±58.2	1.98	<0.13	6.3	<0.152	<0.0787	<0.0787	<0.0787	<0.0787	<0.0787	<0.199
18126-1	8.81±19.0	3.82	<0.13	1.47	<0.152	<0.0787	<0.0787	<0.0787	<0.0787	<0.0787	<0.199
18102	188±25.5	<0.264	<0.13	0.164	<0.162	<0.0837	<0.0837	<0.0837	<0.0837	<0.0837	<0.211
13017	10.3±19.5	0.332	<0.13	0.784	<0.152	<0.0787	<0.0787	<0.0787	<0.0787	<0.0787	<0.199

Notes: *µg/L = micrograms per liter* *pCi/L = picocuries per liter*

ETTP Storm Drain Sampling for Technetium-99 (Tc-99)

The elevated Tc-99 observed in catch basin 18112 (presented above in Table A.1) prompted further investigation into the possible presence of Tc-99 within the collection system and its possible association with a known Tc-99 groundwater plume.

Figure A.2. ETTP Storm Drain Tc-99 Sampling Sites

No other significant detections of Tc-99 were found during the December sampling event. The following table summarizes the results.

Table A.3. ETTP Storm Drain Tc-99 Sampling Results

Sample ID	**Date** 12/08/2022 **Time**	**Technetium-99**[a, b] *via DOE EML HASL-300* **(pCi/L)**
K25- **8064**-120822	1003	-9.48 ± 24.8
DUP-002 (8064)	1003	-0.218 ± 25.5
K25-**18110**-120822	1025	48.1 ± 28.2
K25-**12022**-120822	1050	-11.6 ± 26.5
K25-**12005**-120822	1105	-17.8 ± 26.4
K25-**13154**-120822	1117	-12 ± 25.6
K25-**13163**-120822	1128	14.9 ± 27.0
K25-**13175**-120822	1139	37.6 ± 28.3
FB-02	1355	12.4 ± 24.4

Notes: pCi/L = picocuries per Liter
U = non-detection
a = counting uncertainty (95% confidence level)
b = EPA Max Contaminant Level Tc-99 = 900 pCi/L

K-31/33 Storm Drain Collection System at ETTP

Storm drains at the former K-31/33 site were sampled for a variety of constituents in December 2022 to evaluate sources to outfalls discharging to Poplar Creek. There were no significant findings (see Table A.3).

Figure A.3. ETTP K-31/33 Storm Drain Sampling Site

Table A.4. ETTP K31/33 Storm Water Sampling Results

Sample Date: 12/06/2022													
Units		*pCi/L*		*mg/L*	*µg/L*								
Analytical Method		*EPA 900.0*		*EPA 246.1*	*EPA 200.8*					*8082A*			
Screening Criteria		15[c]	50[d]	0.05[b]	10[a]	4[a]	100[a]	5[a]	5.6[b]	***PCBs:*** 0.00064[b]			
Site ID	***Time***	***Gross α***	***Gross β***	***Hg***	***Ar***	***Be***	***Cr***	***Ni***	***Pb***	***Sb***	***Aroclor 1016***	***Aroclor 1260***	***Aroclor *other***
1030	10:37	1.60 ± 2.78	-2.37 ± 3.55		<0.370		2.24	0.663	1.59				
1027	10:15	-0.912 ± 2.91	1.43 ± 3.32		<0.370		1.15	0.621	0.95				
OF-610	11:50	1.73 ± 1.61	3.91 ± 2.19		0.954		0.922 J	0.52	0.601				
EB-01	15:15	-0.358 ± 0.654	0.012 ± 0.926		<0.370		<0.720	0.362 J	<0.500				
FB-01	15:30	1.090 ± 0.959	1.07 ± 1.42		<0.370		<0.720	0.406 J	<0.500				
6032	09:52	1.87 ± 1.34	1.06 ± 0.883		0.833		1.11	0.756	0.572				
6092	12:25	0.443 ± 0.711	1.54 ± 0.975	< 0.00013	<0.370	<0.112	1.16	0.723	0.667	<0.290	<0.130	<0.169	<0.0670
6093	11:31	2.33 ± 1.39	1.51 ± 0.934		<0.370		1.18	0.728	1.3				
1052	11:15	-1.09 ± 2.15	2.91 ± 2.43		<0.370		1.39	1.02	1.28				
DUP-01 (1052)	-	0.877 ± 1.89	4.56 ± 2.35		<0.370		1.53	0.931	1.2				

pCi/L = picocuries per liter *[a] = TN AWQC Domestic Water* **PCBs* *Aroclor other: Aroclor 1221, 1232, 1242, 1248, 1254*

mg/L = milligrams per liter *[b] = TN AWQC Recreation*

µg/L = micrograms per liter *[c] = EPA MCL*

J = estimated value *[d] = Radionuclide Rule 66 FR 76708*

*Complete Sample ID: K31-33-**XXXX**-120622 [where **XXXX** = unique Site ID listed above]*

PCB Sampling of Treated Wastewater

Using a sub-contractor lab, TDEC had samples collected from two mobile treatment systems analyzed for PCBs using EPA Method 1668A. This method has a method detection limit (MDL) less than the AWQC for PCBs standard of 0.00064 µg/L. The State conducted this sampling to verify compliance with this standard as the DOE's selected PCB sampling methodology did not have an MDL low enough to verify compliance.

EU-13 Soil Excavation

EU-13 at ETTP has been undergoing excavation for the removal of contaminated soils. Accumulated water is treated with a mobile treatment system, and treated wastewater is discharged into the Clinch River. TDEC sampled the treated wastewater on April 5, 2023. All PCBs in the effluent were "non-detect (ND)," demonstrating compliance with TDEC's AWQCs.

Table A.5. PCB Sampling Results for EU-13 Mobile Treatment System

Client Sample ID: EU-13 WTS EFFLUENT
Lab Sample ID: 10648624001
Filename: P230427B_04

Congener Group	Concentration ng/L
Total Monochloro Biphenyls	ND
Total Dichloro Biphenyls	ND
Total Trichloro Biphenyls	ND
Total Tetrachloro Biphenyls	ND
Total Pentachloro Biphenyls	ND
Total Hexachloro Biphenyls	ND
Total Heptachloro Biphenyls	ND
Total Octachloro Biphenyls	ND
Total Nonachloro Biphenyls	ND
DecachloroBiphenyls	ND
Total PCBs	ND

Beta-1 Basement Water

Beta-1 is a large former uranium enrichment facility at the Y-12 National Security Site. Over time, groundwater has seeped into the basement resulting in approximately 3 million gallons of contaminated water accumulating in the basement. In preparation for the demolition of Beta-1, this water must be removed. A mobile treatment system was installed to treat and discharge this water to Upper East Fork Poplar Creek. TDEC sampled the treated wastewater on April 27, 2023. All PCBs in the effluent were “non-detect,” demonstrating compliance with TDEC’s AWQCs.

Table A.6. PCB Sampling Results for Beta-1 Mobile Treatment System

Client Sample ID	BETA-1-WTS-EFF
Lab Sample ID	10651531001-R
Filename	P230529A_10

Congener Group	Concentration ng/L
Total Monochloro Biphenyls	ND
Total Dichloro Biphenyls	ND
Total Trichloro Biphenyls	ND
Total Tetrachloro Biphenyls	ND
Total Pentachloro Biphenyls	ND
Total Hexachloro Biphenyls	ND
Total Heptachloro Biphenyls	ND
Total Octachloro Biphenyls	ND
Total Nonachloro Biphenyls	ND
DecachloroBiphenyls	ND
Total PCBs	ND

EMDF Baseline Surface Water Sampling

In April 2023, the State’s contractor conducted surface water sampling in Bear Creek Valley around the EMDF site to establish a baseline of conditions prior to any land disturbing activities. This was the first round of sampling and included analysis of numerous radiological and chemical constituents. Upon completion of the project, a comprehensive report discussing baseline sampling will be presented in next year’s EMR and will include findings from this sampling event along with findings from future baseline sampling events. Results are being shared with the EMDF-EMWMF Project Team upon availability.