# TENNESSEE DEPARTMENT
# OF
# ENVIRONMENT AND CONSERVATION

## DIVISION OF REMEDIATION
## OAK RIDGE OFFICE

# ENVIRONMENTAL MONITORING REPORT

## For Work Performed:

## July 1, 2019 through June 30, 2020

## March 2021

Tennessee Department of
Environment and Conservation,
Authorization No. 327023

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# ACRONYMS

| | | |
|---|---|---|
| **A** | ASER | Annual Site Environmental Report |
| **B** | BCK | Bear Creek Station or Bear Creek Kilometer |
| | Benthic Life | Organisms that live on or in the streambed (insects, amphibians, spiders, worms, etc.) |
| | Biocides | Any product or substance used in a cooling tower which is intended to destroy, control or prevent the effects of algae, bacteria, sulfate-reducing bacteria, protozoa, and fungi. |
| **C** | CCME | Canadian Council of Ministers for the Environment |
| | CAA | Clean Air Act |
| | CBSQG | Consensus Based Sediment Quality Guidelines |
| | CERCLA | The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (commonly known as Superfund) enacted by Congress on December 11, 1980. |
| | COCs | Contaminants of Concern |
| | COND | conductivity |
| | $Cr_6$ | Hexavalent Chromium |
| | CRK | Clinch River kilometer |
| **D** | D&D | Decontamination and Decommissioning |
| | DO | Dissolved oxygen |
| | DOE | U.S. Department of Energy |
| | DoR | Division of Remediation |
| | DOR-OR | Division of Remediation – Oak Ridge |
| | DWR | Division of Water Resources |
| **E** | EFPC | East Fork Poplar Creek |
| | EMWMF | Environmental Management Waste Management Facility |
| | EPA | Environmental Protection Agency |
| | EPT | Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) |
| | %EPT – Cheum | Percent EPT - Cheumatopsyche |
| | ESOA | Environmental Surveillance Oversight Agreement |
| | ETTP | East Tennessee Technology Park |
| **F** | FFA | Federal Facilities Agreement |
| | FRMAC | Federal Radiological Monitoring and Assessment Center |
| **G** | GCN | greatest conservation need |
| | GPS | Global Positioning System |
| **H** | $H_2SO_4$ | sulfuric acid |
| | HAs | Health Advisory Values |
| | HCl | hydrochloric acid |

| | | |
|---|---|---|
| | HFIR | High Flux Isotope Reactor |
| | Hg | mercury |
| | $HNO_3$ | nitric acid |
| | HRE | Homogeneous Reactor Experiment |
| **L** | LLW | Low-level radioactive waste |
| | LSC | Liquid Scintillation Counting |
| **M** | MCL | Maximum Contaminant Limit see NPDWR |
| | MDL | Minimum Detection Limit |
| | MeHg | methylmercury |
| | MDC | minimum detectable concentration |
| | MIK | Mitchell Branch kilometer |
| | MQL | Minimum Quantification Limit |
| | MSRE | Molten Salt Reactor Experiment |
| **N** | NNSA | National Nuclear Safety Administration |
| | NAREL | National Air and Radiation Environmental Laboratory |
| | NCBI | North Carolina Biotic Index |
| | NOAA | National Oceanic and Atmospheric Administration |
| | NPDWR | National Primary Drinking Water Regulations |
| | NPL | National Priority List |
| | NRC | Nuclear Regulatory Commission |
| | NSDWR | National Secondary Drinking Water Regulations |
| | NT-5 | Bear Creek Northwest Tributary 5 |
| | NTU | nephelometric turbidity units |
| | NUREG | NRC Regulation |
| **O** | 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 |
| | OSL | Optically Stimulated Luminescence Dosimeter |
| | OSWER | Office of Solid Waste and Emergency Response (EPA) |
| | %OC | Percent Oligochaeta and Chironomidae |
| **P** | PCBs | Polychlorinated Biphenyls |
| | PEC | Probable Effects Concentration |
| | PRGs | Preliminary Remediation Goals |
| **Q** | QA/QC | Quality Assurance/Quality Control |
| | QAPP | Quality Assurance Project Plan |
| | QEC | Quality Environmental Containers (Beaver, WI) |
| **R** | RA | Remedial Activities |
| | RADCON | Radiation Control Program |

| | | |
|---|---|---|
| | RAIS | Risk Assessment Information System |
| | RER | Remedial Effectiveness Report |
| | ROD | Record of Decision |
| | RPM | Radiation Portal Monitor |
| | RSLs | Regional Screening Levels |
| **S** | SAIC | Science Applications International Corporation |
| | SAP | Sampling and Analysis Plan |
| | SOP | Standard Operating Procedure |
| | SRS | Southern Research Station |
| | Station | A specific location where environmental sampling or monitoring takes place. |
| | SU | standard units |
| | SD | storm drain |
| | SMCLs | Secondary Maximum Contaminant Levels same as NSDWRs |
| | SWSA | Solid Waste Storage Area |
| **T** | T&E species | State- or Federal-listed threatened and endangered species as protected under the Endangered Species Act of 1973. |
| | 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 |
| | TNUTOL | Total Nutrient Tolerant |
| | TN AWQC | State of Tennessee Ambient Water Quality Criteria |
| | TS | tree swallows |
| | TWQC | Tennessee Water Quality Criteria |
| | TWRA | TN Wildlife Resources Agency |
| **U** | UEFK | Upper East Fork Creek Kilometer |
| | USDI | U.S. Dept. of the Interior |
| | USEPA | United States Environmental Protection Agency |
| | UV | ultraviolet |
| **V** | VOCs | volatile organic compounds |
| **W** | WAC | Waste Acceptance Criteria |
| | WD | wood duck |
| | WCK | White Oak Creek kilometer |

## UNITS OF MEASURE AND THEIR ABBREVIATIONS

| | |
|---|---|
| °C | degrees Celsius/Centigrade |
| μS/cm | micro Siemens per centimeter |
| mV | millivolts |
| DO | amount of gaseous ($O_2$) dissolved in water |
| pH | scale of acidity from 0 to 14 |
| μg/L | micrograms per liter (parts per billion) |
| mg/L | milligrams per liter (parts per million) |
| ng/g | nanograms per gram (parts per billion) |
| μg/g | micrograms per gram (parts per million) |
| ppb | parts per billion |
| ppm | parts per million |
| millirem | A millirem is one thousandth of a rem |
| rem | A rem is the unit of effective absorbed dose of ionizing radiation in human tissue, equivalent to one roentgen of X-rays |
| mrem | Abbreviation for millirem which is a unit of absorbed radiation dose |

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- Robert Bishop – Rain Event
- Don Gilmore – Surface Water Sampling at the EMWMF
- Rebecca Lenz – Groundwater Monitoring of Bear Creek Valley, and Historical Groundwater Trends
- Len Berry – Radiological Uptake in Food Crops
- John Peryam – Haul Road Surveys, and Trapped Sediment
- Jared Brabazon – Ambient Surface Water Sampling, and Ambient Surface Water Parameters
- Natalie Pheasant - RadNet Air Monitoring, and RadNet Precipitation Monitoring
- Gary Riner – Real Time Measurement of Gamma Radiation, and Fugitive Radiological Air Emissions
- Gareth Davies – Environmental Dosimeters, and Surplus Sales Verification
- Dana Higgins – Benthic Macroinvertebrates

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# EXECUTIVE SUMMARY

The Tennessee Department of Environment and Conservation (TDEC), Division of Remediation, Oak Ridge (DoR-OR), submits the annual Fiscal Year 2020 (FY2020) Environmental Monitoring Report (EMR) for activities conducted from the period of July 1, 2019 through June 30, 2020. This report is submitted in accordance with the terms of the Environmental Surveillance and Oversight Agreement (ESOA) and in support of activities being conducted under the Federal Facilities Agreement (FFA). TDEC DoR-OR participates in independent monitoring and verification sampling as well as oversight of current DOE activities across the Oak Ridge Reservation, to confirm existing DOE project results, to support environmental restoration decisions, to evaluate performance of existing remedies and to investigate the extent and movement of legacy contamination.

This FY2020 EMR presents results for 16 independent projects, originally defined in TDEC's FY2020 Environmental Monitoring Plan (EMP) and completed over the course of FY2020 period of performance. The Mercury Assessment Project as well as the Bear Creek Valley Assessment Project, both introduced in the FY2020 TDEC Environmental Monitoring Plan (EMP), will be reported under separate cover following completion of those associated activities. The RadNet Drinking Water Sampling project, addressed in the FY2020 EMP, was not funded in FY2020, was not conducted and will not be addressed further here.

This monitoring report focuses on seven general environmental sampling areas on and across the ORR: Radiological Monitoring, Biological Monitoring, Air Monitoring, Surface Water Monitoring, Sediment Monitoring, Groundwater Monitoring and RadNet. Project summaries are provided below.

## Environmental Dosimeters

The Environmental Dosimeters Project is designed to independently assess the potential dose from radiation exposure at various locations across the ORR. Doses are compared to a reference limit of 100 mrem/yr. The Environmental Dosimeters Project focuses on areas at all three ORR facilities, as well as background sites, in and near Oak Ridge with emphasis placed on areas where radioactive materials are stored, processed, or disposed. This project is intended to provide TDEC, DOE and its contractors and the citizens of Tennessee conservative dose rates for specific areas across the ORR. When compared to the previous year, there were no significant changes in dose rates in the locations being monitored.

## Radiological Uptake in Food Crops

DOE has historically conducted studies on locally grown and harvested food crops and milk to analyze the impacts of airborne releases of radiation and the possible effects on food crops consumed by residents of local communities. The scope of this TDEC project was to build on those similar projects. Limited project specific samples were collected by TDEC during the FY2020 sampling season from within a five-mile radius of the ORR. These samples were compared with the background concentrations, as well as compared with the historical results from similar efforts compiled by DOE.

For FY2020, TDEC milk results were comparable with the most recent DOE 2016 milk study; however, most of the vegetable results showed elevated values when compared to the most recent 1992 and 1996 DOE vegetable studies. It is important to note that despite the increase in isotopic uranium concentrations seen between the 1992 DOE sampling and the 2019 TDEC sampling, the amount of isotopic uranium in the 2019 vegetable samples remains negligible when compared to comparison values such as the IAEA food products standard of 2.7 pCi/g for uranium-235. The increases identified have the potential to be related to varying sample methodology and equipment precision developments that may have occurred between the 1992 sampling and today. As the TDEC food crop sample group for this FY2020 period of performance was limited in size and number, it was not possible to identify any radiological uptake trends that may be present in food crops near the ORR at this time. This project is proposed to be continued in moving forward, and data will be added to this preliminary data set for further evaluation.

### Real Time Measurement of Gamma Radiation

The Real Time Measurement of Gamma Radiation Project, conducted on the Oak Ridge Reservation (ORR), measures exposure rates under conditions where gamma emissions can be expected to fluctuate substantially over relatively short periods of time. Because facilities on the ORR have been known to release variable amounts of gamma radiation, this project is used to monitor five areas on the ORR with the potential for an unplanned release of gamma emitting radionuclides into the environment During the FY2020 monitoring period, gamma monitors were located at the following five locations: Fort Loudoun Dam (Background Site), Environmental Management Waste Management Facility (EMWMF), ORNL Central Campus Remediation / Building 3026 Radioisotope Development Lab, Molten Salt Reactor Experiment (MSRE), and the Spallation Neutron Source (SNS).

During FY2020, no monitored location exceeded the 2 mrem in anyone-hour period comparison limit. Furthermore, no monitored location exceeded the 100 mrem/year limit assessed for impacts to members of the public.

### Surplus Sales Verification

At the request of the ORNL's Excess Properties staff, TDEC performs pre-auction verification surveys on items being auctioned by ORNL’s Excess Properties Sales group. Six independent assessments of surplus sales materials were conducted in FY2020. A total of 11 items with activity above background levels were identified during these surveys and were reported to DOE.

## Haul Road Surveys

TDEC staff perform bimonthly walkover surveys of the Haul Road and other waste transportation routes on the ORR that are used by DOE and their contractors to haul wastes for disposal at the EMWMF. The periodic surveys of the roads used to haul waste to the EMWMF have historically found that waste items may fall from trucks transporting the waste. In FY2020, the Haul Road survey staff identified 30 items along that transport route. No activity measurements on those items exceeded free release limits. The 30 items were reported to and dispositioned by DOE. In addition, all ambient high energy gamma measurements collected during those surveys were within the normal background range for the area.

## Threatened and Endangered Species Summary

Over the course of completing projects across the Oak Ridge Reservation, threatened and endangered species (T&E) information was identified. That information is included in this executive summary for site reference only. Official State of Tennessee T&E information is formally reported by TWRA under separate cover.

Two endangered species were identified on the ORR in FY2020. The Indiana Bat (Myotis sodalist) and the Grey Bat (Myotis grisescens). Additionally, one threatened species was identified, the Northern Long-eared Bat (Myotis septentrionalis). These three species are federally, and state listed, as threatened and endangered (T&E).

## Benthic Macroinvertebrates

The Benthic Macroinvertebrate Monitoring Project monitors the current condition and changing conditions of stream-bottom communities in streams on the Oak Ridge Reservation (ORR). The purpose of the Benthic Macroinvertebrate Project is to document the current condition of these stream communities and to note the changes of these conditions as remedial activities continue under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The physical boundaries of the Benthic Macroinvertebrate Monitoring Project include streams of the major watersheds on the three facilities of the ORR.

The health of the benthic macroinvertebrate communities in Oak Ridge Reservation streams has improved since the 1980's, but this improvement has leveled off or slightly declined for the past few years. Since augmented flow conditions were halted at East Fork Poplar Creek in May 2014, conditions at the upper East Fork Poplar Creek stations have deteriorated. Bear Creek continues to be impacted. Generally speaking, TMI Scores for Bear Creek are lowest at the upstream station (BCK 12.3) and highest at the most downstream station (BCK 3.3). Since 2016, all Bear Creek sites have shown a reduction in Taxa Richness. It is unclear what has contributed to the decline. Mitchell Branch has improved since the 1980's, particularly in its downstream reaches. The lower stations of Mitchell Branch are slowly developing a more natural substrate which is replacing the formerly lined channel. The upstream station in Mitchell Branch appears to be slowly deteriorating in quality due to sediment input.

### Fugitive Radiological Air Emissions

TDEC conducts independent air sampling at select sites across the ORR and compares those results with air sampling data provided by DOE. TDEC samplers are placed with in the ORR boundaries, with focus on locations where the potential for the release of fugitive airborne emissions may be higher (e.g., locations of the excavation of contaminated soils, demolition of contaminated facilities, and waste disposal operations, etc.). The shorter composite interval sampling times executed in TDEC's sampling program as compared to DOE's quarterly composited analyses can support a more focused observation of potential problems and provide an additional data source should events occur. During FY2020, for all eight ORR monitoring locations, the average concentrations, minus background, were below the federal standards for each radiological isotope measured.

### Ambient Surface Water Sampling

An ambient surface water sampling project has been implemented by TDEC each year since 1993. DOE has also implemented a surface water monitoring program for several years that consists of sample collection and analysis along the Clinch River (DOE, 2017; DOE, 2019). While the current DOE project solely samples the Clinch River, this TDEC DoR-OR project builds upon DOE's sampling by looking at specific confluences of exit-pathway streams with the Clinch River. Samples and flow measurements were taken at these streams quarterly, with the intent to provide a preliminary evaluation of the loading of potential contaminants to the Clinch River from those exit pathway streams. An assessment of impact was performed by comparing results to EPA defined maximum contaminant levels (EPA, 2009). Preliminary mercury flux estimates were calculated to give an approximated mass per year that could be loaded from each stream into the Clinch. While it is important to note that these values are only approximations, as they are based on only a few measurements and samples, the results can provide insight into possible loading potential from each stream. East Fork Poplar Creek mercury concentrations specifically had the highest estimated loading, where it was calculated that an estimated 3.4 kilograms of per year of mercury was contributed to the Clinch River.

The larger streams (East Fork Poplar Creek, Melton Branch, Mitchell Branch, and Poplar Creek) were relatively high in mercury concentrations, at times exceeding the TN mercury ambient water quality criterion (AWQC) for water and organisms of 0.051 µg/L. East Fork Poplar Creek mercury concentrations specifically were often above the mercury TN AWQC. Mercury in East Fork Poplar Creek at EFK 23.4 was identified at nearly double the TN criterion, including the February 2020 sampling event where mercury was identified at 1.6 µg/L, or nearly 32 times the criterion for TN water and organisms. Poplar Creek exceeded the TN water and organism criterion in three out of four quarters sampled at PCM2.3. Additionally, in Poplar creek arsenic was identified at levels 28 times greater than the TN criterion of 10 µg/L for water and organisms. Sr-90 levels at Clinch River Kilometer 33.5 were consistently well above the EPA drinking water MCL of 8 pCi/L. Similarly, location CRK33.5 consistently yielded high gross beta particle activities, often well above 50 pCi/L.

Overall, the smaller, historically less studied streams of East Fork Walker Branch, Grassy Creek, McCoy Branch, Raccoon Creek, and Scarboro Creek, were relatively low in mercury concentrations and were found to only contribute a few grams of mercury to the Clinch River. Accordingly, these streams do not appear to be major contributors of mercury loading to the Clinch River. The radionuclide (gross alpha, gross beta, and tritium) activities in these streams were also relatively low.

### Ambient Surface Water Parameters

An ambient surface water parameters project has been implemented by TDEC each year since 2005, contributing water quality parameter data to a database of physical stream parameters (specific conductivity, pH, temperature and dissolved oxygen). That data is used to help assess the degree of surface water impacts on and around the ORR. In FY20 field parameters including conductivity, dissolved oxygen, pH, and temperature were collected monthly from seven monitoring locations. 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. Statistical evaluation of the data set provided some interesting results.

Review of current parameters as well as the historical data set indicates that Bear Creek site BCK 12.3 is statistically significantly higher in conductivity than all other monitored sites.

Conductivity at EFK 23.4 has increased with time with the slope of the regression line showing this increase occurring at roughly 8 µS/cm annually. While there is not AWQC for conductivity, it is important to note elevated conductivity values may be indicative of elevated contaminants in the surface water at those locations, and additional assessment may be prudent. An ANOVA and post hoc Tukey test of pH values indicated two distinct groupings within the data set. Site BCK 4.5 was significantly different with respect to pH of the surface water, than MIK 0.1. All other sites were not statistically different from one another in pH.

As legacy DOE ORR contaminants have historically impacted surface water in our area, TDEC continues evaluating these surface water features via many methods to provide a complete and thorough assessment of the surface water both on and around the ORR. TDEC is committed to ensuring appropriate decisions are made surrounding remedial action activities as well as evaluating remedy effectiveness for sites under active management. These water quality parameter evaluations aid in that mission.

### Rain Event

As remedial actions, contaminated soil excavations, and other demolition activities occur throughout the ORR, water can accumulate in excavation pits, trenches, basins, sumps, basements, or during other soil remediation activities. Accumulated water at these sites has the potential to become contaminated and then be dispersed into the environment. To comply with the National Pollutant Discharge Elimination System (NPDES), DOE collects storm water samples. They also collect accumulated water samples at potentially affected areas before and during remedial activities. DoR-OR conducts random oversight for sampling activities at DOE accumulated water treatment systems and for their storm water sampling program. In addition to performing sampling oversight, DoR-OR reviews DOE treatment system and storm water analytical results. The primary goal is to monitor DOE efforts in preventing contamination from leaving the ORR. TDEC observed ~13% of the sampling events associated with the Tc-99 treatment system at ETTP. TDEC observed ~16% of the K-832 sampling events and ~ 40% of DOE’s storm sampling events. In addition, TDEC reviewed DOE’s analytical results against the Tennessee Code Annotated (TCA) Rule 0400-40-03 for the lowest discharge limits allowed. If a contaminant of concern is not listed in the TCA, the DOE discharge limit was used for review. For this FY20 period of performance, most of the contaminant analysis results were below their associated detection limits.

### Surface Water Sampling at the EMWMF

Contaminated materials from CERCLA remediation activities on the ORR are approved for disposal in the EMWMF, provided they meet the waste acceptance criteria. However, there is concern that associated contaminants over time have the potential to migrate from the facility into the environment and be carried by ground and surface waters off site in concentrations above agreed upon limits. TDEC conducts this project to provide assurance through independent monitoring and evaluation of DOE's similar sampling data, that operations at the EMWMF are protective of public health and the environment and meet the associated remedial actions objectives.

During FY2020, although TDEC measured physical water quality parameters at the landfill monitoring locations, no surface water sampling was conducted due to budgetary constraints during the projects period of performance. Review of the DOE's chemical data provided indication that past TDEC sample results compared favorably to DOE's current year results.  DOE data showed continued detections of low level (insignificant) but increasing contamination (U-238, U233/234, U235) from EMWMF-2 (Underdrain), and that location EMWMF-3 (V-Wier) continues to discharge contaminants, though not in concentrations that violate the EMWMF Record of Decision discharge limits. Water quality parameter monitoring identified as expected readings similar to historical parameter readings for this site during this period of performance.

### Trapped Sediment

The Trapped Sediment Project focused on determining ORR stream health through sampling and analysis of suspended sediment and assessing site remediation efforts through long-term monitoring of suspended sediment.

The analysis of sediment collected from the sediment traps in FY2020, indicates metals contamination at EFK 23.4. Cadmium and copper levels were above the threshold effects concentrations (TEC) at EFK 23.4 and mercury levels exceeded the probable effects concentrations (PEC). Lead and nickel concentrations were above the TEC in 2015 and 2016 at EFK 23.4. When a metal occurs at a concentration above the TEC, a possibility of impairment to benthic macroinvertebrate populations is possible. Above the PEC, it is probable that these populations will be impaired. The concentrations of these metals indicate that there is a probable impairment to the biota of the sediment. At NT-5, results from metals analysis were less than the TEC. Both EFK 23.4 and NT-5 have levels of gross alpha and beta radioactivity that are above background in the trapped sediment samples collected. However preliminary data indicates that the levels do not reach a level in the suspended sediments sampled here, that poses a threat to human health or the stream life.

### Groundwater Monitoring of Bear Creek Valley

The contamination of groundwater beneath several areas of the ORR and the potential pathways that allow for contaminant migration beyond the ORR boundary, makes it imperative for DOE and TDEC to monitor groundwater in areas off the reservation. Specific attention is paid to locations where residential wells may be a primary or sole source of water for local residents. For FY2020, groundwater samples were planned originally to be collected from 17 residential wells and springs, (from five locations in the northeast area, eight locations in the southeast area, and four from Tuskegee area). Due to TDEC budget constraints that sampling event was reduced to only four locations focused in the Tuskegee area. That sampling was intended to complete the sampling in the neighborhood that was started in FY19. Those four samples were planned to be taken during March-April 2020; however, COVID-19 restraints precluded the collection of the samples, and only two samples were taken during FY2020. For this report the 2 Tuskegee sample results from FY2020 are included with the results from earlier Tuskegee sampling events in an attempt to give a more comprehensive understanding of the Tuskegee Area.

The limited TDEC sampling of the Tuskegee neighborhood defined in this report documents mostly only low concentrations, low activities, and sporadic detections of contaminants. This limited data set has a small number of detections above health-based comparison criteria, including Sporadic detections of transuranic isotopes occur in residential well groundwater at very low levels (with one well just above comparison criteria fpr radium 226 and three wells with very low level detections of U238, U233/234 and curium 235.) No determination regarding potential sources of the identified constituents has been made at this time.

**Historical Groundwater Trends**

Groundwater samples have been collected and analyzed by TDEC DoR-OR since the late 1990s. While data has been collected by TDEC DoR-OR for many years, a comprehensive TDEC DoR-OR data evaluation of trends over time has not been completed. This project began the process of compiling and organizing data to support further evaluation of those data sets.

Over the years the TDEC sampling has shown exceedances from comparison criteria for various constituents including: aluminum, lead, lithium, manganese, zinc, total dissolved solids, bismuth 214, lead 214, radium 226, radium 228, uranium 233/234, uranium 238, some elevated pH’s, etc. Preliminary reviews of the data sets during this FY20 period of performance included fingerprinting groundwaters, conducting preliminary evaluations associated with increased sodium concentrations in groundwater, and generally evaluating statistical parameters associated with the groundwater datasets themselves.

While the results from this investigation show that there is not enough data from TDEC projects alone for each individual well or spring, on which to run meaningful statistics, the organization and evaluation of these older TDEC datasets will support further evaluation and correlation with DOE data sets moving forward.

**RadNet:**

RadNet is an EPA lead, nationwide system that monitors the nation's air, precipitation and drinking water to track radiation in the environment. TDEC supported two RadNet sampling projects on the ORR during FY2020.

### RadNet Air Monitoring

The RadNet Air Monitoring project on the ORR began in August of 1996 and provides radiochemical gross beta analysis of air particulate samples collected twice weekly from five air monitoring stations located near potential sources of radiological air emissions on the ORR. Gross beta results from the monitoring stations were compared to background data from the RadNet Air monitoring station in Knoxville, Tennessee, and to the Clean Air Act (CAA) environmental limit for strontium-90, because it is a pure beta emitter with a conservative limit. The gross beta results for each of the five RadNet Air Monitoring stations exhibited similar trends and concentration levels for the period July 2019 through March 2020. All the data during this time period were well below the 1.0 pCi/m$^3$ gross beta value which would warrant further analysis. These samples indicate that ORR activities occurring over this sampling time frame, posed no significant impact to the environment or public health from ORR emissions.

### RadNet Precipitation Monitoring

Nationwide, the RadNet Precipitation Monitoring Project measures radioactive contaminants that are carried to the earth's surface by precipitation. On the Oak Ridge Reservation (ORR), the RadNet Precipitation Monitoring Project provides radiochemical analysis of precipitation samples taken from monitoring stations at three locations.

The highest values seen in the composited monthly precipitation samples for each of the three ORR stations were all below the maximum contaminant levels (MCLs) set by the EPA for drinking water. While there are no regulatory limits for radionuclides in precipitation, the comparison to EPA's drinking water limits were used as a conservative reference. All results for bismuth-212, cesium-137, cobalt-60, thorium-228, and uranium-235 were less than the minimum detectable concentrations (MDCs) for the period January 2019 through March 2020. As with the RadNet air samples described above, these precipitation samples indicate that ORR activities occurring over this sampling time frame, posed no significant impact to the environment or public health from ORR emissions.

**Conclusion:**

While past and current DOE ORR operations have the potential to release a variety of constituents to the environment via atmospheric, surface water, and groundwater pathways, DOE "is committed to enhancing environmental stewardship and managing impacts its operations have and may have had on the environment. Each year extensive environmental monitoring is conducted by DOE across the ORR. Thousands of samples and measurements of air, water, direct radiation, vegetation, fish and wildlife are collected from across the reservation and analyzed for both radioactive and nonradioactive contaminants." (2019 ASER) Likewise, TDEC DoR-OR is committed to assuring the citizens of Tennessee that DOE operations and remedial activities on and around the Oak Ridge Reservation (ORR), Oak Ridge, Tennessee, are being performed in a manner protective of human health and the environment. The assessments and projects described in this EMR report reflect a subset of the work conducted by TDEC DOR-OR office to verify, compare results, oversee actions and evaluate potential impacts to the environment on or around the Oak Ridge Reservation to help ensure that protectiveness is achieved.

# 1.0 INTRODUCTION

## 1.1 PURPOSE OF THE ENVIRONMENTAL MONITORING REPORT (EMR)

The Tennessee Department of Environment and Conservation (TDEC), Division of Remediation Oak Ridge Office (DoR-OR), submits its annual (FY2020) Environmental Monitoring Report (EMR) for the period July 1, 2019 through June 30, 2020, in accordance with the terms of the Environmental Surveillance and Oversight Agreement (ESOA) and in support of activities being conducted under the Federal Facilities Agreement (FFA).

The Environmental Surveillance Oversight Agreement (ESOA) is designed to assure the citizens of the State of Tennessee that the Department of Energy's (DOE) current activities in Oak Ridge, Tennessee, are being performed in a manner that is protective of their health, safety, and environment. Working collaboratively with the Office of Science, National Nuclear Safety Administration (NNSA), and DOE Environmental Management, the state conducts independent monitoring and verification activities, conducts project reviews and provides input and evaluation of the current DOE run monitoring activities.

In support of the triparty (EPA, TDEC and DOE) Federal Facilities Agreement (FFA), DoR-OR personnel also conduct independent environmental monitoring activities. The FFA actions work to ensure DOE's legacy contamination (managed under CERCLA lean up requirements) is managed appropriately. Monitoring conducted under the FFA supports environmental restoration decisions, evaluates performance of existing remedies, and investigates the extent and movement of legacy contamination.

DOE and the State (TDEC DoR-OR), in a spirit of partnership and cooperation, are committed to assure DOE's Oak Ridge activities are performed in a manner that is protective of health, safety, and the environment. This document provides an annual summary report for the FY2020 monitoring and assessment projects conducted by TDEC during this period of performance.

## 1.2 OBJECTIVE

The objective of the TDEC DOR-OR Environmental Monitoring Program is to provide a comprehensive and integrated monitoring, verification and surveillance program for all environmental media (as well as for the emissions of any materials (hazardous, toxic, chemical or radiological) that may occur on the ORR or its surrounding environment as a result of DOE's current or former activities at these sites. These FY2020 monitoring projects are also used to evaluate the effectiveness of the DOE environmental monitoring program, by collecting independent data (samples) to verify DOE's collected sampling data sets.

## 1.3 THE OAK RIDGE RESERVATION

The Oak Ridge Reservation (ORR) is comprised of three major facilities:

- East Tennessee Technology Park (ETTP), formerly K-25
- Oak Ridge National Lab (ORNL), formerly X-10
- Y-12 National Security Complex (Y-12)

Facilities at these sites were constructed initially as part of the Manhattan Project. The ORR was established for the purposes of enriching uranium for nuclear weapons components and pioneering methods for producing and separating plutonium. In the 70 years since the ORR was established, a variety of production and research activities have generated numerous radioactive, hazardous, and mixed wastes. These wastes, along with wastes from other locations, have been, and are being, disposed of on the ORR.

Current operations at these facilities, like historical operations before them, continue to perform missions that have the potential to impact human health and the environment.

The Oak Ridge National Laboratory (ORNL) conducts leading-edge research in advanced materials, alternative fuels, climate change, and supercomputing. ORNL's activities of fuel reprocessing, isotopes production, waste management, radioisotope applications, reactor developments, and multi-program laboratory operations have produced waste streams that have resulted in environmental releases that contain both radionuclides and hazardous chemicals.

The Y-12 National Security Complex (Y-12) continues to be vital to maintaining the safety, security, and effectiveness of the US nuclear weapons stockpile and to reduce the global threat posed by nuclear proliferation and terrorism. Residual waste streams from operational processes at this site have resulted in environmental releases that contain both radionuclides as well as hazardous chemicals.

The East Tennessee Technology Park (ETTP), a former uranium enrichment complex, is being transitioned into an industrial technology park. Even though the gaseous diffusion activities at ETTP have concluded, residual environmental waste streams and ongoing clean up and decommissioning activities have resulted in environmental releases that contain both radionuclides and hazardous chemicals.

In accordance with the ESOA Agreement, the FFA Agreement and the TDEC mission statement, TDEC DoR-OR shall work to assure the citizens of Tennessee that the DOE's activities on and around the Oak Ridge Reservation (ORR), Oak Ridge, Tennessee, are being performed in a manner protective of human health and the environment.

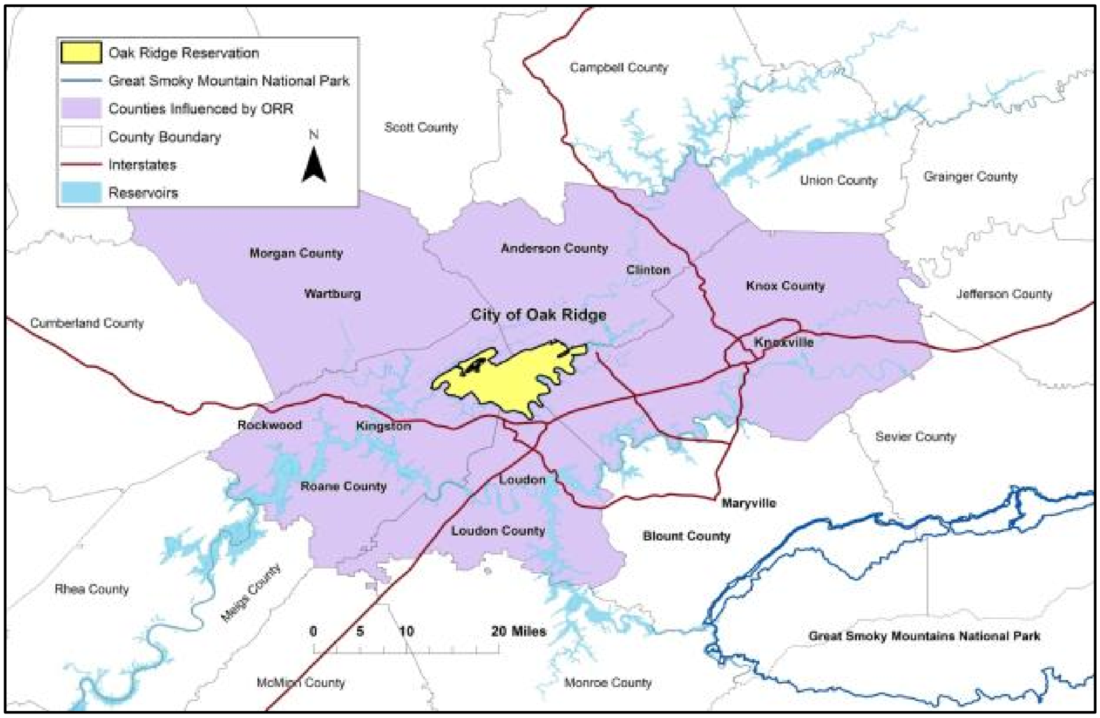

**Figure1.3.1: Location of the Oak Ridge Reservation in Relation to Surrounding Counties**

### 1.3.1 Geography of the ORR Area

Located in the valley of East Tennessee, between the Cumberland Mountains and the Great Smoky Mountains, the ORR is bordered partly by the Clinch River. The ORR is located in the counties of Anderson and Roane, and within the corporate boundaries of the city of Oak Ridge, Tennessee. The reservation is bound on the north and east by residential areas of the city of Oak Ridge and on the south and west by the Clinch River. Counties adjacent to the reservation include Knox to the east, Loudon to the southeast, and Morgan to the northwest. Portions of Meigs and Rhea counties are immediately downstream from the ORR on the Tennessee River. The nearest cities are Oak Ridge, Oliver Springs, Clinton, Kingston, Harriman, Farragut, and Lenoir City. The nearest metropolitan area, Knoxville, lies approximately 20 miles to the east (2019 DOE ASER).

The ORR encompasses approximately 32,500 acres of mostly contiguous land of alternating ridges and valleys of southwest-to-northeast orientation. The Valley and Ridge Province is a zone of complex geologic structures dominated by a series of thrust faults. It is characterized by a succession of elongated southwest-to-northeast trending valleys and ridges. In general, sandstones, limestones, and dolomites underlie the ridges that are relatively resistant to erosion. Weaker shales and more soluble carbonate rock units underlie the valleys. Winds within the valleys can differ substantially in speed and direction from the winds at higher elevation.

### 1.3.2 Climate of the ORR Area

The climate of the ORR region is classified as humid and subtropical; and is characterized by a wide range of seasonal temperature changes between the summer and winter months. Total precipitation during 2019 as measured at meteorological tower (MT)2 was 1,847.7 mm (72.74 in.), which is 38 percent above the 30-year average. (DOE 2019 ASER).

The Great Valley of East Tennessee (its shape, size, depth, and orientation), the Ridge-and-Valley physiography contained therein, the Cumberland Plateau, the Cumberland Mountains, and the Great Smoky Mountains all represent major landscape features that affect the wind flow regimes of Eastern Tennessee. Both the local terrain (for example: lithologic rock types in the subsurface and wind-directing regional landforms) as well as the regional climate (rainfall, etc.) are factors in determining the potential migration of contamination from the ORR to the surrounding areas.

### 1.3.3 Population of the ORR Area

More than one million citizens reside in the counties immediately surrounding the ORR. Knoxville is the major metropolitan area near Oak Ridge. Except for Knoxville, the land is semi-rural. The area is used primarily for residences, small farms, and pastures. Fishing, hunting, boating, water skiing, and swimming are popular recreational activities in the area.

## 1.4 TENNESSEE'S COMMITMENT TO THE CITIZENS OF TENNESSEE

In accordance with the ESOA Agreement, the FFA Agreement and the TDEC mission statement , TDEC DoR-OR will work to assure the citizens of Tennessee that the DOE’s historic and current activities on and around the Oak Ridge Reservation (ORR), Oak Ridge, Tennessee, are being managed or performed in a manner protective of human health and the environment.

# 2.0 RADIOLOGICAL MONITORING

## 2.1 ENVIRONMENTAL DOSIMETERS

### 2.1.1 Background

Radiation is emitted by various radionuclides that have been produced, stored, and disposed of on the Department of Energy's (DOE) Oak Ridge Reservation (ORR). Associated contaminants are evident in ORR facilities and surrounding soils, sediments, and waters. In order to independently assess the risks posed by these radioactive contaminants and from other potential sources, the Oak Ridge Office of the Tennessee Department of Environment and Conservation's Division of Remediation (DoR) began monitoring of ambient radiation levels on and near the vicinity of the ORR in 1995. This project provides:

- Conservative estimates based on continuous monitoring of the potential dose to members of the public from exposure to gamma radiation attributable to DOE activities/facilities on the ORR;
- Baseline values used to assess the need and/or effectiveness of remedial actions.
- Information necessary to establish trends in gamma radiation emissions.
- Information relative to the unplanned release of radioactive contaminants on the ORR.

### 2.1.2 Problem Statements

As environmental cleanup activities progress on the ORR, new temporary radiological waste storage areas are created, and public access areas are expanded. As these changes occur, TDEC strives to verify and confirm that the radiological controls actively in place through DOE are adequate to protect the public from radiation. Specific areas that TDEC identified for assessment and verification, include the following.

- Ongoing demolition activities and the associated radioactive waste storage areas.
- Historically contaminated soils and sediments.
- Current operational activities such as the Spallation Neutron Source.

### 2.1.3 Goals

The goal of the Environmental Dosimeters Project is to maintain independent radiological monitoring to evaluate impacts both on and in the vicinity of the ORR and verify protectiveness of DOE actions. Monitored radiation levels are expected to improve as remediation activities continue, short lived isotopes decay, and stored materials are dispositioned.

Dosimeters were changed out (new deployed and old retrieved) during a two- to three-day period at the beginning of each quarter (in January, July, and October). Every attempt was made to complete the deployment and retrieval (exchange) in a two to three-day period as soon as possible after receipt from Landauer.

### 2.1.4 Scope

The scope of this project is to independently assess, in important areas on the ORR, if the potential public dose from radiation exposure is kept below the NRC NUREG-1757 reference limit of 100 mrem/yr (Schmidt et al, 2006). This project focuses on areas of all three Oak Ridge Reservation facilities, as well as background sites in and near Oak Ridge. Emphasis is placed on areas where radioactive materials are stored, processed, or disposed. Areas where radiation levels are particularly of interest to stakeholders, such as the Environmental Management Waste Management Facility (EMWMF), and parts of the ETTP that are now much more accessible to the public, are also included in this scope. It is important to know where potential problems exist, but it is equally important to inform stakeholders where problems do not exist.

During late 2019 the total number of dosimeters used was reduced from 144 to 25. The reduction was based upon review and evaluation of the previous several years' results, where many locations consistently showed values below or well below the control level used by Landauer in reports (20 mrem) or were locations that if slightly elevated demonstrated clear steady downward trends (such as in areas at ETTP where building demolition has now occurred and sources may have been removed.

### 2.1.5 Methods, Materials, Metrics

All work on the Environmental Dosimeters Project was conducted under the guidance of TDEC DoR-OR's 2020 Health and Safety Plan (TDEC, 2020). In this effort, environmental dosimeters were used to measure the gamma radiation dose attributable to external radiation at selected monitoring stations. Results were compared to background values and to the State's primary dose limit for members of the public.

Dosimeters are currently deployed at the ORNL Main Campus in Bethel Valley, in Melton Valley, at the Spallation Neutron Source at ORNL, on the ORAU South Campus, in the City of Oak Ridge and its vicinity, and at Fort Loudon dam (the latter two are background).

Dosimeters at all sites were changed out by TDEC DoR-OR and analyzed (by Landauer, Inc.) on a quarterly schedule during the months of January, July, and October. A total of 25 dosimeters were deployed/retrieved during each quarter (new ones placed in the field; those in the field returned for processing).

Dosimeters were received from Landauer, Inc. during the first weeks of January, July, and October. Upon receipt, the dosimeters were logged in (to ascertain that all units were received) and prepared for deployment to the various sites. At some of the sites, TDEC DOR-Oak Ridge staff contacted site personnel to arrange for access for the deployment. At certain sites, the TDEC DOR-Oak Ridge staff were accompanied by site personnel during the deployment, at others, gate keys were borrowed to gain access to the areas.

Every attempt was made to complete the task within two to three days (a maximum of one week) of receiving the dosimeters. Much of this depended on the schedules of DOE and Contractor personnel who were site contacts, weather conditions, and other extenuating circumstances (e.g., temporary inability to access certain areas because of ongoing site activities).

After dosimeters were exchanged, they were logged back in to determine if any were missing. The dosimeters were then packaged for shipment to Landauer, Inc. for processing. Packages were shipped via ground delivery to avoid the packages being x-rayed in transit (packages shipped via air are likely to be x-rayed; x-raying will impact dose readings and make the data unusable).

After the dosimeters had been analyzed at Landauer, Inc., data files were downloaded, transferred to Excel spreadsheet format, and then placed in a table or graphical plots to be used in the annual Environmental Monitoring Report (EMR).

### 2.1.6 Deviations from the Plan

During the Spring of 2020, work restrictions from the SARS-Covid 2 virus pandemic prevented dosimeters being exchanged for the April event. Arrangements were made with Landauer, such that the dosimeters would be left in place and exchanged in June 2020. The dose associated with these dosimeters was calculated by Landauer to cover a 1st and 2nd Quarter period combined. This is reflected in Figure 2.1.1 and Figure 2.1.2.

Locations where dosimeters were relocated in FY2020 were at ORNL Materials Storage Area (Building 3607), the Homogeneous Reactor Experiment Site and the dosimeter in the valley south of the HRE Building.

### 2.1.7 Results and Analysis

Figure 2.1.1 shows the distribution of dose values for the deployed dosimeters. Note, that it covers the 1st and 2nd Quarters of 2020. There were no anomalous values and the locations with high dose values are those that would be expected to have such values, such as at ORNL where materials are stored or where there are known fluxes (Group A).

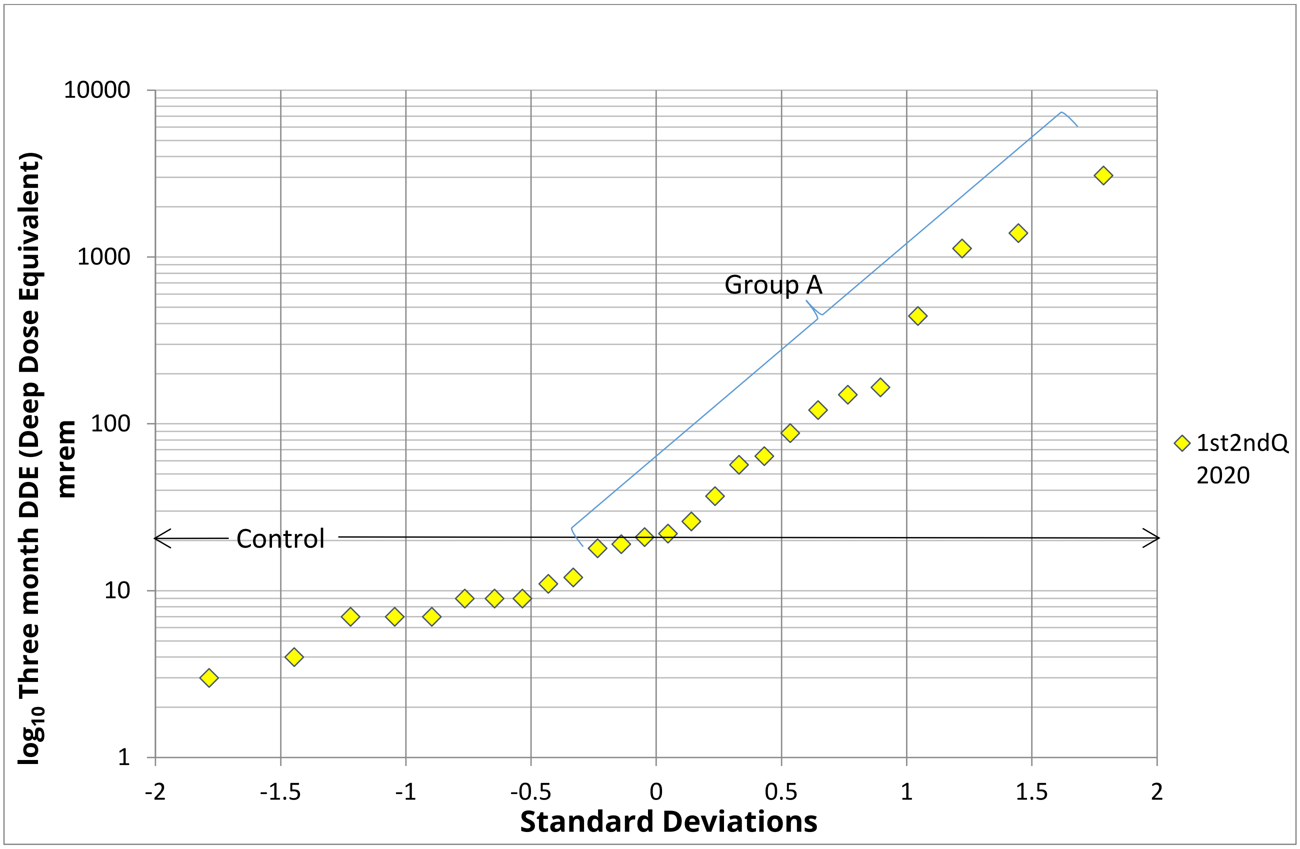

**Figure 2.1.1: Dosimeter DDE Comparison All Sites 1st Qtr 2018 - 1st Qtr 2020**

Figure 2.1.2 shows the new 25 site set plotted alongside the previous 144 set for the previous few years. Even though the values for the new (25) set appear on a different location on the chart, they still generally show the same relative value as might be expected, but again, note are for 1st and 2nd Quarter 2020.

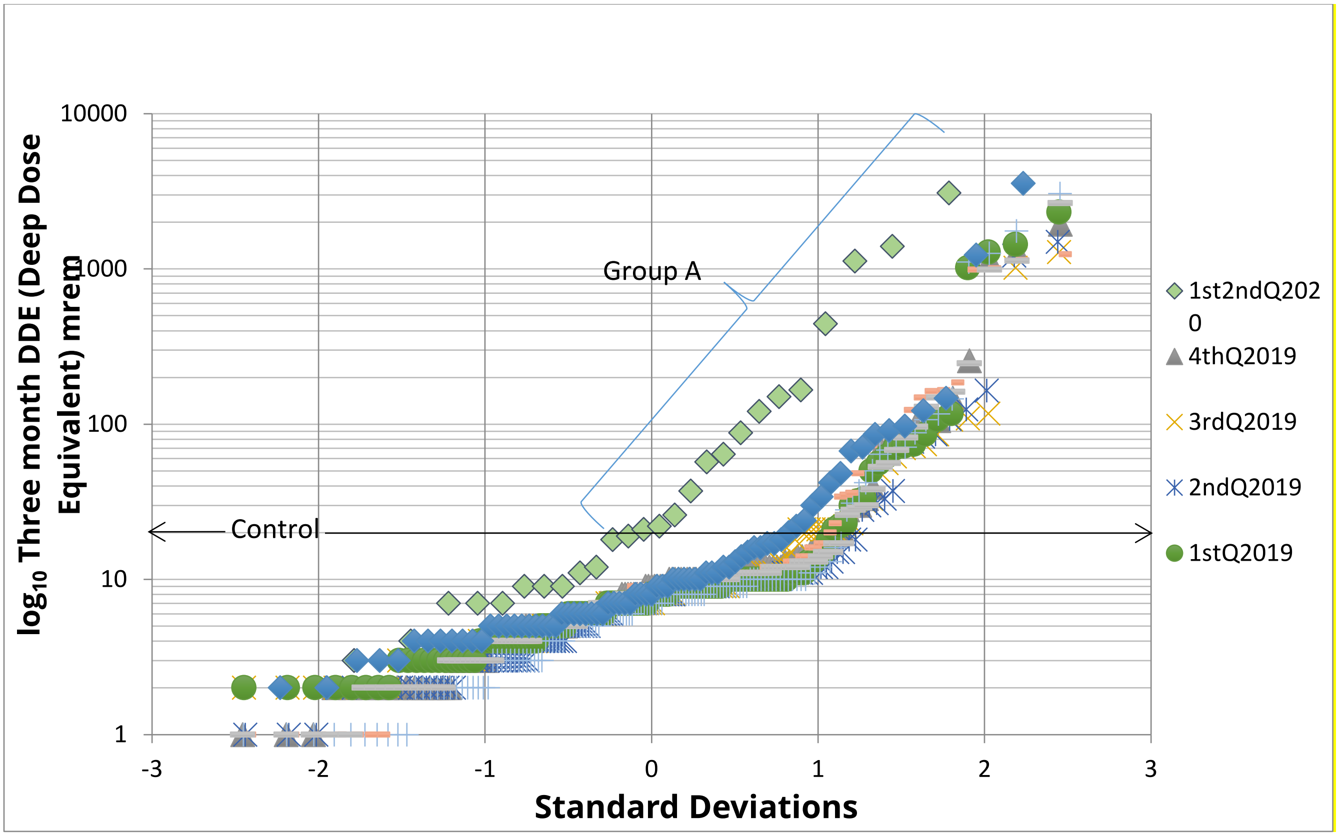

**Figure 2.1.2: Dosimeter DDE Comparison All Sites 1st Qtr 2018 - 1st Qtr and 2nd Qtr (combined) 2020**

Table 2.1.1 shows the data for 2019-2020, the right two columns allow a comparison between the two years.

### Table 2.1.1: TDEC 2019-2020 Results

**2019-2020 Results for TDEC monitoring on the Oak Ridge Reservation using Environmental Dosimetry**

| **Location**<br>*Optically Stimulated Luminescent Dosimeter (OSLs) are reported quarterly & neutron dosimeters are reported semi-annually* | 0 | **Dose Reported for 2019-2020 in mrem**<br>. *M = Below Minimum Reportable Quantity* | | | **2020 Total Dose **** | **2019 Total Dose **** |
|---|---|---|---|---|---|---|
| | | 1st Quarter & 2nd Quarter 2020 Combined | 3rd Quarter (2019) | 4th Quarter (2019) | | |
| Loudoun Dam Air Monitoring Station (Background) | Gamma | 4 | 4 | 4 | 12 | 10 |
| | Neutron | M | M | M | M | M |
| White Oak Dam @ Highway 95 | Gamma | absent | 2 | 18 | 20 | 6 |
| Scarboro Perimeter Air Monitoring Station | Gamma | 13 | 6 | 7 | 26 | 19 |
| ORAU Pumphouse Road | Gamma | 11 | 8 | 11 | 19 | 51 |
| | Neutron | M | M | M | M | M |
| North side of Central Ave. | Gamma | 59 | 30 | 19 | 108 | 80 |
| Building 3038 Northside | Gamma | 108 | 70 | 57 | 235 | 225 |
| Building 3607 Materials Storage Area | Gamma | 6540 | 1936 | 3084 | 11560 | 4953 |
| TH4 Tank | Gamma | 38 | 7 | 7 | 52 | 20 |
| Building 3618 | Gamma | 64 | 74 | 64 | 202 | 209 |
| Hot Storage Garden (3597) | Gamma | 2120 | 1151 | 1125 | 4396 | 3385 |
| Neutralization Plant | Gamma | 621 | 255 | 444 | 1320 | 465 |
| White Oak Creek Weir @ Lagoon Rd | Gamma | 52 | 33 | 22 | 107 | 84 |
| Cask Storage Containment Area | Gamma | 2671 | 1303 | 1393 | 5367 | 4076 |
| Melton Valley Haul Road near creek | Gamma | 285 | 147 | 150 | 582 | 428 |
| New Hydrofracture Facility | Gamma | 198 | 102 | 121 | 421 | 317 |
| Confluence of White Oak Ck & Melton Branch | Gamma | 189 | 83 | 88 | 360 | 216 |
| SWSA 5 TRU Waste Trench | Gamma | 57 | 30 | 26 | 113 | 90 |
| SWSA 5 Near Storage Tank Area | Gamma | 28 | 61 | 12 | 101 | 44 |
| | Neutron | M | M | M | M | M |
| Homogeneous Reactor Experiment Site | Gamma | 5 | 3 | 3 | 11 | 7 |
| High Flux Isotope Reactor | Gamma | 15 | 9 | 7 | 31 | 24 |
| Molten Salt Reactor Experiment | Gamma | 19 | 12 | 9 | 40 | 55 |
| Haw Ridge at Melton Valley Access Road | Gamma | 69 | 39 | 37 | 145 | 109 |
| SNS Central Exhaust Facility | Gamma | 466 | 95 | 166 | 737 | 196 |
| | Neutron | M | M | M | M | M |
| SNS LINAC Beam Tunnel Berm West (#1) | Gamma | 22 | 9 | 9 | 40 | 25 |
| | Neutron | M | M | M | M | M |
| SNS Target Bldg East | Gamma | absent | 5 | 9 | 14 | 16 |
| | Neutron | absent | M | M | M | M |

Notes: Two types of dosimeters are used in the program, optically stimulated luminescent dosimeters (OSLs) and neutron dosimeters. The OSLs measure the dose from gamma radiation, which is considered sufficient for most of the monitoring stations. The neutron dosimeters, which have been placed at selected locations, measure the dose from neutrons in addition to the gamma radiation. At the locations where the neutron dosimeters have been deployed, the total dose is the sum of the doses reported for neutrons and the dose reported for gamma radiation.

The primary dose limit for members of the public specified in both DOE Orders and 10 CFR Part 20 (Standards for Protection Against Radiation) is 100 mrem total effective dose equivalent in a year, exclusive of the dose contributions from background radiation, any medical administration the individual has received, or voluntary participation in medical research programs. The NRC limit for a decommissioned facility is 25 mrem/yr.

NEW = Data for the period does not exist as this station is new.

M = Below minimum reportable quantity (1 mrem for gamma, 10 mrem for thermal neutrons)

NA = Not analyzed (not deployed at location or Landauer lost).

Absent = The dosimeter was not found at the time of collection.

Damaged = The dosimeter was physically damaged, and the results were not consistent with historical values.

*The dose reported for this station is based on an estimated total yearly dose (less than four quarters of data were reported for this station).

** A control dosimeter is provided with each batch of dosimeters received from the vender. The control dosimeters are used to identify the portion of the dose reported due to radiation exposures received in storage and transit. The dose reported for the control dosimeter is subtracted from the dose reported for each field deployed dosimeter.

### 2.1.8 Conclusions

This project continues to provide TDEC, DOE and its contractors and the citizens of Tennessee conservative dose rates for specific areas across the ORR. When compared to the previous year, there were no significant changes in dose rates in the locations being monitored. However, based on the FY2020 monitoring results referenced in the Table 2.1.1, fifteen locations did exceed the 100 mrem/yr preliminary screening levels identified for this project. While it is important to note that these readings do not directly indicate any exceedance of the 100 mrem/yr requirement for a given individual, since it is not reasonable to assume any person would have remained in this one location over time, it is key to note the locations of these elevated readings for further review.

### 2.1.9 Recommendations

none

### 2.1.10 References

Boons, R., M. Van Iersel, and J.L. Genicot. (2012) External and Environmental Radiation Dosimetry with Optically Stimulated Luminescent Detection Device - Developed at the SCK·CEN. World Journal of Nuclear Science and Technology, 2, 6-15 2: 6–15. http://dx.doi.org/10.4236/wjnst.2012.21002.

Schmidt, D.W, K.L. Banovac, J.T. Buckley, D.W. Esh, R.L. Johnson, J.J. Kottan, C.A. McKenney, T.G. McLaughlin, S. Schneider. (2006) Consolidated Decommissioning Guidance, NUREG-1757 2. Retrieved from https://www.nrc.gov/docs/ML0630/ML063000252.pdf

TDEC. 2020 Health and Safety Plan Including Related Policies. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office. Oak Ridge, Tennessee.

TDEC.(2018). Standard Operating Procedure: Environmental Dosimeters Project (Draft). Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office. Oak Ridge, Tennessee.

## 2.2 RADIOLOGICAL UPTAKE IN FOOD CROPS

### 2.2.1 Background

DOE historically conducted studies on locally grown and harvested food crops such as root-plants, tomatoes, turnips, broad-leaf systems (such as lettuce, collard greens, mustard greens), and milk from cattle to analyze the impacts of airborne releases of radiation and the possible effects on food crops consumed by residents of local communities. The Radiological Uptake in Food Crops Project was recommended to TDEC DoR-OR by DOE for comparison to DOE's past results and to determine the possibility of consumers receiving radiation doses resulting from DOE's activities on the ORR. This project serves to determine whether radionuclide contamination extends beyond the bounds of the ORR and is taken up into local food crops.

DOE currently conducts and has previously conducted similar studies as documented in the DOE Environmental Monitoring Plan CY2020. Data pulled from DOE's OREIS database in February 2020 show that DOE sampled milk from cattle as recently as 2016 in Claxton and Maryville, but vegetables from the local area have not been sampled since 1996. These milk samples were screened for beryllium-7, potassium-40, strontium-90, and tritium, and the results can be viewed in Table 2.2.1, below.

**Table 2.2.1: Results of DOE's milk sampling program from 2016. Results are presented as pCi/L.**

| | Claxton | | Maryville | |
|---|---|---|---|---|
| | Mean | Maximum | Mean | Maximum |
| Beryllium-7 | 6.44 | 16 | -5 | -1.48 |
| Potassium-40 | 1330 | 1350 | 1325 | 1360 |
| Strontium-90 | 0.55 | 1.13 | -0.33 | 0.19 |
| Tritium ($H^3$) | 474 | 590 | 260 | 266 |

### 2.2.2 Problem Statements

- Radiological materials from DOE operations have been released into the atmosphere, groundwater, surface water, soils, and sediment.

- Members of the public have the potential to be exposed to doses of radiological materials through the consumption of locally grown food crops.

- Radionuclide deposition from past DOE activities may become disturbed by ongoing DOE D&D and remedial activities and may be transported beyond the boundaries of the ORR.

- Transfer of contamination may take place outside of the sampling and monitoring program put in place by DOE on the ORR.

### 2.2.3 Goals

The goals of this project follow:

- Obtain data to ascertain if there is any radionuclide contamination in the food crops received by consumers because of DOE activities on the ORR.

- Compare TDEC's food crops sampling against historical results from DOE's past food crops sampling program.

### 2.2.4 Scope

The scope of this project was to determine, by sampling food crops from home gardens or dairies within a five-mile radius of the ORR, whether radionuclide contamination extends beyond the boundary of the ORR and is impacting local food crops. Assessment to be conducted by analyzing those samples for the following contaminants: gross alpha/beta, gamma spec, and uranium-234, -235, and -238.

### 2.2.5 Methods, Materials, Metrics

A five-mile radius surrounding the ORR was defined and five local food producers, or vendors, were identified for sampling (Figure 2.2.1). Vegetable and milk samples were collected during a single collection event depending on seasonal availability. A minimum of 1 Kg (2.2 pounds) of vegetation was collected, and sampling was coordinated at the typical time of readiness to harvest. A minimum of one square meter of hay was also collected, as it is feed for milk-producing livestock. All vegetable, hay, and milk samples were shipped to the Tennessee Department of Health (TDH) lab for analysis, and results were compared to appropriate regulatory limits and DOE's historical food crops sampling data.

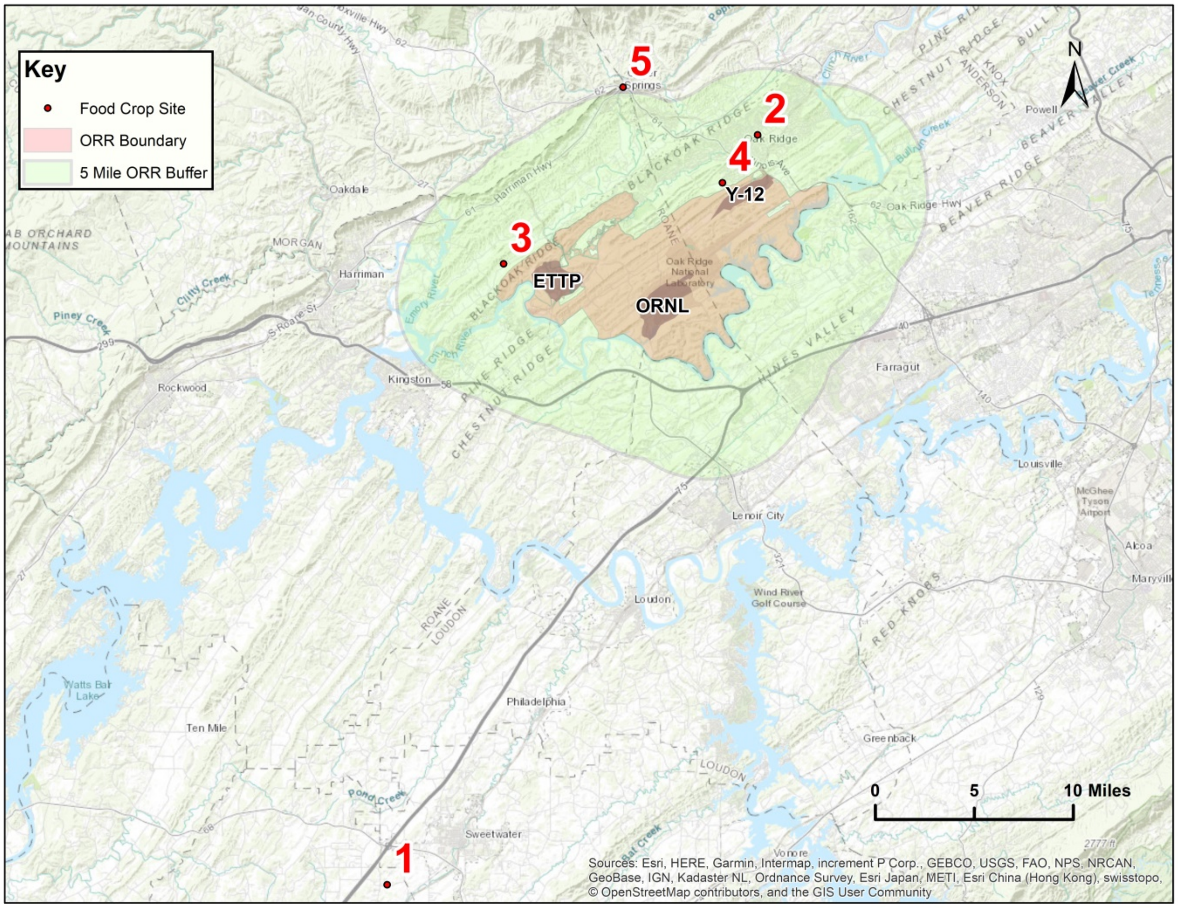

**Figure 2.2.1: Map of the five-mile radius around the ORR and sampling locations for food crops. (1 = Background, Niota, Sweetwater, TN; 2 = East End – Oak Ridge, TN; 3 = West End – Oak Ridge, TN; 4 = Scarboro Area – Oak Ridge, TN; 5 = Oliver Springs Area – Oak Ridge, TN)**

### 2.2.6 Deviations from the Plan

Due to extenuating circumstances, only background milk samples were collected, and hay, tomatoes, and greens sampling was limited to background (site 1) and East End – Oak Ridge (site 2), with one additional tomato sample from the Oliver Springs area during FY2020.

### 2.2.7 Results and Analysis

Background samples collected by TDEC included hay collected from McMinn County (southwest of Oak Ridge), tomatoes collected from Rhea County (west of Watts Bar Reservoir), and milk collected from Loudon County (south of the ORR and across the Clinch River). The results from background sample analysis are in Table 2.2.2, below. DOE did not collect hay samples as part of its previous food crops sampling program, but the background hay sample collected from McMinn County has gross alpha and gross beta activities of 0.84 pCi/g and 14.5 pCi/g, respectively, while isotopic uranium (U-234, -235, and -238) activities ranged from 0.0041 – 0.0193 pCi/g. Background tomato samples from Rhea County had gross alpha and beta activities similar to, and potassium-40 concentrations lower than, DOE's most recent offsite tomato samples from 1996. Isotopic uranium in this tomato sample was several orders of magnitude higher than in DOE's most recent samples from 1996; however, these concentrations are negligible. TDEC's Loudon County milk samples had potassium-40 concentrations lower than those documented by DOE from Claxton and Maryville in 2016, and the strontium-90 concentrations were comparable.

**Table 2.2.2: Results of TDEC 2019 background food crops sample analysis.**

| | McMinn Co / Hay (pCi/g) | Rhea Co / Tomatoes (pCi/g) | Loudon Co / Milk (pCi/L) |
|---|---|---|---|
| Gross Alpha | 0.84 | 0.05 | -- |
| Gross Beta | 14.5 | 1.5 | -- |
| Actinium-228 | 0.53 | -- | -- |
| Bismuth-214 | 0.54 | 0.78 | -- |
| Potassium-40 | 13 | 1.64 | 945 |
| Lead-214 | 0.23 | 0.069 | -- |
| Strontium-89 | -0.019 | 0.000547 | 6 |
| Strontium-90 | 0.042 | -0.00046 | 0.73 |
| Uranium-234 | 0.0181 | 0.00119 | -- |
| Uranium-235 | 0.0041 | 0.00034 | -- |
| Uranium-238 | 0.0193 | 0.00132 | -- |

Food crop samples collected from the East End – Oak Ridge area included hay, tomatoes, and greens. An additional sample of tomatoes was collected from the Oliver Springs area. Screening results of these samples are presented below in Table 2.2.3. Hay collected from east of the ORR had a gross alpha activity similar to the background sample collected in McMinn County. This hay sample had gross beta activity about 1/3 of that in the background sample. However, strontium-90 in this hay sample exceeded the International Atomic Energy Agency (IAEA) standard for food products by about six-six times. Isotopic uranium in the East End – Oak Ridge hay sample was similar to that from the background hay sample.

DOE did not measure gross alpha or gross beta in tomato samples in the 1990s, but potassium-40 concentrations are lower in both the east end – Oak Ridge and the Oliver Springs tomato samples. Again, isotopic uranium is 3-4 orders of magnitude more concentrated in both the east end – Oak Ridge and the Oliver Springs tomatoes compared to DOE's tomato samples from 1992 and 1996, though the 2019 isotopic uranium concentrations are negligible.

Finally, leafy greens collected from the east end – Oak Ridge area in 2019 had a gross alpha activity similar to lettuce samples collected by DOE in the 1990s, but the gross beta activity was about 40% higher than DOE's lettuce samples. Additionally, strontium-90 in the greens sample is approaching the IAEA standard for food products of 2.7 pCi/g. Potassium-40 concentrations in the leafy greens collected in 2019 were comparable to the lettuce samples from the 1990s, but isotopic uranium concentrations were once again 2-3 orders of magnitude higher.

**Table 2.2.3: Results of TDEC 2019 East End – Oak Ridge and Oliver Springs food crops sample analysis.**

| | East End – Oak Ridge | | | Oliver Springs |
|---|---|---|---|---|
| | Hay (pCi/g) | Tomatoes * (pCi/g) | Greens (pCi/g) | Tomatoes (pCi/g) |
| Gross Alpha | 0.37 | 0.056 | 0.09 | 0.06 |
| Gross Beta | 4.4 | 1.66 | 3.6 | 0.9 |
| Beryllium-7 | 13.3 | -- | -- | --- |
| Bismuth-214 | 0.25 | -- | -- | --- |
| Lead-212 | -- | 0.022[a] | -- | --- |
| Lead-214 | 0.22 | -- | -- | --- |
| Potassium-40 | -- | 2.29 | 4.68 | 1.35 |
| Strontium-89 | -44.2 | -0.301 | -2.4 | -0.833 |
| Strontium-90 | 12 | 0.024 | 2.45 | 0.292 |
| **Uranium metal | U | U | U | U |
| Uranium-234 | 0.0061 | 0.0005 | 0.0016 | 0.001 |
| Uranium-235 | 0.0017 | 0.0004 | 0.0006 | 0.0005 |
| Uranium-238 | 0.0063 | 0.0001 | 0.0012 | -0.0003 |

* Tomato results represent the average of three samples collected. ** Uranium metal units are mg/kg. U = undetected. [a] Lead-212 was only detected in a single tomato sample.

### 2.2.8 Conclusions

Food crops, vegetation, and milk samples were collected by TDEC for this assessment, from background locations that were identified a reasonable distance away from the ORR, in McMinn County, Rhea County and Loudon County.

Limited project specific samples were also collected by TDEC during the FY2020 sampling season, from within a five-mile radius of the ORR, at the East End – Oak Ridge and Oliver Springs locations. These samples were compared with the background concentration levels presented above, as well as compared with the historical results from similar efforts of DOE.

DOE’s historical data records were specifically from DOE’s most recent food crops sampling program,), where vegetable samples were collected in 1992 and 1996 around the ORR, and milk samples were collected from Maryville and Claxton as recently as 2016. Those data sets were acquired from data stored by DOE and their contractors in the Oak Ridge Environmental Information System (OREIS) database.

In general, the background milk sample collected by TDEC in 2019 was comparable to DOE’s offsite milk samples collected from Maryville and Claxton in 2016, and in both cases, these samples were well-below the FDA derived intervention limit of 4400 pCi/L for strontium-90 in milk.

Strontium-90 concentrations of hay collected from the East End – Oak Ridge area during this FY20 sampling event, exceeded available IAEA standards for food products. While hay is not a human food product, hay is feed for cattle and other livestock that provide food for the local human population. Strontium-90 concentrations in leafy greens collected from the same area approached the IAEA food products standard as well.

Vegetable samples collected by TDEC during this 2019/2020 sampling event showed gross alpha and gross beta activities listed at 2-10 times higher and isotopic uranium concentrations 2-4 orders of magnitude higher than DOE’s 1992 and 1996 vegetable samples, with a few exceptions, but it is important to note that despite the increase in isotopic uranium concentrations seen between the 1992 DOE sampling and the 2019 TDEC sampling, the amount of isotopic uranium in the 2019 vegetable samples remains negligible when compared to comparison values such as the EPA Preliminary Remediation Goals for tap water of 0.74 pCi/L for uranium-234 and 0.75 pCi/L for uranium-235 and -238 or the IAEA food products standard of 2.7 pCi/g for uranium-235. The EPA PRGs for tap water do not represent regulatory thresholds for food, but they are used here for reference only. There are no identified FDA limits for isotopic uranium available for comparison at this time.

### 2.2.9 Recommendations

TDEC food crop sample sizes were small and incomplete due to extenuating circumstances, so interpretation of results should be done with caution. However, despite these limitations, these results certainly indicate a continued necessity to sample vegetation and food crops in the vicinity of the ORR. TDEC recommends that additional food crop 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 against historical DOE data and against EPA and FDA contaminant limits.

### 2.2.10 References

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EPA. (2009). National Primary Drinking Water Regulations Complete Table. EPA 816-F-09-004. US Environmental Protection Agency, Washington, DC. Retrieved from https://www.epa.gov/sites/production/files/2016-06/documents/npwdr_complete_table.pdf

FDA. (2005). Guidance Levels for Radionuclides in Domestic and Imported Foods (CPG 7119.14). Retrieved from https://www.fda.gov/food/chemicals/guidance-levels-radionuclides-domestic-and-imported-foods-cpg-711914

Savannah River Ecology Laboratory. 2014. Technical Assessment of DOE Savannah River Site-sponsored Radionuclide Monitoring Efforts in the Central Savannah River Area. SREL CAB REC_317 Technical Review.

SCDHEC. 2012. South Carolina Department of Health and Environmental Control Environmental Data Report, Bureau of Environmental Services, Environmental Surveillance and Oversight Program, Aiken, South Carolina.

## 2.3 REAL TIME MEASUREMENT OF GAMMA RADIATION

### 2.3.1 Background

The K-25 Gaseous Diffusion Plant, now called the East Tennessee Technology Park (ETTP), began operations in World War II as part of the Manhattan Project. Its original mission was to produce uranium, enriched in the uranium-235 isotope (U-235), for use in the first atomic weapons and later to fuel commercial and government-owned reactors. The K-25 plant was permanently shut down in 1987. As a consequence of operational practices and accidental releases, many of the facilities scheduled for decontamination and decommissioning (D&D) at ETTP are contaminated to some degree. Uranium isotopes are the primary contaminants, but technetium-99 and other fission and activation products are also present, due to the periodic processing of recycled uranium obtained from spent nuclear fuel.

The Y-12 Plant was also constructed during World War II to enrich uranium in the U-235 isotope, in this case, by the electromagnetic-separation process. In ensuing years, the facility was expanded and used to produce fuel for naval reactors, to conduct lithium/mercury enrichment operations, to manufacture components for nuclear weapons, to dismantle nuclear weapons, and to store enriched uranium.

Construction of what is now the Oak Ridge National Laboratory (ORNL), originally known as the X-10 Plant, began in 1943. ORNL focused on reactor research and the production of plutonium and other activation and fission products. These were chemically extracted from uranium, irradiated in ORNL's graphite reactor and later at other ORNL and Hanford reactors. During early operations, leaks and spills were common in the facilities and associated radioactive materials were released from operations as gaseous, liquid, and solid effluents, with little or no treatment (ORAU, 2003).

The EMWMF was constructed in Bear Creek Valley near the Y-12 National Security Complex to dispose of low-level radioactive waste and hazardous waste generated by remedial activities from all three sites on the Oak Ridge Reservation (ORR).

DoR-OR has deployed gamma-radiation exposure monitors, equipped with microprocessor-controlled data loggers, on the ORR since 1996. The data loggers supplement the DoR-OR Environmental Dosimeters Project that measures cumulative dose at specific locations quarterly. The Real Time Measurement of Gamma Radiation Project tracks gamma exposure rates over time. Exposure rate monitors measure and record gamma radiation levels at predetermined intervals (e.g., minutes) over extended periods of time (months) and provide an exposure rate profile that can be correlated with activities and or changing conditions.

### 2.3.2 Problem Statements

The Real Time Monitoring of Gamma Radiation Project on the Oak Ridge Reservation measures exposure rates under conditions where gamma emissions can be expected to fluctuate substantially over relatively short periods of time. Facilities on the ORR have been known to release variable amounts of gamma radiation and there is the potential for an unplanned release of gamma emitting radionuclides.

### 2.3.3 Goals

The results from monitored sites was compared to:

- The State of Tennessee (State) limit for the maximum dose to an unrestricted area (2 mrem in any one-hour period).
- State and DOE primary dose limits for members of the public (100 mrem/year).

### 2.3.4 Scope

Candidate monitoring locations for the placement of gamma radiation monitoring instrumentation include sites undergoing remedial activities, waste disposal operations, pre- and post-operational site investigations, and areas of environmental response activities. Anomalous results from DoR-OR's Environmental Dosimeters Project may warrant conducting additional gamma radiation monitoring at other locations. Figure 2.3.1 shows the

FY2020 sampling locations. Data recorded by the gamma monitors was evaluated by comparing the data to background gamma exposure rates. The data was also compared to the State maximum dose limits and to State and DOE primary dose limits (listed above). For FY2020, gamma exposure rate monitors were located at the following six locations:

1. Fort Loudoun Dam (Background Site)
2. Environmental Management Waste Management Facility (EMWMF) Portal Monitor
3. ORNL 3000 area/Central Campus Remediation/former building 3026 Radioisotope Development Lab
4. ORNL Molten Salt Reactor Experiment (MSRE)
5. ORNL Spallation Neutron Source (SNS) stack
6. ORNL White Oak Creek (WOC)

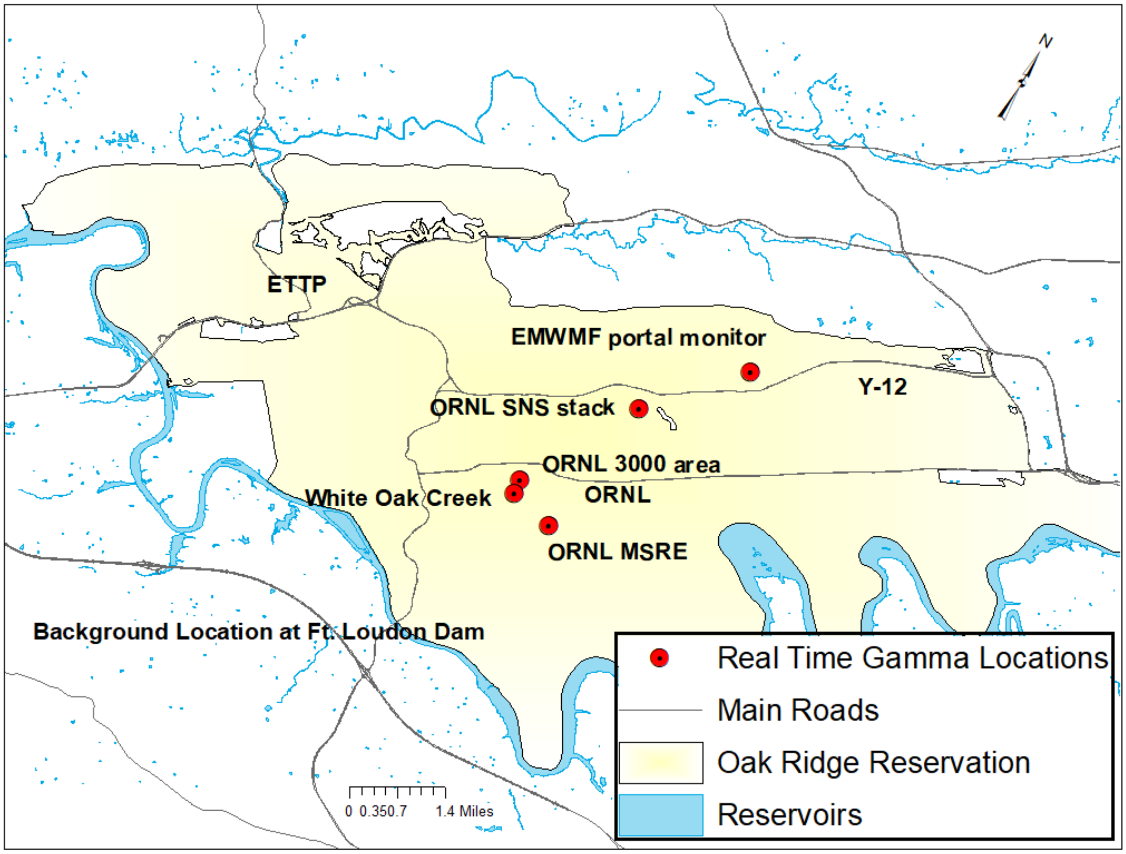


Figure 2.3.1: Gamma Monitor Locations

## 2.3.5 Methods, Materials, Metrics

The gamma exposure rate monitors deployed for the DoR-OR Real-Time Measurement of Gamma Radiation Project on the Oak Ridge Reservation, are manufactured by Genitron

Instruments and are marketed under the trade name GammaTRACER®. Each unit contains two Geiger-Muller tubes, a microprocessor-controlled data logger, and lithium batteries sealed in a weather-resistant case to protect the internal components. The instruments can be programmed to measure gamma exposure rates from one µrem/hour to one rem/hour at predetermined intervals from one minute to two hours. The results reported are the average of the measurements recorded by the two Geiger-Muller detectors. The data for any interval from each detector can be accessed. The results recorded by the data loggers were downloaded to a computer by DoR-OR personnel using an infrared transceiver and associated software.

### 2.3.6 Deviations from the Plan

The instrument located at SNS was inoperable from 04/03/2019 through 06/06/2019. Data for this time period is not available.

### 2.3.7 Results and Analysis

#### Fort Loudoun Dam Background

To better assess exposure rates measured on the ORR and the influence that natural conditions have on these rates, DoR-OR maintains one gamma monitor at Fort Loudoun Dam in Loudon County to collect background information. During FY2020, 07/01/2019 through 06/30/2020, exposure rates averaged 9.09 µrem/hour and ranged from 8 to 17 µrem/hour, which is equivalent to a dose of approximately 79.6 mrem/year.

#### Environmental Management Waste Management Facility

The EMWMF was constructed in Bear Creek Valley (west of Y-12) to dispose of wastes generated by CERCLA activities on the ORR.

DoR-OR has a gamma monitor acting as a portal monitor at the check-in station for trucks transporting waste into the EMWMF for disposal. Trucks, entering the facility, pass the gamma radiation detector allowing the monitor to read any gamma radiation-emitting materials that have passed on the way to disposal at the waste cells. This monitoring system allows for the assessment of gamma exposure rates at the monitoring detector over a defined time period, and can be used to corroborate DOE's reporting system, allowing for confirmation, if required, that excessive amounts of radiation-emitting materials have not inadvertently passed the monitoring point to be disposed of in the EMWMF facility.

Measurements taken during FY2020 (07/01/2019 through 06/30/2020) averaged 6.9 µrem/hour and ranged from 3 to 14 µrem/hour, similar to the background measurements collected during the same period at Fort Loudoun Dam and seen in Figure 2.3.2.

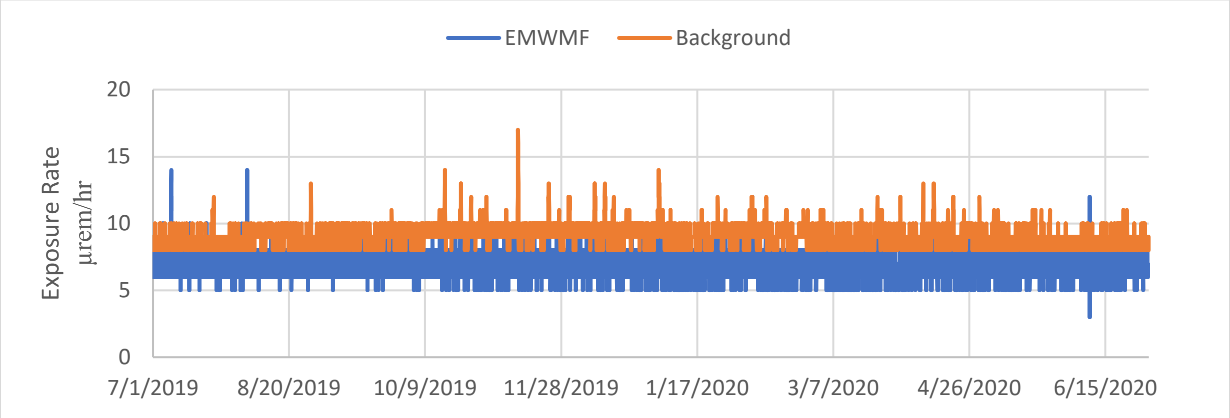


**Figure 2.3.2 EMWMF Gamma Exposure Rates**

### ORNL Central Campus Remediation/Building 3026 Radioisotope Development Lab

Monitoring on the ORNL Central Campus began in 2012 and has continued through June 2020. Due to the nature of past activities at ORNL, concerns include potential radiological releases during the demolition of high-risk facilities centrally located on ORNL's main campus in close proximity to pedestrian and vehicular traffic.

During FY2020 (07/01/2019 through 06/30/2020) gamma radiation measured at this ORNL site ranged from 9 to 30 µrem/hour and averaged 13.6 µrem/hour (Figure 2.3.3).

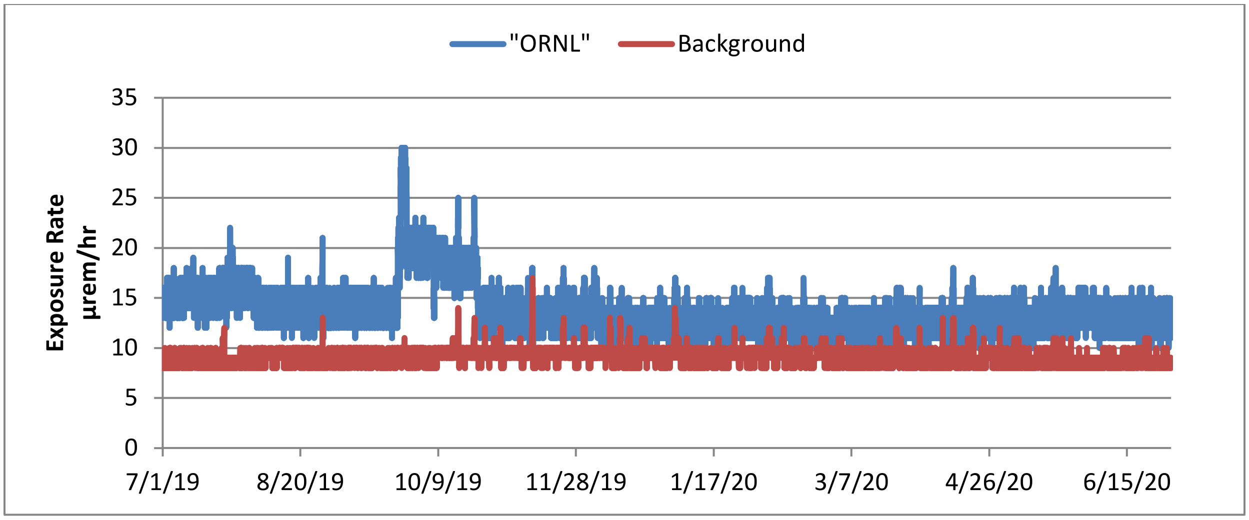


**Figure 2.3.3: ORNL Central Campus Gamma Exposure Rates**

### The Molten Salt Reactor Experiment

Gamma monitoring has been conducted at the Molten Salt Reactor Experiment (MSRE) site from November 1, 2012 through June 30, 2020. DoR-OR records gamma exposure rates with a gamma monitor, placed near the gate where trucks containing radioactive materials (e.g., reactor salts removed from drain tanks) exit MSRE. The monitoring location is near a radiation area, established to store equipment used in remediation activities at this site.

During the FY2020 (07/01/2019 through 06/30/2020) monitoring period, the average exposure rate ranged from 8 to 164 μrem/hour and averaged 25.1 μrem/hour (Figure 2.3.4). The major source of the radiation dose above background that was measured is assumed to result from a salt probe being temporarily stored in the radiation area, adjacent to the monitoring station.

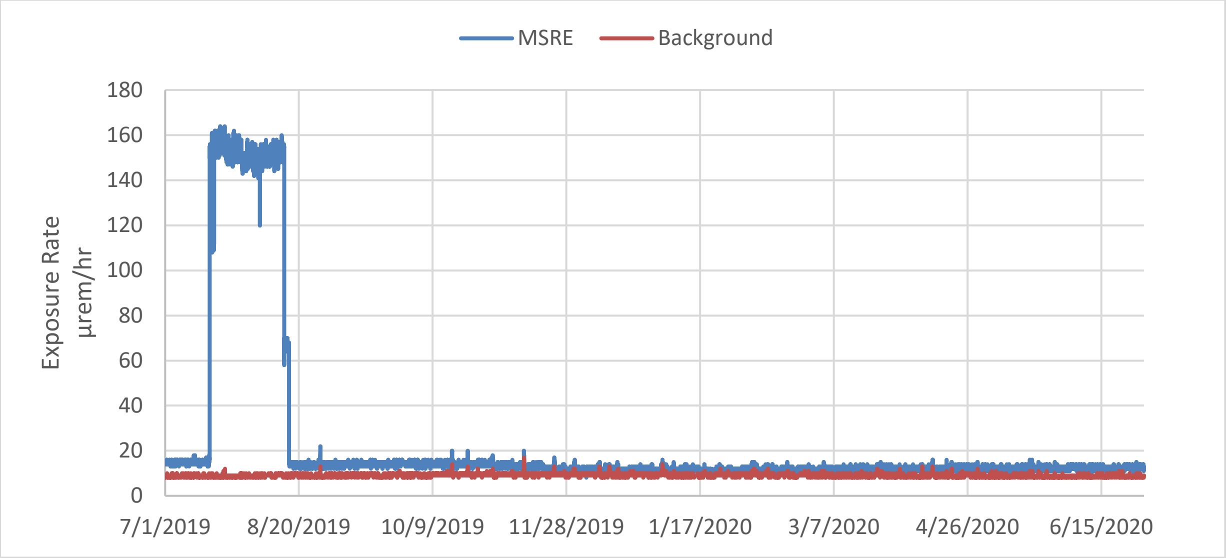


**Figure 2.3.4: Gamma Exposure Rate at Molten Salt Reactor Experiment**

### Spallation Neutron Source

To assess the gamma component of air releases from the Spallation Neutron Source (SNS), DoR-OR's exposure rate monitor is located on the central exhaust stack used to vent air from process areas inside the linear accelerator (linac) and sample target building. The exposure rates vary based on the operational status of the accelerator. During periods when the accelerator is not online, the rates are similar to background measurements. However, much higher levels are recorded during operational periods. The exposure rates measured throughout the sampling period for FY2020 (07/01/2019 through 06/30/2020) was interrupted by COVID-19 restrictions resulting in a loss of data from 03/11/2020 through 04/17/2020. For the available FY2020 data, measurements ranged from 6 to 1860 µrem/hour and averaged 231 µrem/hour (Figure 2.3.5). For contextual purposes, the exposure rate of 231 µrem/hour would exceed both State and DOE limits of 100 mrem within one year. However, this location is not accessible to the public.

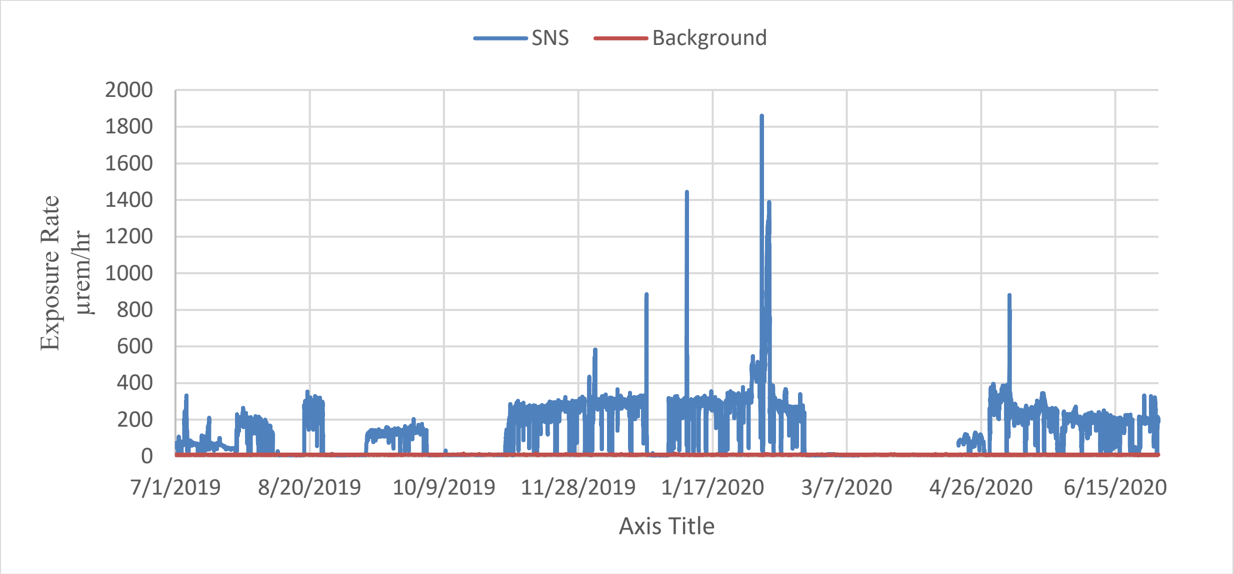


**Figure 2.3.5: Spallation Neutron Source**

### ORNL White Oak Creek

White Oak Creek has historically received radiological contaminants from previous ORNL operations. Some contaminants may continue to leach into the creek. The monitoring location is on an unused Third Street bridge which crosses White Oak Creek just downstream from an area that was previously the 3513 ponds, which have been filled, paved, and are now used as parking lots. The monitoring location is also near ORNL water treatment facilities. It is noteworthy that the decreases in rate observed in Figure 2.3.6 correspond to rainfall events. Additional water depth in the creek appears to provide shielding. Measurements were collected from 8/5/19 to 6/30/2020. Measurements ranged from 11 to 46 µrem/hour and averaged 32 µrem/hour.

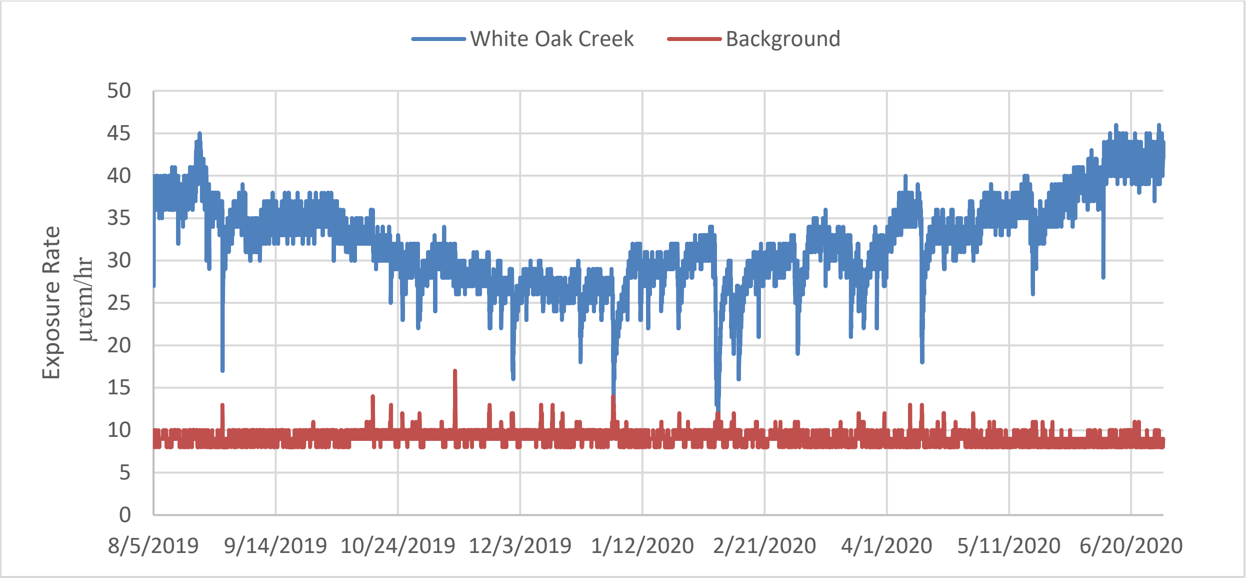


**Figure 2.3.6: ORNL White Oak Creek**

## 2.3.8 Conclusions

The following conclusions are drawn, based on the data collected from 07/01/2019 through 06/30/2020 at the gamma monitoring locations covered in this report:

- No monitored location exceeded the 2 mrem in any one-hour period.
- No monitored location exceeded the 100 mrem /year limit for members of the public.

## 2.3.9 Recommendations

- TDEC DoR-OR proposes to review the current monitoring locations and make modifications according to DOE activities on the ORR.
- As DOE does not have a similar monitoring program, TDEC DoR-OR proposes to continue this program.

## 2.3.10 References

The State limit for the maximum dose to an unrestricted area (2 mrem in any one-hour period). State and DOE primary dose limits for members of the public (100 mrem/year).

https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1301.html

## 2.4 Surplus Sales Verification

### 2.4.1 Background

The Tennessee Department of Environment and Conservation, Division of Remediation Oak Ridge Office (DoR-OR), in an oversight capacity of the U.S. Department of Energy (DOE) and its contractors, conducts radiological surveys of surplus materials originating from the Oak Ridge Reservation (ORR), which are designated for sale to the public. In addition to performing the surveys, the office reviews the procedures used for release of materials under DOE radiological regulations. DOE currently operates their surplus materials release program under DOE Order 458.1 Admin Chg 3, *Radiation Protection of the Public and the Environment*.

Some materials, such as scrap metal, may be sold to the public under annual sales contracts, whereas other materials are staged at various sites around the ORR awaiting auction i.e., sale. Practices have changed over time at both the Y-12 National Security Complex (Y-12) and at the Oak Ridge National Laboratory (ORNL) regarding surplus sales. With rare exceptions, materials are no longer sold directly to the public by either facility. Materials from ETTP may be released through ORNL Property Excessing. Y-12 now uses an out-of-state contractor to handle the majority of their sales and ORNL focuses their resale operations currently to nine or ten organizations that are approved to bid on sales of materials by the truckload.

At the request of ORNL and/or Y-12 Property Excessing staff, DoR-OR conducts supplemental radiological verification screening surveys to help ensure that no potentially contaminated materials reach the public. Direct readings are converted to dpm/100 $cm^2$ (dpm = disintegrations per minute) and reported. In the event that elevated radiological activity is detected above the removable contamination limits set forth in NUREG-1757, Volume 1, Revision 2, Section 15.11.1.1 *Release of Solid Materials with Surface Residual Radioactivity* (Schmidt et al., 2006) or *Reg. Guide 1.86*, a quality control check is made with a second meter. If both meters show elevated activity, DoR-OR immediately reports the finding(s) to the DOE surplus sales program supervisor. A removable contamination assessment may be performed. DoR-OR then follows the response of the sales organizations to see that appropriate steps (i.e., removal of items from sale, resurveys, etc.) are taken to protect the public.

### 2.4.2 Problem Statements

Although the procedure for surplus of materials from the ORR has changed (materials are no longer directly auctioned to the public) the potential for items being released to pre-approved bidders may potentially reach the public.

Even when items of concern are found, they may not ultimately prove to be problematic. What first appears as an item with surface contamination may (with a resurvey) prove to be an instance where the suspected contamination can no longer be detected, is a non-reportable daughter product, or is a naturally occurring radioactive material.

### 2.4.3 Goals

DoR-OR's intent is to verify that materials that have been staged for sale, at ORNL's 115 Union Valley Road Property Excessing Facility or at other locations, are released in compliance with DOE's release policy. The project attempts to locate any contaminated items that may have evaded detection prior to being staged for sale. In rare instances where items of concern are found, it prevents the release of potentially contaminated materials to the public.

### 2.4.4 Scope

DoR-OR staff performs pre-auction verification surveys on items being auctioned by ORNL's Excess Properties Sales. These surveys are performed at the request of ORNL's Excess Properties staff per the ESOA Grant, as an additional check before release to the public. When a request is received, every attempt is made to fulfill that request. Typically, no more than eight events occur during a calendar year. DoR-OR has had no difficulty responding to all requests.

### 2.4.5 Methods, Materials, Metrics

Surplus sales verification work is performed under the guidance of *DoR-OR's 2017 Health and Safety Plan* (TDEC 2017) and other references below. Prior to sales of surplus items being released to the public, DoR-OR (when requested) conducts a pre-auction survey. The intent of this survey is to spot check items that are for sale with appropriate radiation survey instruments in order to ensure that no radioactively contaminated items are released to the public. Not all items or surfaces of a specific item are surveyed for potential radioactive contamination. Specific attention is paid to well-used items where material damage, uncleanliness, or staining is present. However, clean looking items may also be checked. When activity (alpha or beta/gamma) above the removable contamination limit is detected, the item is brought to the attention of Excess Property staff.

Based on DoR-OR's survey results, the Excess Property staff decides whether or not to have the item rechecked by ORNL RADCON. DoR-OR does not attempt to determine if a particular item meets DOE release criteria, but does try to locate items where, depending on which isotopes are involved, there is a potential for the item not meeting unrestricted release criteria set forth by the State of Tennessee, Division of Radiological Health.

### 2.4.6 Deviations from the Plan

There were no deviations from the plan.

### 2.4.7 Results and Analysis

The office responded to a total of six Surplus Sales Survey requests from July 2019 to June 2020. During these visits a total of 11 items were identified with activity above the ambient background. Most of these are TV displays, equipment that contains ceramics ($^{40}K$), or HVAC components. In each case these items were not only initially scanned by ORNL staff, but some had smears taken (obvious from the markings on the equipment). One piece of equipment, a transformer box, was from Northwind Corporation and ORNL staff said they would contact the Northwind staff for resolution.

The survey results were shared with ORNL in an e-mail message and the trip report was written and uploaded to the states records management system, DoRway.

### 2.4.8 Conclusions

The independent Surplus Sales Verification Project performed by TDEC DOE-OR is useful as a final check of equipment and material that will be transferred or sold to the general public. All of the lots are adequately scanned, but there were some pieces with surface areas where either the alpha or beta activity exceeded the ambient background. These surveys assist DOE in deciding whether equipment meets release criteria.

### 2.4.9 Recommendations

It is recommended that the Surplus Sales Verification Project continue; the project is functional and useful and provides a way for DOE to have an independent survey to confirm their own work. It also allows TDEC staff to become conversant with measuring radioactivity using the proper methods.

### 2.4.10 References

FRMAC Monitoring and Sampling Manual, Vols. 1 & 2. (2012) DOE/NV/11718-181-Vol. 1 & Vol. 2. Federal Radiological Monitoring and Assessment Center, National Nuclear Security Administration.

Tennessee Department of Environment and Conservation (TDEC), Division of Remediation. Operation and Use of a Ludlum Model 2224 (-1) and 43-93 Probe (Dual Phosphorus Meter) (SOP T-532). 2019.

Tennessee Department of Environment and Conservation (TDEC), Division of Remediation. Operation and Use of a Ludlum Model 2221 and 44-10 Probe (NaI Meter) (SOP T-540). 2019.

Tennessee Department of Environment and Conservation (TDEC) , Division of Remediation, Oak Ridge Office (DoR OR) 2017 Health and Safety Plan Including Related Policies, January 2017. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office, Oak Ridge, Tennessee.

## 2.5 HAUL ROAD SURVEYS

### 2.5.1 Background

The Tennessee Division of Environment and Conservation's (TDEC) Division of Remediation (DoR) Oak Ridge Office (OR) staff performs bimonthly surveys of the Haul Road and other waste transportation routes on the Oak Ridge Reservation (ORR). The Haul Road was constructed and reserved for trucks transporting Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) radioactive and hazardous waste from remedial activities on the ORR to the Environmental Management Waste Management Facility (EMWMF) for disposal.

To account for wastes that may have fallen from the trucks in transit, DoR-OR personnel perform walk over inspections of different segments of the nine-mile-long Haul Road and associated access roads on a bimonthly basis. Anomalous items noted along the roads are scanned for radiation, logged, marked with contractor's ribbon, and their descriptions and locations submitted to the Department of Energy (DOE) for disposition.

### 2.5.2 Problem Statements

In the history of the Haul Road a number of incidents resulting in potentially contaminated materials being freed in transport have highlighted the need for regular radiological surveys. Throughout the history of this project (HRSP), numbers of anomalous items have been identified such as waste debris, personal protection equipment, tarp patches, waste stickers, steel pipe, etc.

### 2.5.3 Goals

To prevent the spread of contamination resulting from the transportation of radioactive and hazardous waste from the originating remedial action locations on the ORR to the waste disposal location. In particular, the objectives include the following:

- To locate waste that may have been blown or dropped from waste-hauling trucks in transit.
- To allow DOE and their contractors to continue transporting waste in a manner that limits potential environmental concerns on the Haul Road and the surrounding areas.

### 2.5.4 Scope

The scope of this project is limited to locating, surveying, and reporting to DOE (for disposition) any ORR-derived waste materials that may have blown, spilled, or dropped from waste-hauling trucks on the Environmental Management Waste Management Facility (EMWMF) Haul Road.

### 2.5.5 Methods, Materials, Metrics

As previously noted, the nine-mile long Haul Road is surveyed in segments, typically consisting of one to two miles. For safety and by agreement with DOE and its contractors, DoR-OR (TDEC) staff coordinate with Haul Road site personnel when they intend to perform a survey on the Haul Road. The DOE contractor is responsible for providing briefings on road conditions and any known situation that could present a safety hazard while on the road. When the DOE contractor is not working, staff members call the designated DOE site safety office for the segment being surveyed. Should excessive traffic present a safety concern, the survey is postponed to a later date. Alternate entrances are sometimes used to access and egress the road with DOE approval, but the basic requirements remain in effect.

When staff members arrive at the segment of the road to be surveyed, the vehicle is parked completely off the road, as far away from vehicular traffic as possible. No fewer than two people perform the surveys, each walking in a serpentine pattern along opposite sides of the road to be surveyed or one person walking in a serpentine pattern across the entire road accompanied by an approved safety buddy. Typically, a Ludlum Model 2221 Scaler Ratemeter with a Model 44-10 2"X2" NaI Gamma Scintillator probe, held approximately six inches above the road's surface, is used to scan for gamma emitting radioactive contaminants as the walkover proceeds. A Ludlum 2224 Scaler with a Model 43-93 Alpha/Beta dual detector is used to investigate potential surface contamination on the road surfaces or anomalous items found along the road that may be associated with waste shipments. Other than ordinary conditions (i.e. anomalous conditions) that would be identified to DOE for follow up include: any areas or items with contamination levels exceeding 200 dpm/100 cm2 removable beta, 1000 dpm/100 cm2 total beta, 20 dpm/100 cm2 removable alpha, and/or 100 dpm/100 cm2 total alpha that may require further investigation as to the source or the anomaly or which may have the potential to spread of contamination.

Anomalous items, found during the survey, are marked with contractor's ribbon and moved to the side of the road and a description of each item and its location are logged and reported to DOE and its contractors for disposition. A survey form is completed for each walkover survey and is retained at the DoR-OR office. When staff members return to the road for the subsequent inspection, staff members perform a follow-up inspection of items found and reported during previous weeks. If any items remain on the side of the road, they are included in subsequent reports until removed by DOE or its contractors.

### 2.5.6 Deviations from the Plan

For this period of performance, no surveys were conducted after March 5, 2020 due to restrictions imposed by the COVID-19 pandemic.

### 2.5.7 Results and Analysis

The Haul Road walkover surveys identified 30 items in the July 2019 – March 2020 time frame, potentially originating from hazardous and/or radioactive waste being transported to the EMWMF. No surface contamination readings exceeded the free release limits. All ambient high energy gamma readings were within the normal background range for the area.

### 2.5.8 Conclusions

The periodic surveys of the roads used to haul waste to the EMWMF indicate waste items routinely fall from trucks transporting waste.

### 2.5.9 Recommendations

More decommissioning and demolition and remedial activities are planned for ETTP and Y-12 in the coming years. The wastes from these projects will be transported on the Haul Road. Based on previous findings, it is recommended that the TDEC Haul Road Surveys Project be continued in the upcoming year. This project has been useful for identifying to DOE, and ultimately supporting dispositioning of anomalous items that may have fallen or been blown from trucks during active operations.

### 2.5.10 References

FRMAC Monitoring and Sampling Manual, Vols. 1 & 2. (2012) DOE/NV/11718-181-Vol. 1 & Vol. 2. Federal Radiological Monitoring and Assessment Center, National Nuclear Security Administration.

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, Oak Ridge, Tennessee. DOE/OR/01-2220&D1. U.S. Department of Energy. (2005)

Tennessee Department of Environment and Conservation (TDEC), Division of Remediation. Operation and Use of a Ludlum Model 2224 (-1) and 43-93 Probe (Dual Phosphorus Meter) (SOP T-532). (2019).

Tennessee Department of Environment and Conservation (TDEC), Division of Remediation. Operation and Use of a Ludlum Model 2221 and 44-10 Probe (NaI Meter) (SOP T-540). (2019).

Tennessee Department of Environment and Conservation (TDEC),, Division of Remediation, Oak Ridge Office (DoR OR) 2017 Health and Safety Plan Including Related Policies, January 2017. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office, Oak Ridge, Tennessee.

# 3.0 BIOLOGICAL MONITORING

## 3.1 BENTHIC MACROINVERTEBRATES

### 3.1.1 Background

The Benthic Macroinvertebrate Monitoring Project monitors the current condition and changing conditions of stream-bottom communities in streams on the Oak Ridge Reservation (ORR). These streams have been negatively impacted by historical Manhattan Project activities as well as current operational activities at the three facilities on the reservation; East Tennessee Technology Park (ETTP) Oak Ridge National Laboratory (ORNL), and the Y-12 National Security Complex (Y-12). The purpose of the Benthic Macroinvertebrate Project is to document the current condition of these stream communities and to note the changes of these conditions as remedial activities continue under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

Stream-bottom communities (aquatic insects and other macroinvertebrate species) serve as indicators of the health of aquatic systems. The majority of the lives of these organisms are spent in water. They are continually exposed to conditions caused by direct or indirect discharges to these waters. Un-impacted reference streams are used to define what a healthy community would look like. That determination is then compared to those assessments of impacted sites in streams on the ORR to help determine the extent of the suspected impacts.

East Fork Poplar Creek (EFPC), Bear Creek, Mitchell Branch, and White Oak Creek (WOC) are the four main watersheds studied at the three facilities on the ORR. EFPC and Bear Creek serve as the watersheds on the Y-12 site. Mitchell Branch serves as the main watershed on the ETTP site. WOC is the primary watershed on the ORNL site. The headwaters of WOC and Mitchell Branch serve as the reference sites for those watersheds. Because EFPC and Bear Creek are both impacted in the headwaters, other onsite and offsite streams serve as reference sites for those watersheds.

ORNL staff also conduct benthic macroinvertebrate monitoring on some of the same streams as TDEC Division of Remediation, Oak Ridge (DoR-OR). However, a number of the specific sites monitored differ between the two organizations. Even where the specific sites are the same, TDEC’s sampling serves as an independent check on ORNL’s monitoring results. Determining impacts on stream bottom communities is a difficult task and results and interpretations may vary among different sampling and analysis personnel, which may cause some results to be slightly different.

An independent evaluation helps to produce a clearer picture of actual conditions in ORR streams.

All work on this project follows the requirements of TDEC Division of Remediation Oak Ridge *Office Health and Safety Plan* (TDEC 2019).

### 3.1.2 Problem Statements

Benthic macroinvertebrate communities at the majority of sites in the four main watersheds in this study do not compare well with healthy communities from un-impacted reference streams. Intolerant species (organisms that do not survive well in polluted areas) are found in significantly smaller instances and quantities at a number of ORR sampling sites. Similarly, tolerant species (organisms that survive and can tolerate polluted areas) are found in significantly higher instances and quantities in a number of ORR sampling sites. These findings indicate stream impairment due to anthropogenic activity. Many of the impacts affecting these streams result from both historical Manhattan Project activities as well as current operational activities on the ORR. The majority of these impacts are due to typical industrial contaminants (e.g., residual chlorine and other chemical releases [both chronic and acute], and organic loading from point and non-point discharges) and are not related to the radiological contamination of the ORR sampling sites. In areas where stream sections have been channelized, problems may be due to a lack of appropriate substrates for the establishment of healthy stream-bottom communities.

Variability in the data may result from a multitude of factors. Part of this variability is due to the natural year-to-year fluctuations in benthic communities (flow rates, heat waves, storm events… etc.). Another part of this variability is due to variation among samplers. Because of these sources of variability, data recorded from benthic community monitoring benefits from long term sampling and sampling with different experienced personnel.

As remedial activities continue on the ORR, ongoing benthic sampling and analysis will help to clarify if this remedial work is improving stream conditions or if other factors, not directly related to remedial activities, are responsible for the impacted conditions of the ORR streams.

### 3.1.3 Goals

The goals of the Benthic Macroinvertebrate Monitoring Project are varied:

- Primary among these goals is to monitor the current condition and health of benthic communities at stream sites on the Oak Ridge Reservation. The existence of historical data from these streams will help in the interpretation of whether these sites have improved, further degraded, or remained the same since remedial activities began on the ORR. This evaluation may be based on the use of various metrics, as well as the species composition and community density of benthic populations.

- A second goal is to provide data for comparison with other ongoing DOE studies of benthic communities. As indicated above, there is a normal year-to-year variation in benthic communities, as well as sampling- and analysis-induced variation. A comparison of data from different sources could clarify the actual current conditions at the ORR sites.
- A third goal is to better understand the causes of impacts in benthic communities on the ORR. At sites where pollution-tolerant organisms predominate, the problems could be due to organic loading of the streams by point and or non-point sources. At sites where mayfly populations are absent or extremely limited, metals toxicity problems of a chronic or acute nature may be responsible. At sites where benthic community densities (i.e., organisms/$m^2$) are very low, acute, and/or episodic, toxicity problems (e.g., chlorine or biocides) could be to blame.
- A fourth goal of benthic macroinvertebrate monitoring is to provide recommendations on potential changes that may be made to help improve the current health of streams on and off the ORR where primary impacts are due to the Oak Ridge facilities. These recommendations could run the gamut from pointing out areas where banks need stabilization, defining areas where suitable substrate is unavailable and identifying data interpretations where a clearer picture of the existing problems may be provided.
- A fifth goal is to attempt to elucidate impacts from sources other than the ORR facilities which may be affecting streams that flow both on and off the ORR (e.g., Mitchell Branch, East Fork Poplar Creek, Bear Creek). Not all impacts in a watershed are due to ORR facilities. Other sources affecting stream recovery must also be identified.

### 3.1.4 Scope

The physical boundaries of the Benthic Macroinvertebrate Monitoring Project include streams of the major watersheds on the three facilities of the ORR. At ORNL, these streams include White Oak Creek from its headwaters to near its confluence with White Oak Lake and Melton Branch. At Y-12, these streams include East Fork Poplar Creek from its headwaters to approximate kilometer 6.3 and, Bear Creek from the headwaters to its confluence with East Fork Poplar Creek. At ETTP, Mitchell Branch is surveyed from its headwaters to near its confluence with Poplar Creek. Also included in these physical boundaries are offsite reference sites for the study which include Mill Branch, Hinds Creek and Clear Creek.

On an annual basis the TDEC DoR, Oak Ridge Office conducts benthic macroinvertebrate monitoring surveys of the watersheds, streams, and stations listed in Table 3.1.1. Maps for all current sampling sites are included in Figures (3.1.1-3.1.5). The sampling for the project includes two one-m$^2$ composited samples for each study site. In addition, duplicate samples are taken at two sites for quality control.

The temporal boundaries for the Benthic Macroinvertebrate Monitoring Project are sampling of all stations in the study between the beginning of May and the middle of June of a given year. Specific sampling dates were dependent on availability of staff to perform the sampling, vehicles, and recent weather conditions (i.e., sampling is best completed under normal, not high-water flows). At sites where samples were taken both by TDEC DoR and ORNL, care was taken to plan for a two- to three-week sampling time difference to allow for recovery of the benthic community.

**Table 3.1.1: Sampling Sites for Benthic Macroinvertebrate Monitoring**

| Facility | Watershed | Stations | Reference Stations |
|---|---|---|---|
| ORNL | White oak Creek | WCK 3.9 | WCK 6.8 |
| | | WCK 3.4 | |
| | | WCK 2.3 | |
| | | MEK 0.3 | |
| Y-12 | East Fork Poplar Creek | EFK 25.1 | HCK 20.6 |
| | | EFK 24.4 | |
| | | EFK 23.4 | |
| | | EFK 13.8 | |
| | | EFK 6.3 | |
| | Bear Creek | BCK 12.3 | |
| | | BCK 9.6 | MBK 1.6 |
| | | BCK 3.3 | |
| ETTP | Mitchell Branch | MIK 0.71 | MIK 1.43 |
| | | MIK 0.45 | |

WCK = White Oak Creek Kilometer; MEK = Melton Branch Kilometer; EFK = East Fork Poplar Creek Kilometer; BCK = Bear Creek Kilometer; MIK = Mitchell Branch Kilometer; HCK = Hinds Creek Kilometer; MBK = Mill Branch Kilometer.

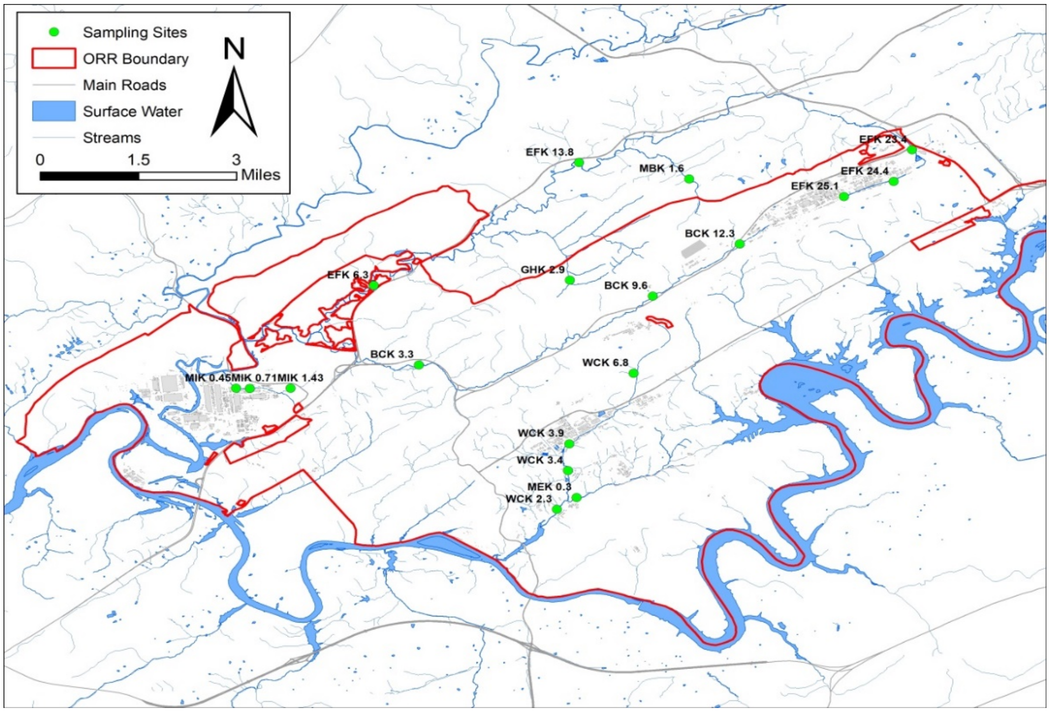


**Figure 3.1.1: All Benthic Macroinvertebrate Monitoring Stations (Excluding reference HCK 20.6)**

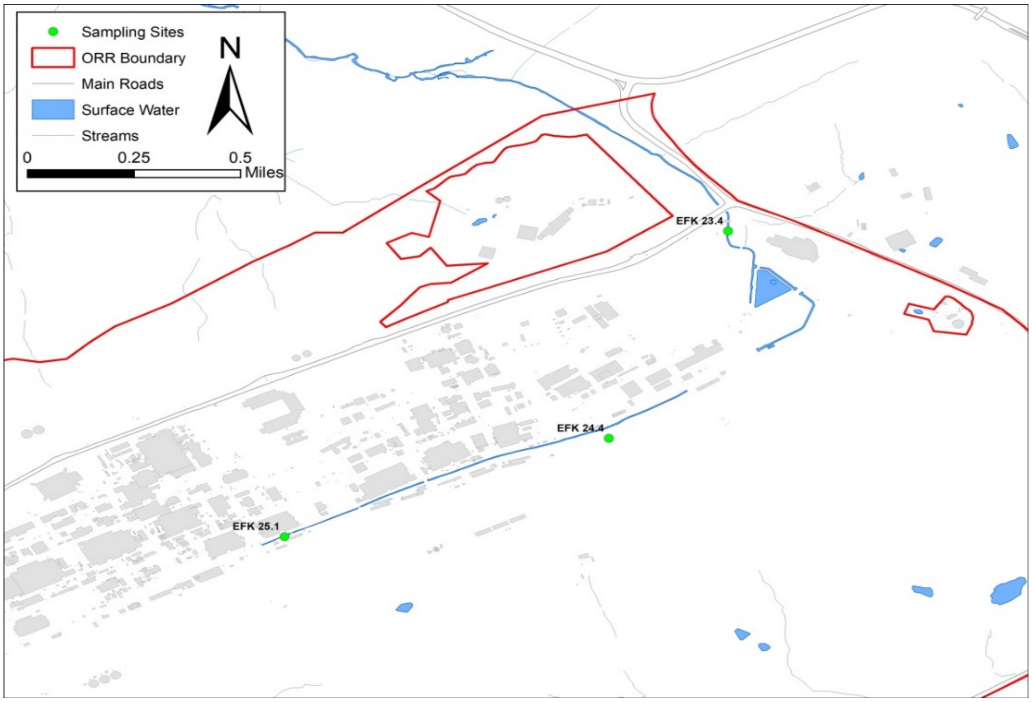


**Figure 3.1.2: Benthic Macroinvertebrate Monitoring Stations in Upper East Fork Poplar Creek**

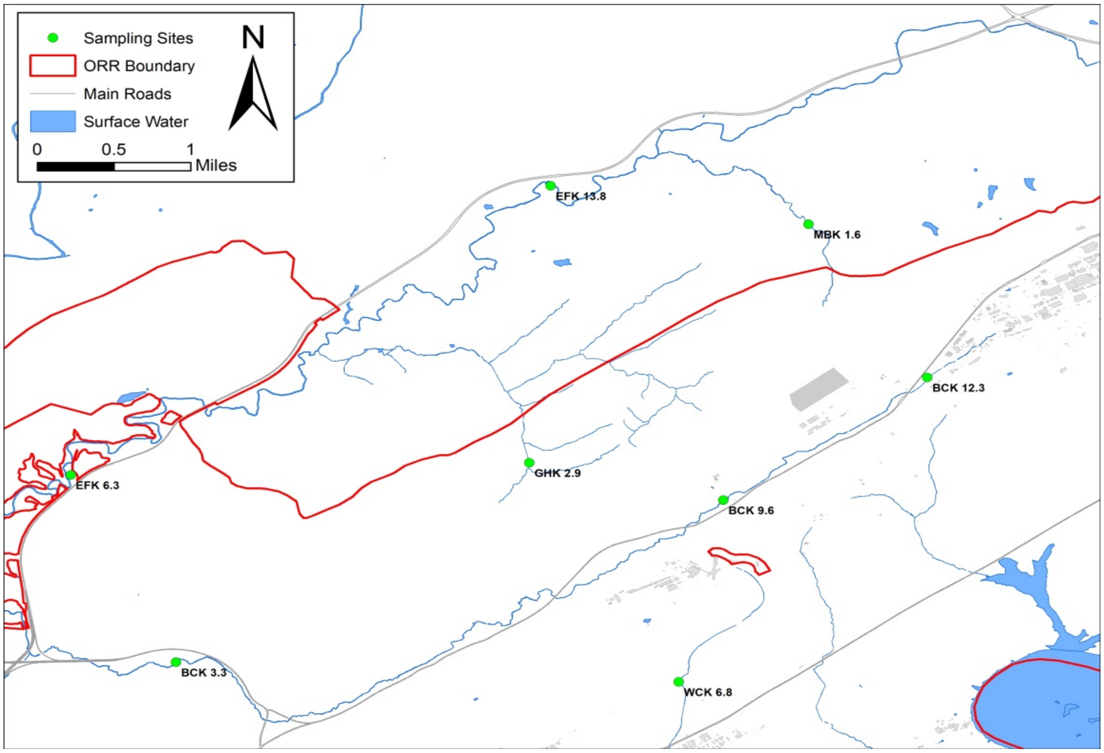


**Figure 3.1.3: Benthic Macroinvertebrate Monitoring Stations in Bear Creek, Mill Branch Creek, and Lower East Fork Poplar Creek**

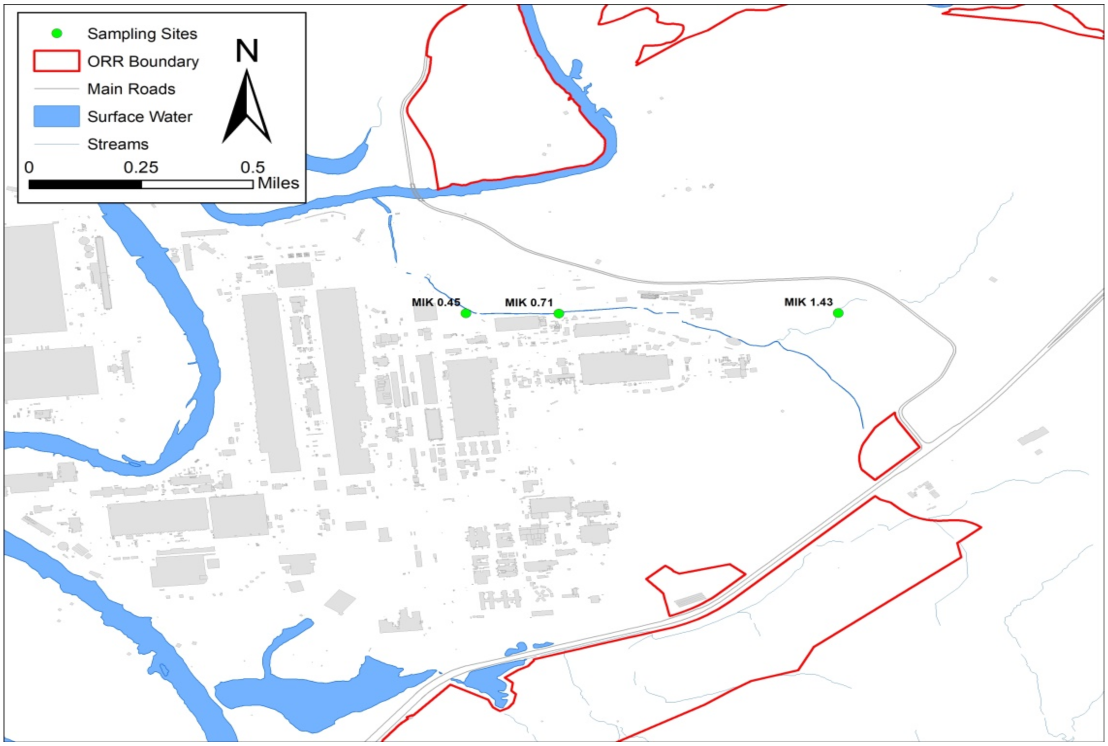


**Figure 3.1.4: Benthic Macroinvertebrate Monitoring Sites at Mitchell Branch**

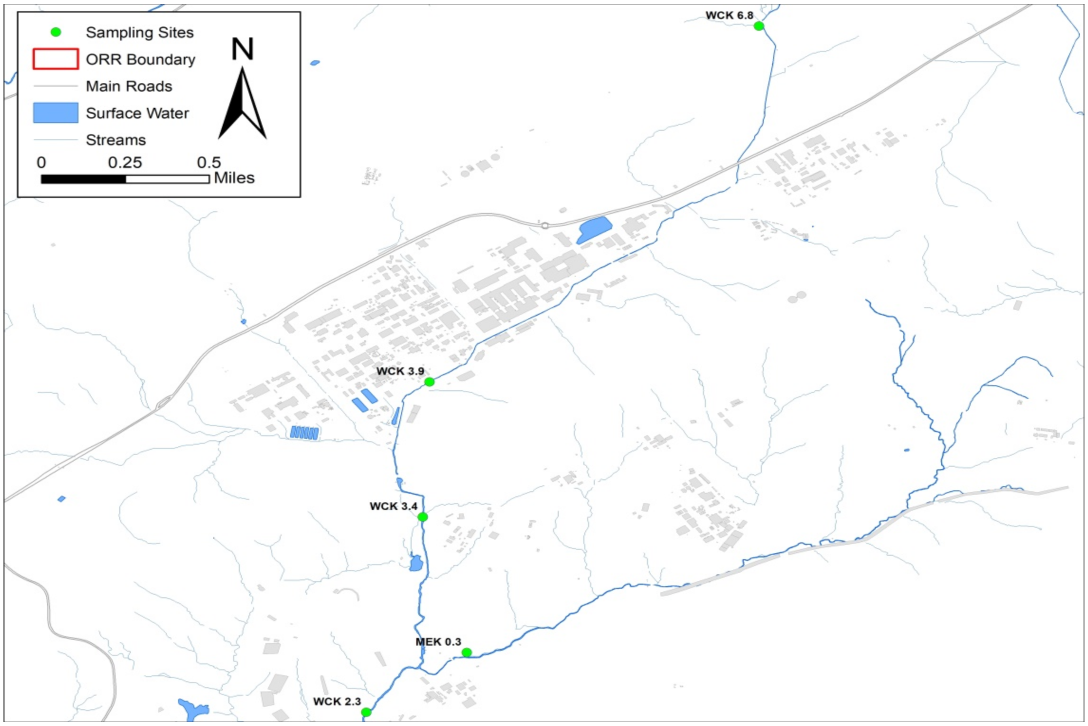


**Figure 3.1.5: Benthic Macroinvertebrate Monitoring Sites at ORNL**

### 3.1.5 Methods, Materials, Metrics

**Sample Collection:**

Sampling for this project requires two people at a minimum. One person sets a one-square-meter kick net with a 500-micron mesh across a predetermined riffle. The other person, using a heavy-duty garden rake, disturbs approximately 1 $m^2$ area of the stream substrate directly upstream of that net. The organisms, sediment, and detritus flow into the net. The net is then carefully lifted out of the water and carried horizontally to the streambank. The bottom of the net is positioned in a 500-micron sieve bucket. The net is thoroughly rinsed into the sieve bucket. This process is repeated using a second riffle. The two kicks are then composited, placed in a plastic container, and preserved with 95% ethanol.

**Sample Processing:**

Processing of benthic samples consists of two major steps. The first step is sample sorting, where benthic organisms are removed from the detrital material collected along with the organisms.

The second step in processing is sample identification of the organisms collected. The larger macroinvertebrates are identified by an experienced taxonomist using a binocular dissecting scope and the appropriate organism identification keys, where needed. The smaller macroinvertebrates, which include the *Chironomidae* (non-biting midges) and the smaller *Oligochaeta* (worms), are often mounted on slides and identified by an experienced taxonomist using a binocular compound light microscope and the appropriate keys.

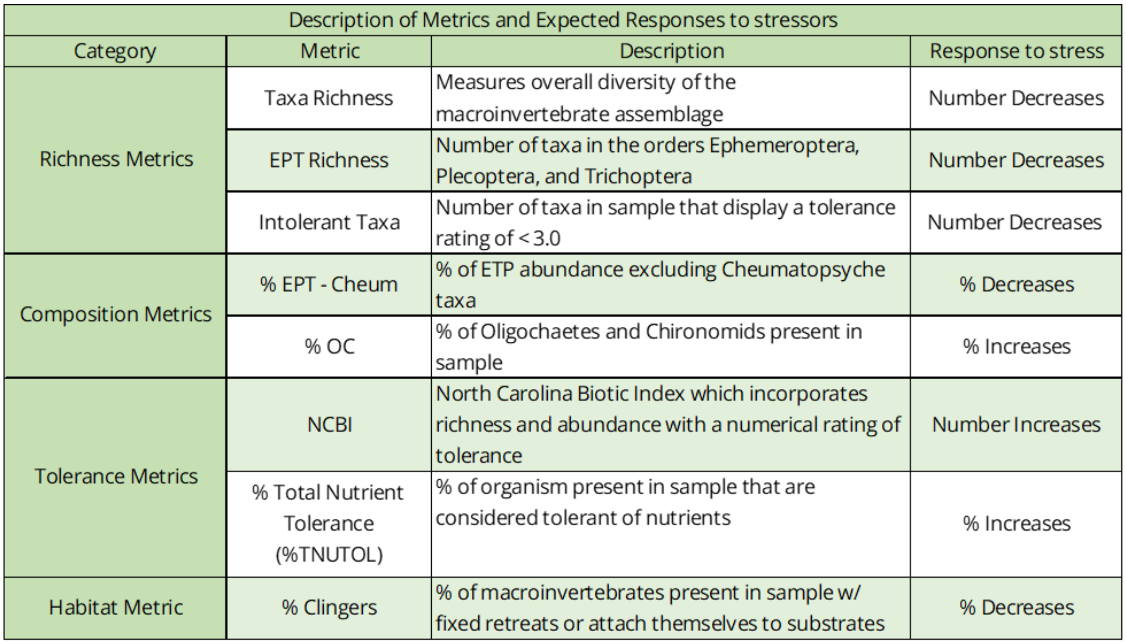
The majority of the samples are preserved and brought to the DoR-OR laboratory for processing. In the case of White Oak Creek and Melton Branch, where elevated levels of radionuclides occur in the samples, sorting is performed in the field so that contaminated sediments can be returned to their source and not brought into the laboratory.

Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys (TDEC 2017) requires identification of taxa to only the genus-level. Calculations of all metrics for this study were determined using the genus-level identifications.

**Data Analysis:**

Once sample identifications are complete, the identifications for each sample are totaled for each genus and entered into an Excel spreadsheet. The data are then transferred to another Excel spread sheet for calculation of the various metrics used in the analysis. Metrics are then totaled for each sample and comparisons of impacted sites to reference sites are made. A description of each metric and their expected responses to environmental stressors is listed in Table 3.1.2.

**Table 3.1.2. Description of Metrics and Expected Responses to Stressors**



| Description of Metrics and Expected Responses to stressors | | | |
|---|---|---|---|
| Category | Metric | Description | Response to stress |
| Richness Metrics | 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 |
| | Intolerant Taxa | Number of taxa in sample that display a tolerance rating of < 3.0 | Number Decreases |
| Composition Metrics | % EPT - Cheum | % of ETP abundance excluding Cheumatopsyche taxa | % Decreases |
| | % OC | % of Oligochaetes and Chironomids present in sample | % Increases |
| Tolerance Metrics | NCBI | North Carolina Biotic Index which incorporates richness and abundance with a numerical rating of tolerance | Number Increases |
| | % Total Nutrient Tolerance (%TNUTOL) | % of organism present in sample that are considered tolerant of nutrients | % Increases |
| Habitat Metric | % Clingers | % of macroinvertebrates present in sample w/ fixed retreats or attach themselves to substrates | % Decreases |

## 3.1.6 Deviations from the Plan

Some of the streams being monitored on the ORR did not meet the conditions necessary for comparison of results to bioregion biocriteria of Tennessee. An alternative reference stream method cited in the *2017 Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys (TDEC 2011)* was used to evaluate the study's results. The primary condition not met was that certain streams in the study were headwater streams (< 2 square miles of drainage area). The description of the alternative reference stream method is provided in Section 1.I, Protocol K: Pages 3 and 4 of the Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys (TDEC 2017).

In order to generate a table of values for comparison of reference stations to potentially impacted stream stations, eight metrics were first calculated for all of the reference stations (CCK 1.45, GHK 2.9, HCK 20.6, MBK 1.6, MIK 1.43, and WCK 6.8). Based on the average value of each metric and using the calculations provided in Section I.I, Protocol K: Page 5 of the *Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys (TDEC 2017)*, ranges of values for ratings of 6, 4, 2, and 0 for each metric were further determined. The adjusted metric data for the 2010 - 2019 data is found in Table 3.1.6.

**Table 3.1.3: Alternative Reference Stream Metrics**

| Alternative Reference Stream Metrics | | | | |
|---|---|---|---|---|
| Metric | 6 | 4 | 2 | 0 |
| Taxa Richness | >38 | 25-37 | 12-24 | <12 |
| EPT Richness | >14 | 9-13 | 4-8 | <4 |
| % EPT - Cheum | >30.61 | 20.41-30.60 | 9.80-20.40 | <9.80 |
| % OC | <=45.39 | 45.40-63.59 | 63.60-81.79 | >81.79 |
| NCBI | <=4.99 | 5.00-6.66 | 6.70-8.33 | >8.33 |
| % Clingers | >26.77 | 17.85-26.76 | 8.01-17.84 | <8.01 |
| %Tnutol | <=39.43 | 39.44-59.62 | 59.63-79.81 | >79.82 |
| % Intolerant Taxa | >=15 | 11-14 | 8-10 | <8 |

## 3.1.7 Results and Analysis

### East Fork Poplar Creek

Tennessee Macroinvertebrate Index (TMI) scores (alternative reference stream method), and biological condition ratings are presented in Table 3.1.4 for the East Fork Poplar Creek watershed. The stream numbers represent distances in kilometers that decrease from headwaters (EFK 25.1) towards the mouth downstream (EFK 0.0).

The reference stream for the EFPC watershed is Hinds Creek (HCK 20.6). In 2013 and 2014, Gum Hollow Creek (GHK 2.9) was used as a reference stream.

Impacts occur from the headwaters of East Fork Poplar Creek to a considerable distance downstream in the watershed. The headwaters of the stream originate from tributaries that flow through stormwater conduits in the main industrialized portion of Y-12. Near its origin, East Fork Poplar Creek receives inputs of contaminants such as mercury, uranium, volatile organic compounds (VOCs) and other metals and organics. Once leaving the Y-12 boundary, East Fork Poplar Creek receives further contaminant loading from urban and suburban runoff as well as a sewage treatment plant discharge. Downstream, it flows through urbanized and suburbanized sections of Oak Ridge before flowing through less developed areas prior to its confluence with Poplar Creek. Only near its mouth does East Fork Poplar Creek flow through relatively undisturbed terrain.

**Table 3.1.4: TMI Scores and Biological Condition Ratings for East Fork Poplar Creek and Reference Station**

| | Total | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EFK 25.1 | | EFK 24.4 | | EFK 23.4 | | EFK 13.8 | | EFK6.3 | | HCK 20.6 | |
| | TMI | RATING | TMI | RATING | TMI | RATING | TMI | RATING | TMI | RATING | TMI | RATING |
| 2010 | 14 | **C** | 24 | **B** | 20 | **C** | 30 | **B** | 28 | **B** | 46 | **A** |
| 2011 | 10 | **C** | 20 | **C** | 20 | **C** | 34 | **A** | 30 | **B** | 40 | **A** |
| 2012 | 20 | **C** | 28 | **B** | 26 | **B** | 30 | **B** | 30 | **B** | 38 | **A** |
| 2013 | 26 | **B** | 22 | **B** | 20 | **C** | 32 | **A** | 28 | **B** | *48 | **A** |
| 2014 | 22 | **B** | 32 | **A** | 28 | **B** | 38 | **A** | 28 | **B** | *48 | **A** |
| 2015 | 14 | **C** | 22 | **B** | 20 | **C** | 32 | **A** | 26 | **B** | 44 | **A** |
| 2016 | 20 | **C** | 22 | **B** | 24 | **B** | 38 | **A** | 28 | **B** | 46 | **A** |
| 2017 | 18 | **C** | 24 | **B** | 26 | **B** | 30 | **B** | 28 | **B** | 42 | **A** |
| 2018 | 16 | **C** | 14 | **C** | 26 | **B** | 34 | **A** | 28 | **B** | 42 | **A** |
| 2019 | 26 | **B** | 20 | **C** | 26 | **B** | 32 | **A** | 28 | **B** | 46 | **A** |
| Key: | A = Supporting / Non Impaired (TN Macro. Index Scores >= 32) | | | | | | | | | | | |
| | B = Partially Supporting / Slightly Impaired (TMI Scores 21 - 31) | | | | | | | | | | | |
| | C = Partially Supporting / Moderately Impaired (TMI Scores 10 - 20) | | | | | | | | | | | |
| | D = Non Supporting / Severely Impaired (TMI Scores < 10) | | | | | | | | | | | |
| | * Gum Hollow Creek Km 2.9 was used as a refenence in 2013 and 2014 | | | | | | | | | | | |

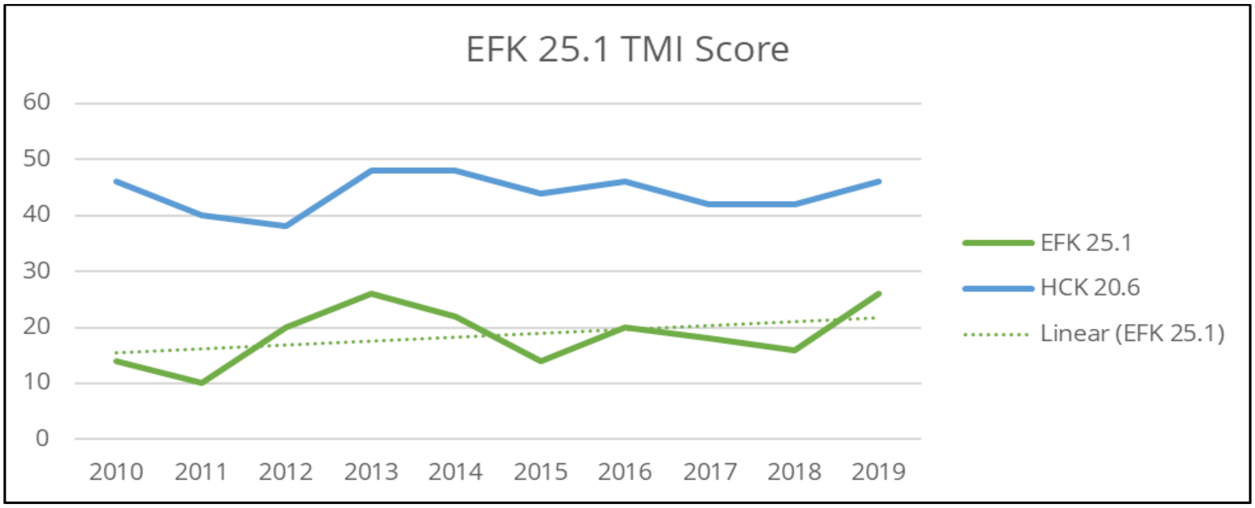


**Figure 3.1.6: EFK 25.1 Total Metric Index Score from 2010 to 2019**

EFK 25.1 routinely performs lowest among the stations monitored. However, there is evidence that benthic communities are slowly recovering as more natural substrates replace the channelized stream bed and active contamination is reduced. The total metric index for EFK 25.1 does not compare well with its reference stream HCK 20.6 (Figure 3.1.6). On average, the total metric index for EFK 25.1 is 25 points lower than HCK 20.6.

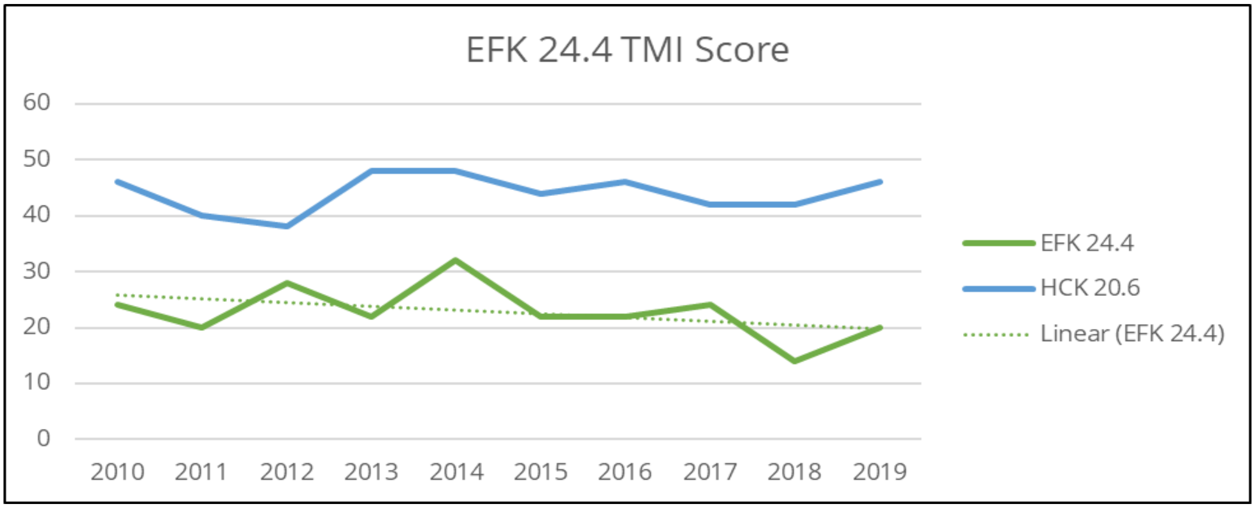


**Figure 3.1.7: EFK 24.4 Total Metric Index Score from 2010 to 2019**

The data collected from EFK 24.4 shows a steady decline in benthic macroinvertebrate communities and is currently rated as “partially supporting/moderately impaired” (Figure 3.1.7). The most noticeable deterioration is observed with regards to the composition of the macroinvertebrate populations. The benthic community at EFK 24.4 is primarily made up of tolerant organisms (Cheumatopsyche, Oligochaetes, etc...). These organisms, once established, push out more diverse, sensitive species. There has been a decline in biodiversity at EFK 24.4 from 2014 to 2019.

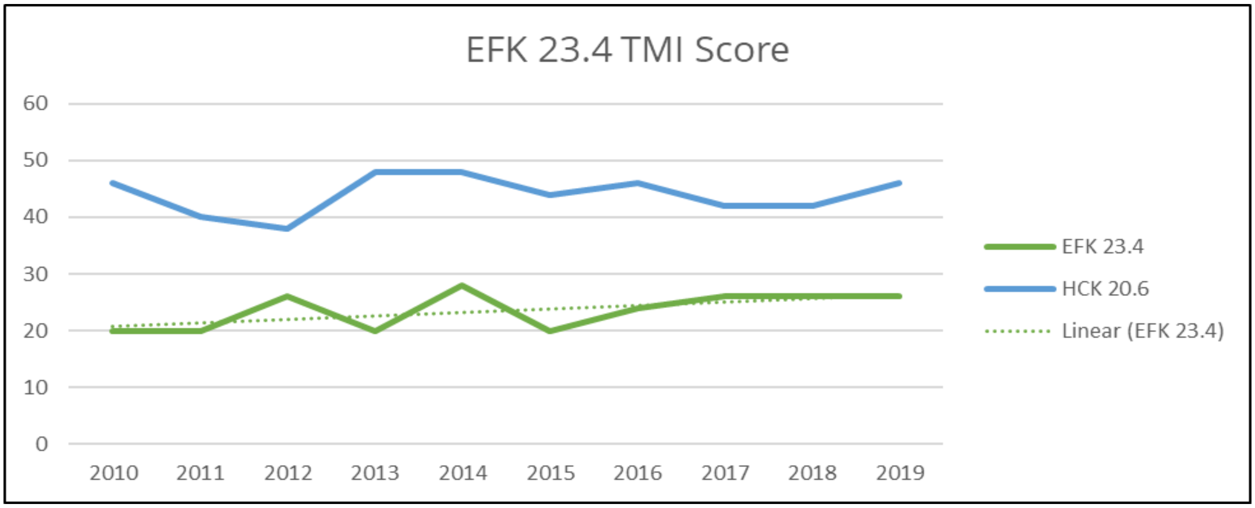


**Figure 3.1.8: EFK 23.4 Total Metric Index Score from 2010 to 2019**

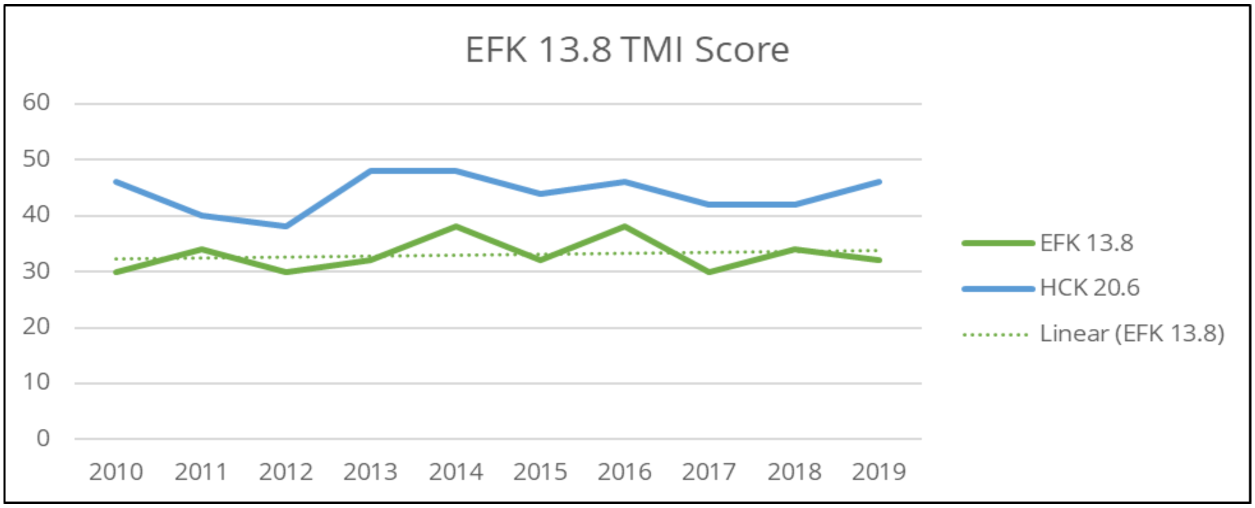


**Figure 3.1.9: EFK 13.8 Total Metric Index Score from 2010 to 2019**

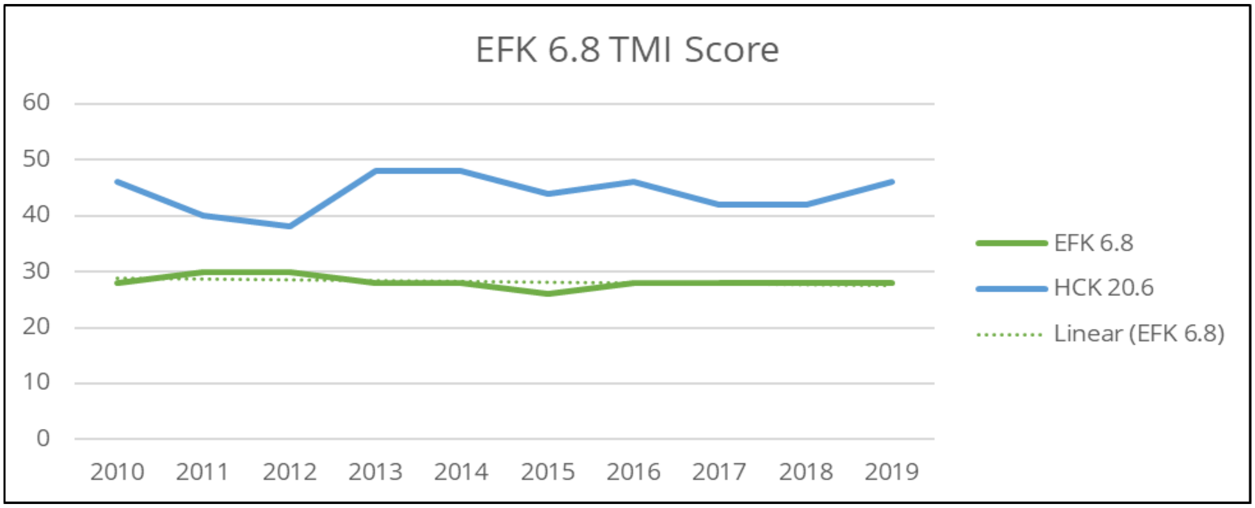


**Figure 3.1.10: EFK 6.8 Total Metric Index Score from 2010 to 2019**

From 2010 to 2014, the total metric index for all monitoring locations on East Fork Poplar Creek were trending upward, with 2014 being the best year overall for EFPC, with the exception of EFK 6.8 which has remained consistent over the 2010 – 2019 monitoring period. Benthic macroinvertebrate populations appeared to be recovering from the known environmental stressors. The biological improvements were likely due to the increased flow caused by the augmentation of water from the Clinch River into the headwaters of East Fork Poplar Creek. Beginning in May 2014, flow augmentation was halted from the Clinch River, causing a decrease in the total metric index for all sites. Effects from the change in flow can be seen clearly in the graphs X-X. The total metric index decreased by an average of 8.6 in upper section of the stream (EFK 25.1, EFK 24.4, and EFK 23.4) and decreased by an average of 4 in the lower section of the stream (EFK 13.8 and EFK 6.8).

From 2015 – 2019 the total metric index for EFK 24.4, EFK 23.4, EFK 13.8, and EFK 6.8 stabilized, but remained well below the levels of comparable reference streams. EFK 25.1 had considerable variation in the total metric index. This variation is most likely due to receiving the highest concentration of contaminants from Y-12 and a channelized substrate. The channelized substrate causes a lack of available habitat, leaving the macroinvertebrate populates more vulnerable to changes in water composition and changes in flow.

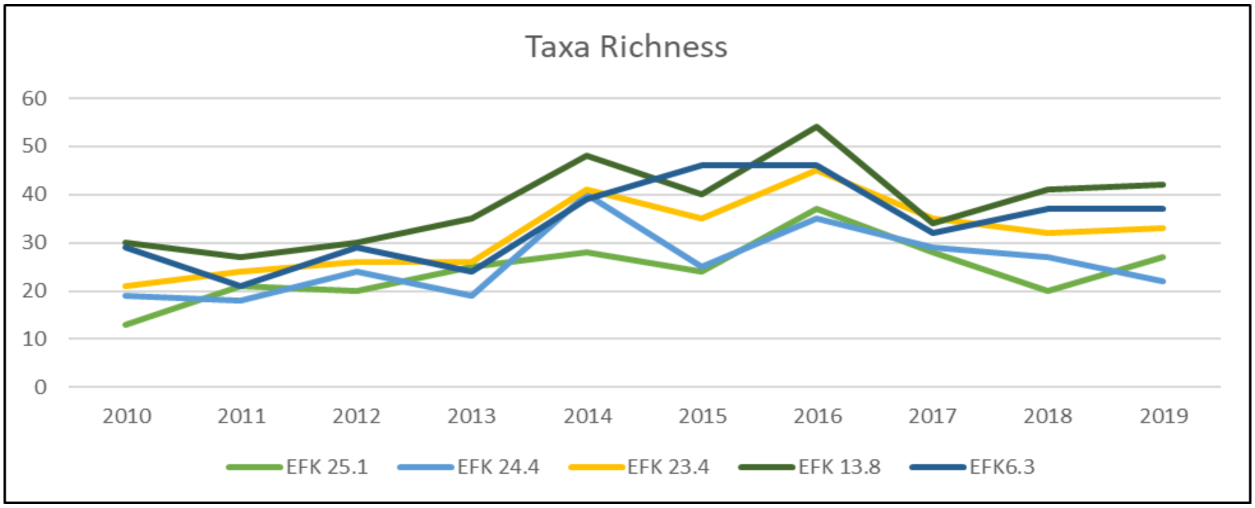


**Figure 3.1.11: Taxa Richness in East Fork Poplar Creek from 2010 to 2019**

In 2017, there is a noticeable sudden decrease in taxa across the board for all East Fork Poplar Creek sites, deviating from their upward trajectory (Figure 3.1.11). The cause is unknown at this time.

### 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 (<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 stations (MIK 0.71 and MIK 0.45). Historically, MIK 1.43 has been relatively unimpacted by the presence of ETTP. The lower stations (MIK 0.71 and MIK 0.45) have been impacted not only from former industrial activities at ETTP and waste areas but have also been channelized with much of the channel being replaced with unnatural substrate.

## Table 3.1.5: TMI Scores and Biological Condition Ratings for Mitchell Branch

| Total | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | MIK 0.45 | | MIK 0.71 | | MIK 1.43 | |
| | | | TMI | RATING | TMI | RATING | TMI | RATING |
| 2010 | | | 24 | **B** | 24 | **B** | 26 | **B** |
| 2011 | | | 20 | **C** | 26 | **B** | 24 | **B** |
| 2012 | | | 24 | **B** | 30 | **B** | 46 | **A** |
| 2013 | | | 24 | **B** | 32 | **A** | 42 | **A** |
| 2014 | | | 34 | **A** | 32 | **A** | 44 | **A** |
| 2015 | | | 28 | **B** | 32 | **A** | 44 | **A** |
| 2016 | | | 26 | **B** | 32 | **A** | 34 | **A** |
| 2017 | | | 30 | **B** | 30 | **B** | 36 | **A** |
| 2018 | | | 30 | **B** | 38 | **A** | 40 | **A** |
| 2019 | | | 34 | **A** | 30 | **B** | 28 | **B** |
| Key: | A = Supporting / Non Impaired (TN Macro. Index Scores >= 32) | | | | | | | |
| | B = Partially Supporting / Slightly Impaired (TMI Scores 21 - 31) | | | | | | | |
| | C = Partially Supporting / Moderately Impaired (TMI Scores 10 - 20) | | | | | | | |
| | D = Non Supporting / Severely Impaired (TMI Scores < 10) | | | | | | | |

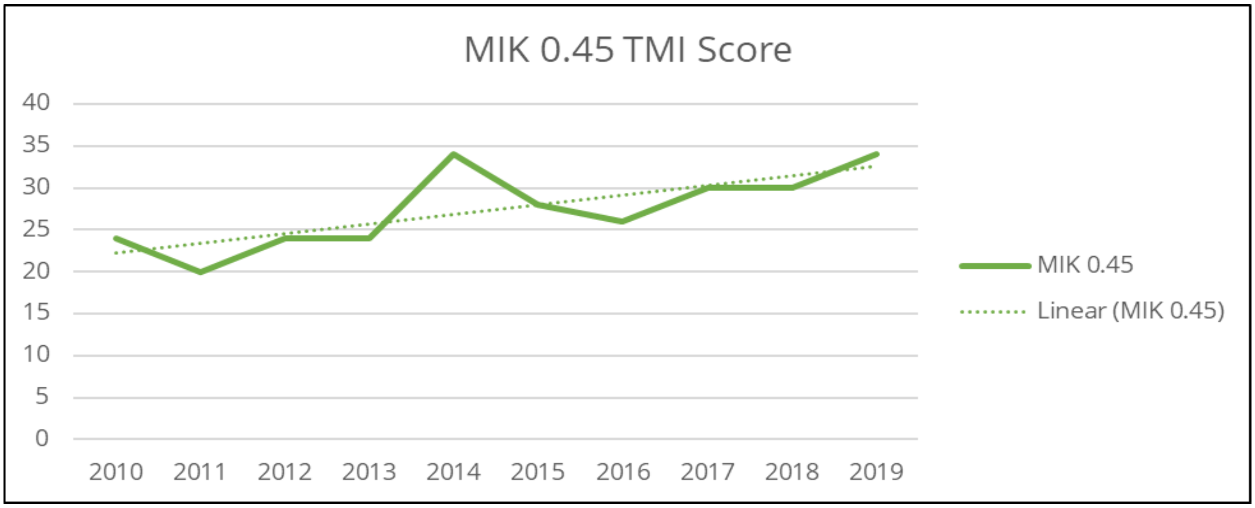


**Figure 3.1.12: MIK 0.45 Total Metric Index Score from 2010 to 2019**

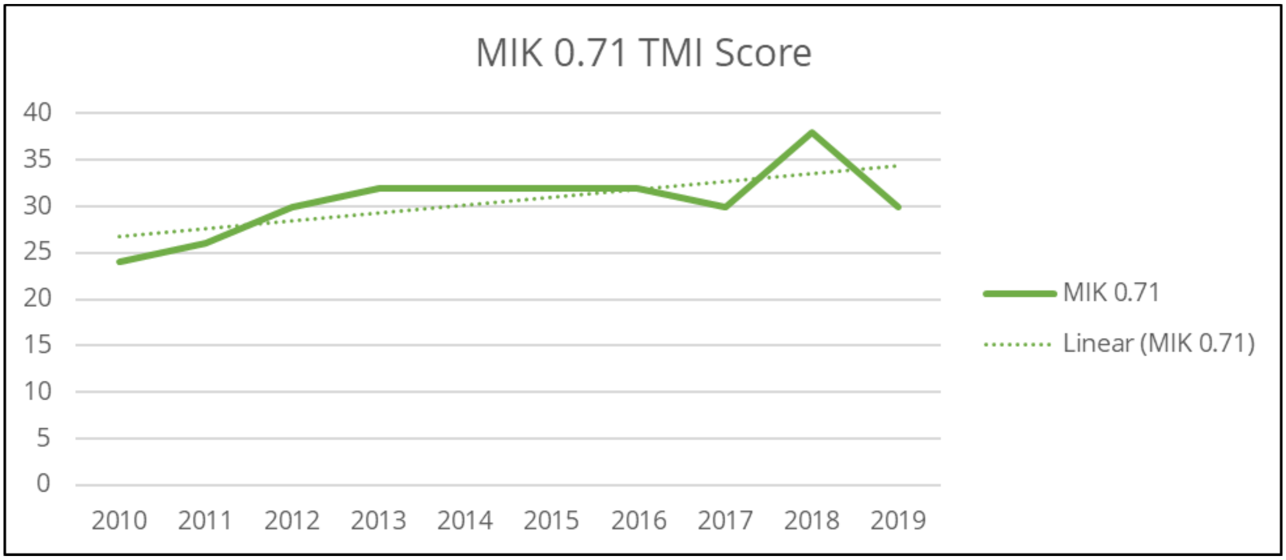


**Figure 3.1.13: MIK 0.71 Total Metric Index Score from 2010 to 2019**

From 2010 to 2019, MIK 0.45 and MIK 0.71 have shown a steady increase in biological integrity with respect to their total metric index (Figure 3.1.12-3.1.13). MIK 0.45 has shown the most improvement over this time period. In 2011, MIK 0.45 has a TMI score of 20 and was rated as "partially supporting/moderately impaired". In this year's collection, 2019, MIK 0.45 had a TMI score of 34 and is rated as "supporting/non-Impaired" (Table 3.1.5). Based on the majority of metrics, MIK 0.45 and MIK 0.71 appear to be improving in condition. 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 remedial activities will allow Mitchell Branch to continue to improve.

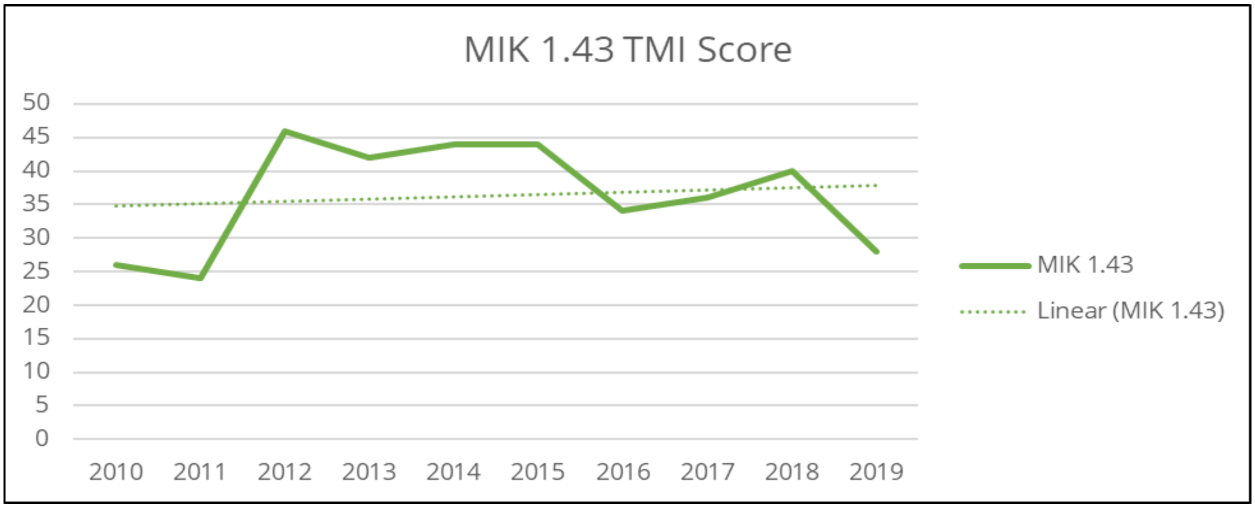


**Figure 3.1.14: MIK 1.43 Total Metric Index Score from 2010 to 2019**

Perhaps more significant than these improvements is the apparent slow degradation of the upstream portions of Mitchell Branch from 2012 - 2019. Siltation and inconsistent flow due to flood and drought events, appear to be having a negative impact on the health of MIK 1.43. It is difficult to see appreciable differences between MIK 1.43 (reference station) and the lower two impacted Mitchell Branch stations (MIK 0.71 and MIK 0.45) (Figure 3.1.15).

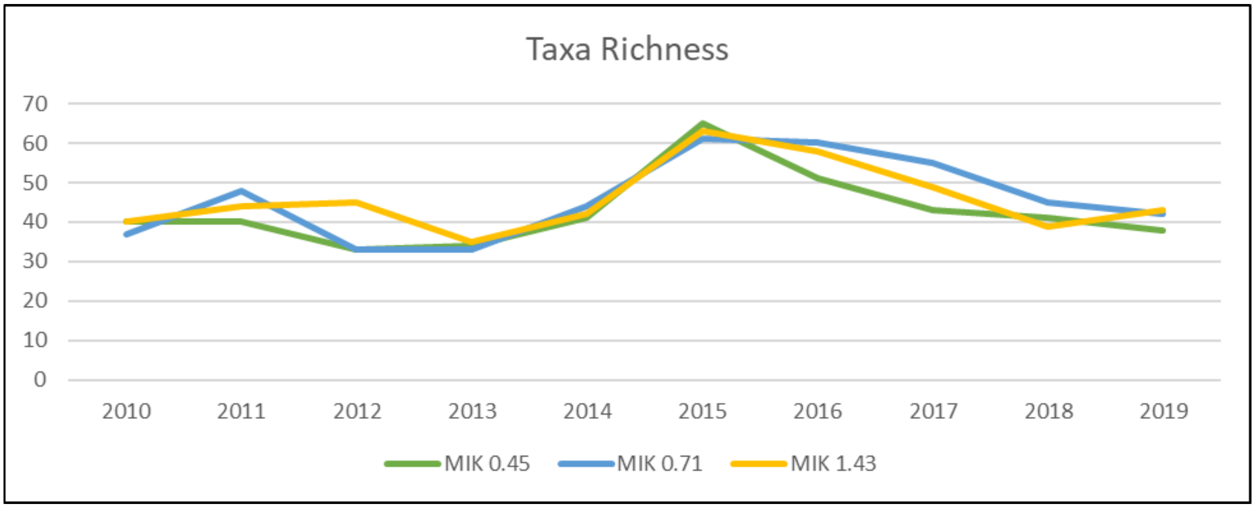


**Figure 3.1.15: Taxa Richness in Mitchell Branch from 2010 to 2019**

**Bear Creek**

Bear Creek is a small to moderate-sized stream whose headwaters begin partly in the west end of the industrialized complex at Y-12. Historically, Bear Creek has received pollution from industrial activities, as well as waste disposal activities at Y-12. Former waste sites, such as the S3 ponds located at its headwaters, continue to negatively influence the water quality of the stream. Heading downstream from its source, Bear Creek continues to be impacted by inputs from various former and current waste sites. Bear Creek is also a stream where shallow groundwater and surface waters mingle freely throughout its length to its confluence with East Fork Poplar Creek. Because Bear Creek is impacted from its headwaters, a small tributary to East Fork Poplar Creek is utilized as its reference (Mill Branch, MBK 1.6).

**Table 3.1.6: Metric Values, Scores, and Biological Condition Ratings for Bear Creek**

| | Total | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | BCK 12.3 | | BCK 9.6 | | BCK 3.3 | | MBK 1.6 | |
| | TMI | RATING | TMI | RATING | TMI | RATING | TMI | RATING |
| 2010 | 14 | **C** | 30 | **B** | | | 44 | **A** |
| 2011 | 16 | **C** | 36 | **A** | | | 48 | **A** |
| 2012 | 18 | **C** | 30 | **B** | | | 36 | **A** |
| 2013 | 14 | **C** | 36 | **A** | | | 48 | **A** |
| 2014 | 14 | **C** | 42 | **A** | | | 48 | **A** |
| 2015 | 26 | **B** | 38 | **A** | | | 48 | **A** |
| 2016 | 26 | **B** | 40 | **A** | 46 | **A** | 48 | **A** |
| 2017 | 14 | **C** | 36 | **A** | 42 | **A** | 48 | **A** |
| 2018 | 14 | **C** | 36 | **A** | 46 | **A** | 48 | **A** |
| 2019 | 16 | **C** | 34 | **A** | 44 | **A** | 48 | **A** |
| Key: | A = Supporting / Non Impaired (TN Macro. Index Scores >= 32) | | | | | | | |
| | B = Partially Supporting / Slightly Impaired (TMI Scores 21 - 31) | | | | | | | |
| | C = Partially Supporting / Moderately Impaired (TMI Scores 10 - 20) | | | | | | | |
| | D = Non Supporting / Severely Impaired (TMI Scores < 10) | | | | | | | |

TMI Scores for the reference station MBK 1.6 are consistently good, with the maximum score observed eight out of the last ten years (Table 3.1.6). Generally speaking, TMI Scores for Bear Creek are lowest at the upstream station (BCK 12.3) and highest at the most downstream station (BCK 3.3). Both BCK 9.9 and BCK 3.3 were rated as "Supporting/Non Impaired". BCK 12.3 was rated as "Partially Supporting/Moderately Impaired".

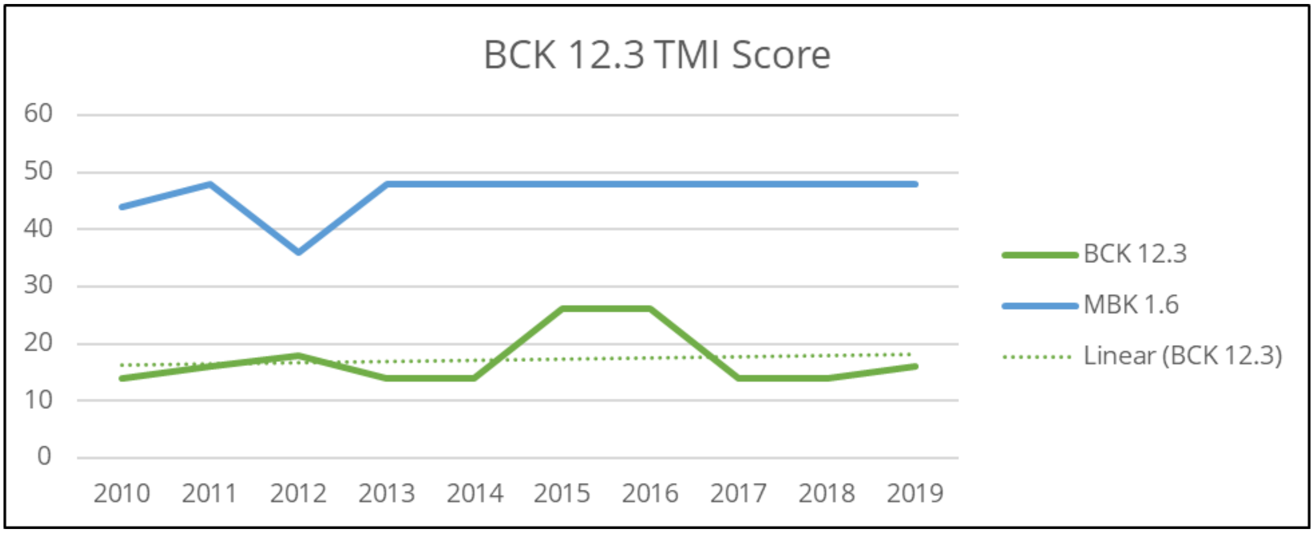


**Figure 3.1.16: BCK 12.3 Total Metric Index Score from 2010 to 2019**

Bear Creek 12.3 displays a reduced benthic macroinvertebrate community. It consistently ranks among the poorest performing sites monitored in this project. Bear Creek 12.3 continues to receive the highest concentration of contaminants from Y-12 former and current waste sites and is subject to low flows for a significant portion of the year. The watershed upstream of BCK 12.3 is limited in size, thus affecting the amount of flow at the station, particularly in the summer. BCK 12.3 lacks adequate substrate for colonization by aquatic organisms. BCK 12.3 suffers from reduced aquatic macroinvertebrate refuges in its vicinity from which recolonization of the station can occur. Enhancing the stream bottom with more natural substrates would help remediate this stream by providing more habitat for the benthic communities.

With the exception of the 2015 and 2016 sampling, the benthic communities at BCK 12.3 are stable and show only slight variation in population composition from year to year. At this time, it is unclear why BCK 12.3 performed significantly better in 2015 and 2016 compared to other years.

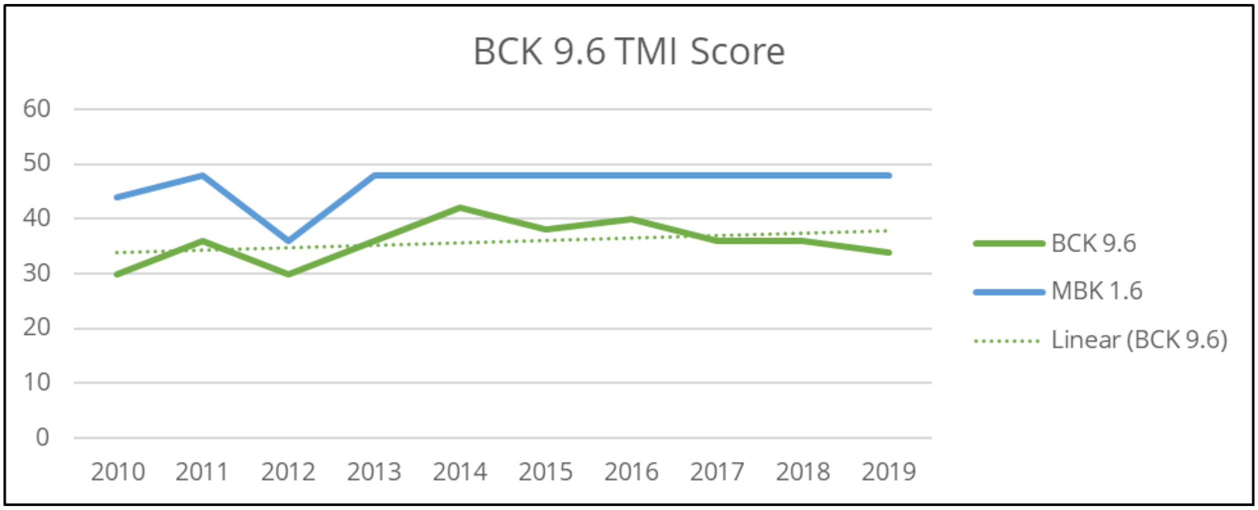


**Figure 3.1.17: BCK 9.6 Total Metric Index Score from 2010 to 2019**

BCK 9.6 shows modest improvement from 2010 to 2014. Since 2014, however, BCK 9.6 has shown a slight decline in its TMI Score, mostly due to the reduced quantity of clingers and the increased number of tolerant taxa.

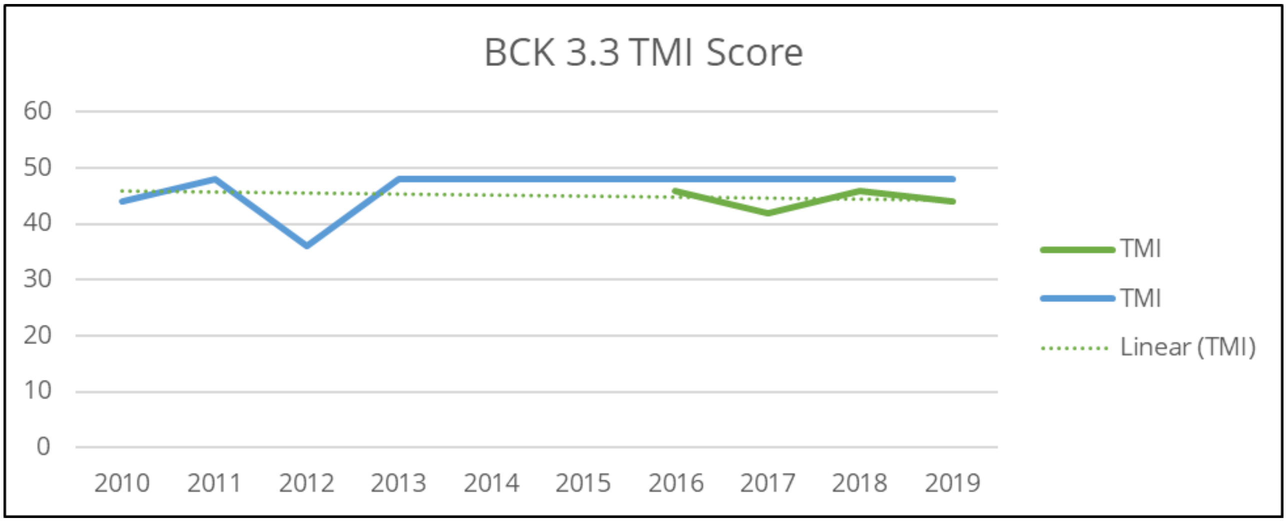


**Figure 3.1.18: BCK 3.3 Total Metric Index Score from 2010 to 2019**

When BCK 3.3 is compared to MBK 1.6, we observe only a slight reduction in the TMI Score from 2016-2019. This is likely due to the dilution of contaminants from Y-12 and greater habitat availability. BCK 3.3 is the farthest downstream site that TDEC monitors. It has a greater flow, a more natural substrate, and a pool to riffle ratio that is more conducive for macroinvertebrate habitation.

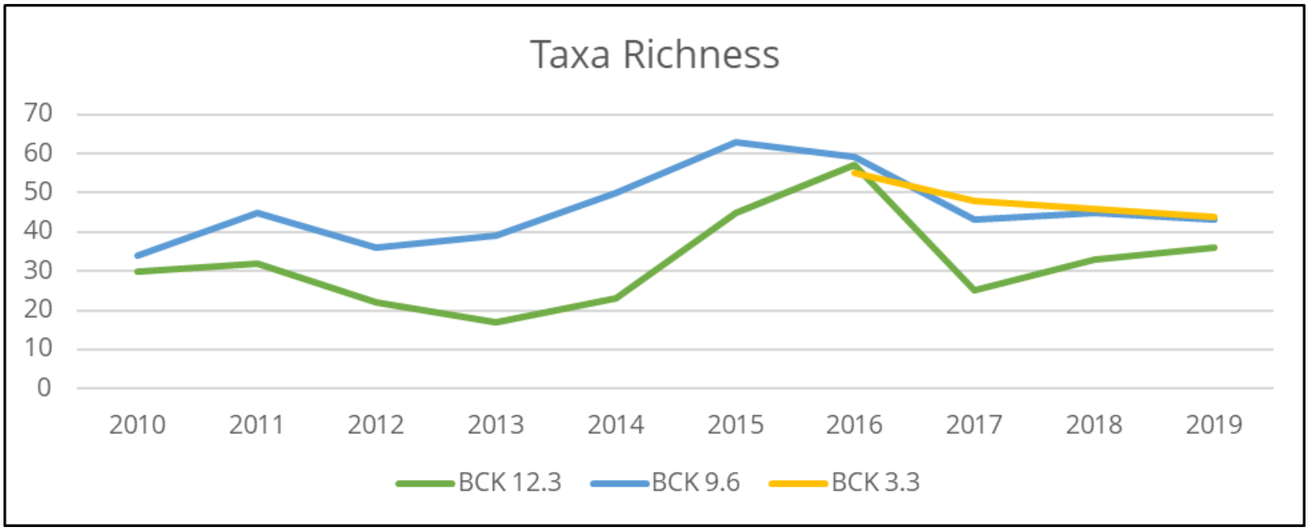


**Figure 3.1.19: Taxa Richness in Bear Creek from 2010 to 2019**

Since 2016, all Bear Creek sites have shown a reduction in Taxa Richness. It is unclear what has contributed to the decline. However, ongoing activity at Y-12 along with recent major flood events may be contributing factors.

### White Oak Creek and Melton Branch

White Oak Creek is the main drainage for the majority of ORNL's disturbed areas. It flows from its headwaters near the Spallation Neutron Source and through the main plant area in Bethel Valley, then passing into Melton Valley, flowing through the Solid Waste Storage Areas and entering White Oak Lake before exiting the reservation through White Oak Embayment and flowing into the Clinch River. The reference station (WCK 6.8) is in the headwaters fed by several springs just below SNS. Station WCK 3.9 is located in the main plant area in Bethel Valley, with both WCK 3.4 and WCK 2.3 located in the SWSAs in Melton Valley. Melton Branch drains the eastern portion of Melton Valley with the sampling station MEK 0.3 being located near the High Flux Isotope Reactor facility. Before the development of SNS, WCK 6.8 was relatively unimpacted. The construction of SNS resulted in some sediment inputs into White Oak Creek, but the negative impacts caused by that sedimentation have since dissipated. WCK 3.9 is located on the south side of the ORNL complex and downstream of Fifth Creek, which receives inputs from a large part of the main campus of ORNL. This station at one time was impacted heavily by discharges, spills, and former waste sites. WCK 3.4 is located on the north side of the solid waste storage areas (SWSAs) soon after White Oak Creek passes over into Melton Valley. WCK 3.4 receives inputs from the main portion of White Oak Creek as well as inputs from First Creek. WCK 2.3 is on the south side of the SWSAs and receives added impact from the SWSAs. MEK 0.3, located near HFIR, historically received impacts from HFIR and other facilities in the area. Parts of Melton Branch have also been channelized.

Traditionally, all samples were collected in the field, preserved in ethanol, and returned to the TDEC laboratory for processing; however, processing samples in the TDEC lab left TDEC with radioactive sediments to be properly disposed. In 2015, the decision was made to process White Oak Creek contaminated sites (WCK 3.9, WCK 3.4, WCK 2.3, and MEK 0.3) in the field to avoid having to return sediments to the laboratory. In 2019, all contaminated sites were processed in the field removing all organisms and returning the sediments to the site of their origin. The complete sorts done in the field were later identified in the TDEC laboratory.

**Table 3.1.7: Metric Values, Scores, and Biological Condition Ratings for White Oak Creek and Melton Branch**

| | Total | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | WCK 6.8 | | WCK 3.9 | | WCK 3.4 | | WCK 2.3 | | MEK 0.3 | |
| | TMI | RATING | TMI | RATING | TMI | RATING | TMI | RATING | TMI | RATING |
| 2010 | 44 | **A** | 30 | **B** | 26 | **B** | 30 | **B** | 36 | **A** |
| 2011 | 48 | **A** | 30 | **B** | 30 | **B** | 24 | **B** | 30 | **B** |
| 2012 | 46 | **A** | 30 | **B** | 28 | **B** | 30 | **B** | 30 | **B** |
| 2013 | 44 | **A** | 34 | **A** | 30 | **B** | 26 | **B** | 44 | **A** |
| 2014 | 48 | **A** | 24 | **B** | 28 | **B** | 28 | **B** | 38 | **A** |
| 2015 | 48 | **A** | 24 | **B** | 32 | **A** | 20 | **C** | 34 | **A** |
| 2016 | 48 | **A** | 28 | **B** | 32 | **A** | 28 | **B** | 40 | **A** |
| 2017 | 48 | **A** | 24 | **B** | 30 | **B** | 34 | **A** | 36 | **A** |
| 2018 | 48 | **A** | 26 | **B** | 26 | **B** | 28 | **B** | 38 | **A** |
| 2019 | 48 | **A** | 22 | **B** | 22 | **B** | 28 | **B** | 30 | **B** |
| Key: | A = Supporting / Non Impaired (TN Macro. Index Scores >= 32) | | | | | | | | | |
| | B = Partially Supporting / Slightly Impaired (TMI Scores 21 - 31) | | | | | | | | | |
| | C = Partially Supporting / Moderately Impaired (TMI Scores 10 - 20) | | | | | | | | | |
| | D = Non Supporting / Severely Impaired (TMI Scores < 10) | | | | | | | | | |

The sites monitored on White Oak Creek and Melton Branch do not compare well with reference station WCK 6.8. WCK 3.9, WCK 3.4, WCK 2.3 and MEK 0.3 are rated as “Partially Supporting/Slightly Impaired” and a slight decline in TMI Scores has been observed over the past several years. In comparison, reference station WCK 6.8 has received the maximum score of 48, seven out of the last ten years. It is unclear at this time what is directly causing this decline, however recent industrial activity at ORNL may be a contributing factor.

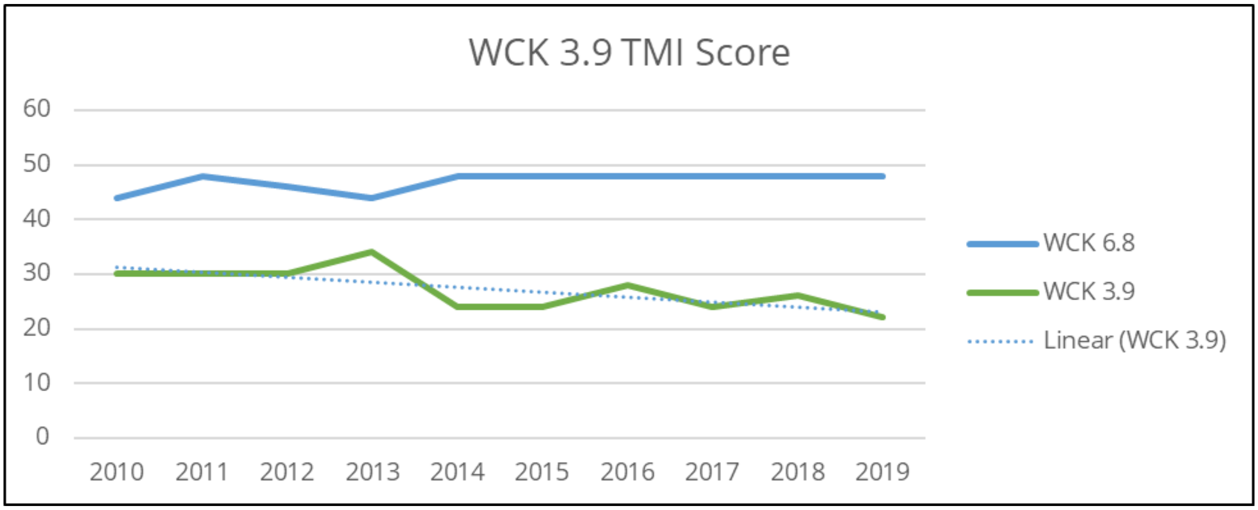


**Figure 3.1.20: WCK 3.9 Total Metric Index Score from 2010 to 2019**

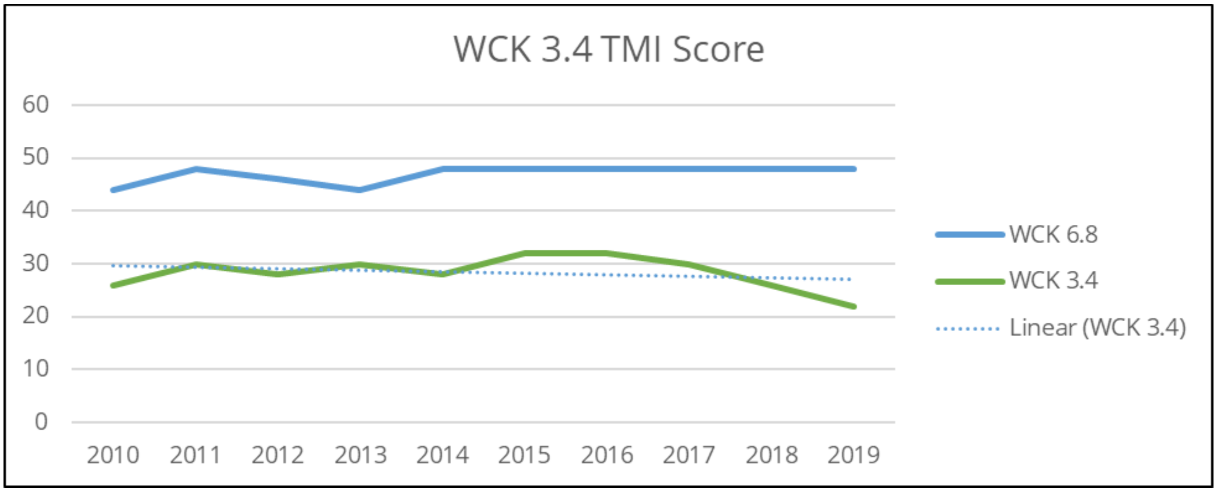


Figure 3.1.21: WCK 3.4 Total Metric Index Score from 2010 to 2019

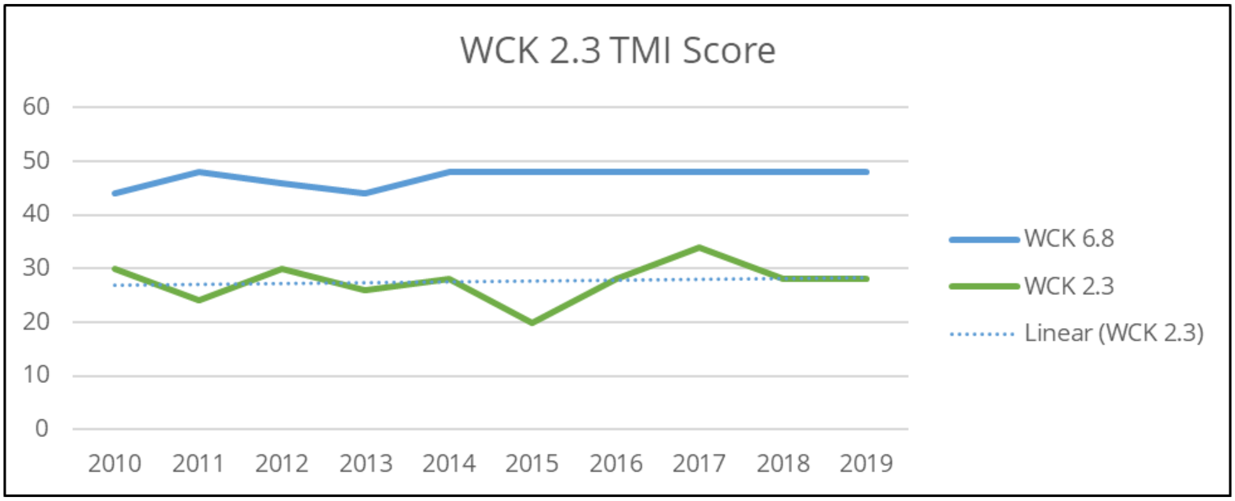


Figure 3.1.22: WCK 2.3 Total Metric Index Score from 2010 to 2019

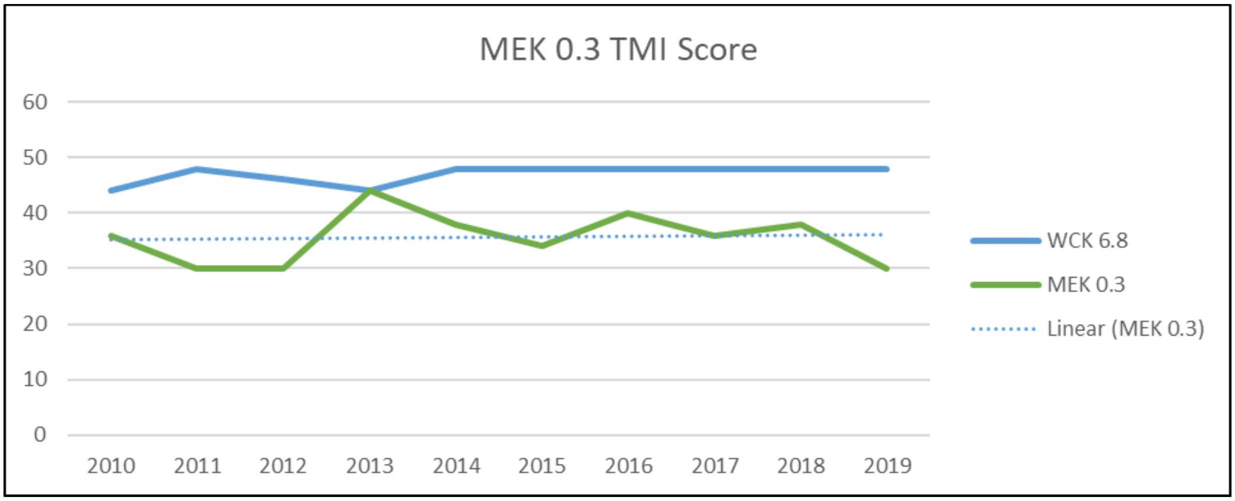


Figure 3.1.23: MEK 0.3 Total Metric Index Score from 2010 to 2019

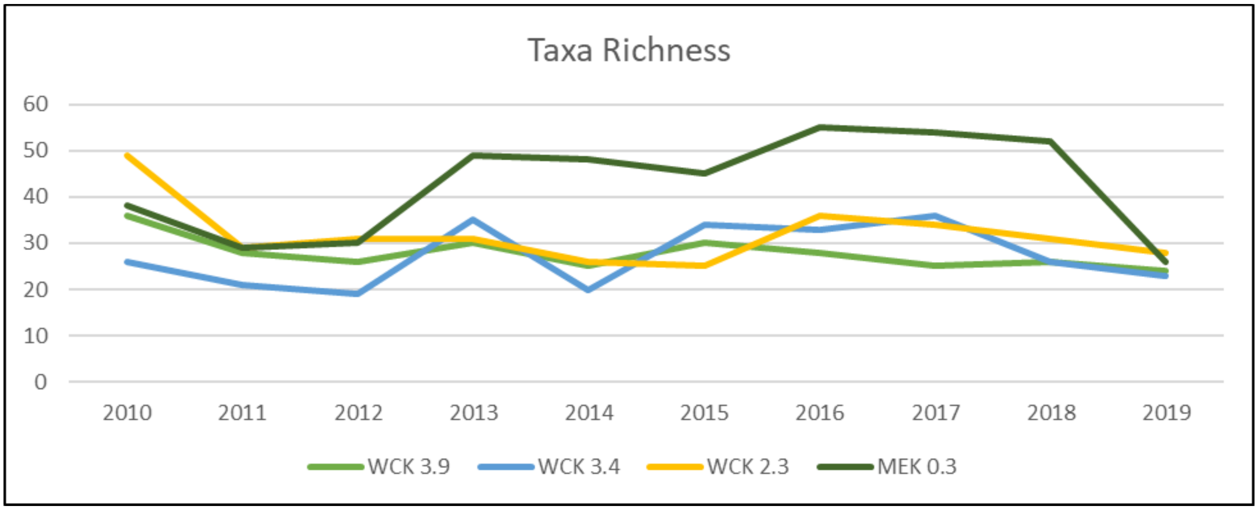


**Figure 3.1.24: White Oak Creek and Melton Branch Taxa Richness from 2010 to 2019**

### 3.1.8 Conclusions

The health of the benthic macroinvertebrate communities in Oak Ridge Reservation streams has improved since the 1980's, but this improvement has leveled off or slightly declined for the past few years. East Fork Poplar Creek has improved over the years, particularly in its headwater reaches. A great part of this improvement was due to the augmented flow that was provided during the period August 1996 through May 2014. Since augmented flow conditions were halted, conditions at the upper East Fork Poplar Creek stations have deteriorated. Bear Creek continues to improve slightly, particularly in its downstream reaches. BCK 12.3 remains somewhat impaired but continues to support some pollution intolerant taxa.

Mitchell Branch has improved since the 1980's, particularly in its downstream reaches. The lower stations of Mitchell Branch are slowly developing a more natural substrate which is replacing the formerly lined channel. The upstream station in Mitchell Branch appears to be slowly deteriorating in quality due to sediment input. Fears are that the construction of the proposed airport in its headwaters may further deteriorate this section of Mitchell Branch.

### 3.1.9 Recommendations

Benthic communities in streams on the Oak Ridge Reservation should continue to be monitored on a regular basis. Changes in the condition of these communities (improvement or otherwise) serves as an indicator of positive remediation effects or negative effects of pollution. Every effort should be made to protect the current quality of streams that meet their designations and to improve those that do not.

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# 4.0 AIR MONITORING

## 4.1 FUGITIVE RADIOLOGICAL AIR EMISSIONS

### 4.1.1 Background

The K-25 Gaseous Diffusion Plant, now called ETTP, began operations in World War II as part of the Manhattan Project. Its original mission was to produce uranium enriched in the 235 isotope (U-235) for use in the first atomic weapons and later to fuel commercial and government owned reactors. The plant was permanently shut down in 1987. Because of operational practices and accidental releases, many of the facilities scheduled for decontamination and decommissioning (D&D) at East Tennessee Technology Park (ETTP) are contaminated to some degree. Uranium isotopes are the primary contaminants, but technetium-99 and other fission and activation products are also present due to the periodic processing of recycled uranium obtained from spent nuclear fuel.

The Y-12 National Security Complex (Y-12) was also constructed during World War II to enrich uranium in the U-235 isotope, in this case by the electromagnetic separation process. In ensuing years, the facility was expanded and used to produce fuel for naval reactors, to conduct lithium/mercury enrichment operations, to manufacture components for nuclear weapons, to dismantle nuclear weapons, and to store enriched uranium.

Construction of the Oak Ridge National Laboratory (ORNL) began in 1943. While the initial mission of the K-25 and Y-12 plants was the production of enriched uranium, ORNL's mission focused on reactor research and the production of plutonium as well as other activation and fission products, which were chemically extracted from uranium irradiated in ORNL's Graphite Reactor and later at other ORNL and Hanford reactors. During early operations, leaks and spills were common and associated radioactive materials were released from operations as gaseous, liquid, and solid effluents, with little or no treatment (ORAU, 2003).

### 4.1.2 Problem Statements

- Many of the facilities at ETTP, Y12, and ORNL scheduled for decommissioning and demolition (D&D) are contaminated. D&D operations at these facilities, as well as the placement of waste from these facilities at the Environmental Management Waste Management Facility (EMWMF), can result in fugitive (non-point source) dispersal of contaminated constituents. This dispersion is aided by winds that tend to blow up the Tennessee Valley (northeast) in the daytime and then reverse direction by blowing down the Tennessee Valley (southwest) at night.

- At ETTP, uranium isotopes are the primary contaminants, but technetium-99 and other fission and activation products are also present, due to the periodic processing of recycled uranium obtained from spent nuclear fuel from offsite.

- Many of the facilities at ORNL are contaminated with a long list of fission and activation products in addition to uranium and plutonium isotopes. Some of these facilities are considered the highest risk facilities at ORNL due to their physical deterioration, the presence of loose contamination, and their close proximity to pedestrian, vehicular traffic, privately funded facilities, and active ORNL facilities.

- At Y-12, facilities contaminated with various isotopes of uranium are scheduled for D&D.

- Much of the material from D&D activities on the Oak Ridge Reservation (ORR) is disposed of at EMWMF.

### 4.1.3 Goals

- To protect human health and the environment, TDEC will conduct independent air sampling and compare the results with air sampling data provided by U.S. Department of Energy (DOE) to verify DOE's ORR activities are not adversely impacting the public.

- TDEC-DoR-OR personnel will review the air monitoring sections of the DOE ORR Environmental Monitoring Plan (EMP) and suggest relevant revisions to the DOE EMP.

### 4.1.4 Scope

TDEC conducted continuous fugitive radiological air emissions monitoring to evaluate DOE's compliance with Clean Air Act (CAA) regulatory standards to ensure potential DOE ORR radiological emissions will not cause a member of the public to receive an effective dose greater than 10 millirem (mrem) in one year, specifically in the areas of remedial and/or waste management activities. Sampler locations were selected to maximize the likelihood of collecting representative samples from potential sources of airborne contamination.

### 4.1.5 Methods, Materials, Metrics

Eight high-volume air samplers were used in this project. One was stationed at Fort Loudoun Dam in Loudon County to collect background data for comparison while the remaining samplers were placed at ORR locations where the potential for the release of fugitive airborne emissions is greatest (locations of the excavation of contaminated soils, demolition of contaminated facilities, and waste disposal operations) (Figure 4.1.1).

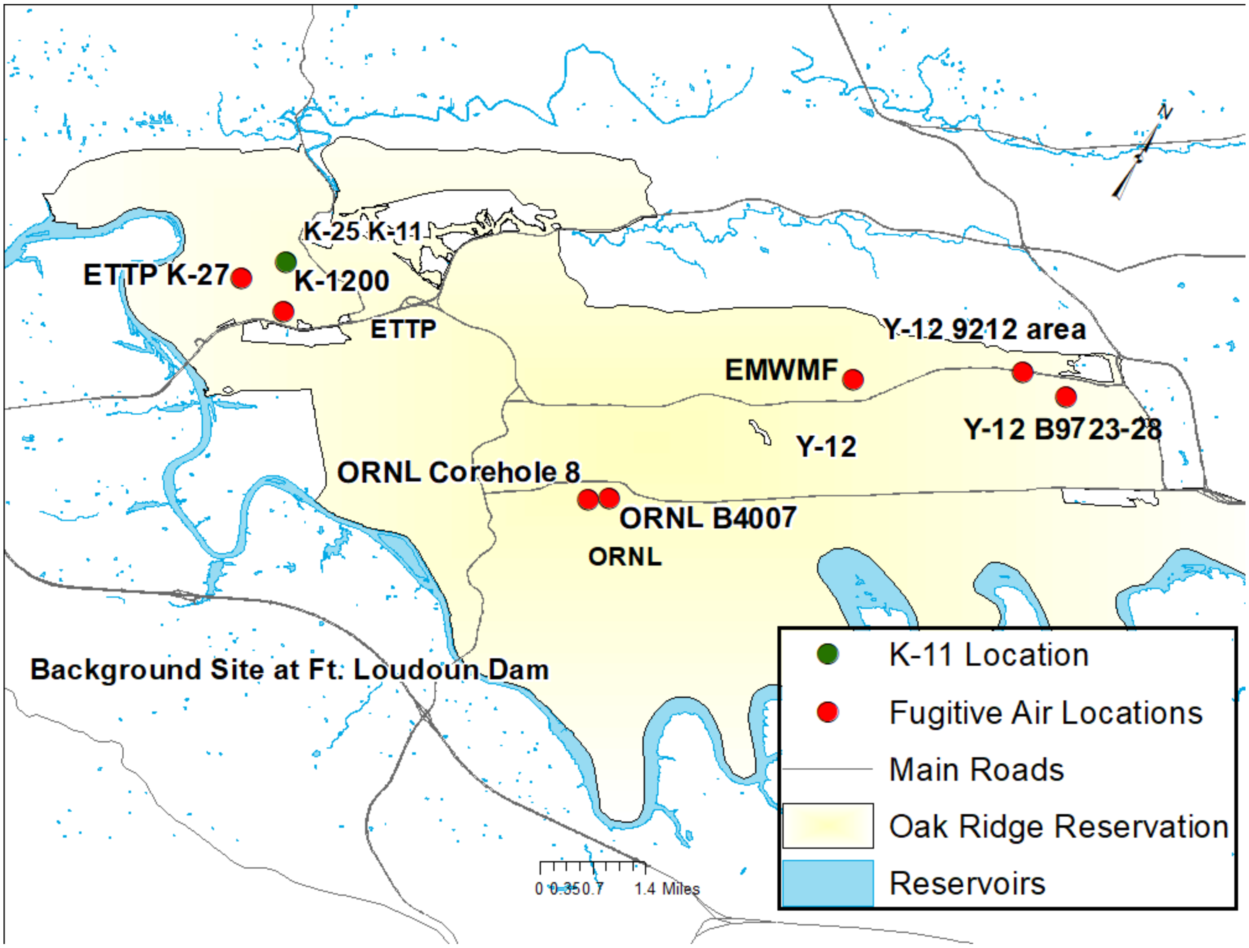


**Figure 4.1.1: Fugitive Air Monitoring Locations**

Each of the air samplers used an 8x10-inch, glass fiber filter to collect particulates from air as it was drawn through the unit at a rate of approximately 35 cubic feet per minute. To ensure accuracy, airflow through each sampler was calibrated quarterly, using a Graseby General Metal Works variable resistance calibration kit.

Samples were collected from each sampler weekly and composited every four weeks then analyzed at the State of Tennessee's Environmental Laboratory.

To assess the concentrations of the contaminants measured for each location, results from each station were compared with the background data and the standards provided in the CAA. Associated findings were supplied to DOE and its contractors when requested and included in TDEC DoR-OR's annual Environmental Monitoring Report submitted to DOE and the public.

Fugitive Air monitoring was conducted by TDEC-DoR-OR to compare to the standards provided by the CAA. Title 40 of the Code of Federal Regulations Part 61 (40CFR61), 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) limits DOE radiological emissions to quantities that would not cause a member of the public to receive an effective dose equivalent greater than 10 millirem (mrem) in a year.

### 4.1.6 Deviations from the Plan

The original project plan was to collect and report on data through June 2020. However, the most recent sampling results are for the sampling period that ended 03/18/2020. The original plan was to composite four-weekly samples for each analysis. The majority of the data examined in this report is for 11 four-week composited samples and one six-week composite interval. The K-25 K-11 location was sampled from 4/4/2019 through 12/26/2019. The sampler was then moved to ETTP K-1200 site and was operated from 12/26/2019 through 3/18/2020. Other than composite intervals and date changes mentioned, the sampling and analysis was conducted as planned.

### 4.1.7 Results and Analysis

#### East Tennessee Technology Park

Two radiological air monitors were used at ETTP, the site of the original K-25 Gaseous Diffusion Plant. One was moved from the K-25 K-11 location to a location closer to building K-1200 at the end of 2019. Analyses for the air samples collected from air monitors at ETTP include three isotopes of uranium (U-234, U-235, U-238) and technetium-99 (Tc-99) as shown in Tables 4.1.1, 4.1.2, and 4.1.3.

Table 4.1.1 shows the results from the samples taken at ETTP K-25/K-11. The sum of fractions of less than one indicates that regulatory limits were not exceeded.

Table 4.1.2 shows the results from the K-27 area sampling location. The sum of fractions of less than one indicates that regulatory limits were not exceeded.

Table 4.1.3 shows the results from the K-1200 area sampling location. The sum of fractions of less than one indicates that regulatory limits were not exceeded.

### Table 4.1.1: ETTP K-25/K-11 Air Monitoring Average Results (pCi/m$^3$)

| K-25 K-11 Sampling Location | U-234 | U-235 | U-238 | Tc-99 | Sum of Fractions |
|---|---|---|---|---|---|
| Average through 12/26/2019 | 1.49E-04 | 2.41E-05 | 2.28E-04 | 6.65E-04 | |
| Average background | 5.39E-05 | 9.91E-06 | 3.92E-05 | 6.10E-04 | |
| Net Activity (Avg. minus background) | 9.49E-05 | 1.42E-05 | 1.89E-04 | 5.49E-05 | |
| 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) | 1.23E-02 | 2.00E-03 | 2.28E-02 | 3.92E-04 | 3.75E-02 |

### Table 4.1.2: ETTP K-27 Air Monitoring Average Results for (pCi/m$^3$)

| K-27 Sampling Location | U-234 | U-235 | U-238 | Tc-99 | Sum of Fractions |
|---|---|---|---|---|---|
| Average through 3/18/2020 | 9.48E-05 | 1.23E-05 | 1.30E-04 | 5.03E-04 | |
| Average background | 5.39E-05 | 9.91E-06 | 3.92E-05 | 6.10E-04 | |
| Net Activity (Avg. minus background) | 4.09E-05 | 2.36E-06 | 9.11E-05 | -1.07E-04 | |
| 40CFR Part 61 Limit, Appx. E (Table 2) | 7.70E-03 | 7.10E-03 | 8.30E-03 | 1.40E-01 | |
| Fraction of Limit (Net/Limit) | 5.31E-03 | 3.32E-04 | 1.10E-02 | -7.62E-04 | 1.59E-02 |

### Table 4.1.3: ETTP K-1200 Air Monitoring Average Results for (pCi/m$^3$)

| ETTP K-1200 Sampling Location | U-234 | U-235 | U-238 | Tc-99 | Sum of Fractions |
|---|---|---|---|---|---|
| Average from 12/26/2019 through 3/18/2020 | 5.17E-05 | 9.49E-06 | 5.16E-05 | 3.19E-04 | |
| Average background | 5.39E-05 | 9.91E-06 | 3.92E-05 | 6.10E-04 | |
| Net Activity (Avg. minus background) | -2.21E-06 | -4.15E-07 | 1.24E-05 | -2.90E-04 | |
| 40CFR Part 61 Limit, Appx. E (Table 2) | 7.70E-03 | 7.10E-03 | 8.30E-03 | 1.40E-01 | |
| Fraction of Limit (Net/Limit) | -2.87E-04 | -5.84E-05 | 1.49E-03 | -2.07E-03 | -9.27E-04 |

## Y-12 National Security Complex

Two samplers were used at Y-12. Analyses for the air samples collected from air monitors at Y-12 include three isotopes of uranium (U-234, U-235, U-238) and Tc-99.

Table 4.1.4 shows the results from the samples taken at the Building 9212 area of Y-12. The sum of fractions of less than one indicates that regulatory limits were not exceeded.

**Table 4.1.4: 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 | Sum of Fractions |
|---|---|---|---|---|---|
| Average Through 3/18/2020 | 2.08E-04 | 1.88E-05 | 5.24E-05 | 6.89E-04 | |
| Average background | 5.39E-05 | 9.91E-06 | 3.92E-05 | 6.10E-04 | |
| Net Activity (Avg. minus background) | 1.54E-04 | 8.88E-06 | 1.32E-05 | 7.90E-05 | |
| 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) | 2.00E-02 | 1.25E-03 | 1.59E-03 | 5.64E-04 | 2.34E-02 |

Table 4.1.5 shows the results from the samples taken at the Building 9723-28 area of Y-12. The sum of fractions of less than one indicates that regulatory limits were not exceeded.

**Table 4.1.5: Y-12 Building 9723-28 Area Air Monitoring Average Results (pCi/m$^3$)**

| Y-12 B9723-28 Sampling Location | U-234 | U-235 | U-238 | Tc-99 | Sum of Fractions |
|---|---|---|---|---|---|
| Average through 3/18/2020 | 8.22E-05 | 1.63E-05 | 4.82E-05 | 4.77E-04 | |
| Average background | 5.39E-05 | 9.91E-06 | 3.92E-05 | 6.10E-04 | |
| Net Activity (Avg. minus background) | 2.83E-05 | 6.40E-06 | 9.07E-06 | -1.33E-04 | |
| 40CFR Part 61 Limit, Appx. E (Table 2) | 7.70E-03 | 7.10E-03 | 8.30E-03 | 1.40E-01 | |
| Fraction of Limit (Net/Limit) | 3.68E-03 | 9.01E-04 | 1.09E-03 | -9.51E-04 | 4.72E-03 |

## Oak Ridge National Laboratory

Two samplers were used at ORNL. Analyses for the air samples collected from air monitors at ORNL include three isotopes of uranium (U-234, U-235, U-238) and gamma spectrometry.

The gamma spectrometry analysis results are not shown because only naturally occurring daughter products of radon were detected. No instances of elevated impacts were noted. The sum of fractions of less than one indicates that regulatory limits were not exceeded, as seen in tables 4.1.6 and 4.1.7.

**Table 4.1.6: ORNL B4007 Air Monitoring Average Results (pCi/m$^3$)**

| ORNL B4007 Sampling Location | U-234 | U-235 | U-238 | Sum of Fractions |
|---|---|---|---|---|
| Average through 3/18/2020 | 5.16E-05 | 7.05E-06 | 4.23E-05 | |
| Average background | 5.39E-05 | 9.91E-06 | 3.92E-05 | |
| Net Activity (Avg. minus background) | -2.30E-06 | -2.86E-06 | 3.10E-06 | |
| 40CFR Part 61 Limit, Appendix E (Table 2) | 7.70E-03 | 7.10E-03 | 8.30E-03 | |
| Fraction of Limit (Net/Limit) | -2.98E-04 | -4.03E-04 | 3.73E-04 | -3.28E-04 |

**Table 4.1.7: ORNL Corehole 8 Air Monitoring Average Results (pCi/m$^3$)**

| ORNL Corehole 8 Sampling Location | U-234 | U-235 | U-238 | Sum of Fractions |
|---|---|---|---|---|
| Average through 3/18/2020 | 4.69E-05 | 5.97E-06 | 4.39E-05 | |
| Average background | 5.39E-05 | 9.91E-06 | 3.92E-05 | |
| Net Activity (Avg. minus background) | -7.02E-06 | -3.94E-06 | 4.71E-06 | |
| 40CFR Part 61 Limit, Appendix E (Table 2) | 7.70E-03 | 7.10E-03 | 8.30E-03 | |
| Fraction of Limit (Net/Limit) | -9.12E-04 | -5.55E-04 | 5.68E-04 | -8.99E-04 |

### The Environmental Management Waste Management Facility

One sampler is located at EMWMF in Bear Creek Valley near Y-12. Analyses for the air samples collected from air monitor at EMWMF includes three isotopes of uranium (U-234, U-235, U-238) and Tc-99. No identified instances of elevated impacts were noted (Table 4.1.8). The sum of fractions of less than one indicates that regulatory limits were not exceeded.

**Table 4.1.8: EMWMF Air Monitoring Average Results (pCi/m$^3$)**

| EMWMF Sampling Location | U-234 | U-235 | U-238 | Tc-99 | Sum of Fractions |
|---|---|---|---|---|---|
| Average through 3/18/2020 | 7.69E-05 | 1.59E-05 | 5.63E-05 | 5.10E-04 | |
| Average background | 5.39E-05 | 9.91E-06 | 3.92E-05 | 6.10E-04 | |
| Net Activity (Avg. minus background) | 2.30E-05 | 6.00E-06 | 1.71E-05 | -1.00E-04 | |
| 40CFR Part 61 Limit, Appx. E (Table 2) | 7.70E-03 | 7.10E-03 | 8.30E-03 | 1.40E-01 | |
| Fraction of Limit (Net/Limit) | 2.99E-03 | 8.46E-04 | 2.06E-03 | -7.16E-04 | -2.40E+06 |

### 4.1.8 Conclusions

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

This project's shorter composite intervals can result in the timelier observation of potential problems than other available sampling programs such as the DOE program which analyzes quarterly composite samples.

In past years, this TDEC 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 10% of the actual calculated values. Results from this program continue to be used by DOE contractors for comparison purposes.

### 4.1.9 Recommendations

TDEC DoR-OR will review the current monitoring locations and consider sampling modifications according to DOE activities on the ORR.

The air monitoring section of the DOE Environmental Monitoring Plan for the Oak Ridge Reservation was reviewed. There were no recommendations submitted by this project at the time.

### 4.1.10 References

40CFR Part 61 Limit, Appx. E (Table 2)

Title 40 of the Code of Federal Regulations Part 61 (40CFR61), 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)

# 5.0 SURFACE WATER MONITORING

## 5.1 AMBIENT SURFACE WATER SAMPLING

### 5.1.1 Background

While legacy waste across the ORR may be responsible for a large portion of contamination to surface water, current projects and processes at these sites also have potential to significantly contribute to surface water contamination. To help monitor potential contamination, an ambient surface water sampling project has been implemented by TDEC each year since 1993. This monitoring project began by investigating the water quality of the Clinch River at five locations near the ORR. The sampling locations for this project have been modified throughout the years, sometimes adding or discontinuing sampling at particular locations. Most recently, monitoring focused on five primary ORR exit-pathway streams as well as the Clinch River. This project monitors surface water by sampling for contaminants in waterways that have been potentially impacted by past and present activities on the ORR.

DOE has also 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, 2017; DOE, 2019). Currently, DOE collects samples quarterly at four sites along the Clinch River at river kilometers 16, 32, 58, and 66 (see Figure 5.1.1) (DOE, 2019). The purpose of the current DOE project is to assess impacts of site operations, both past and present, to surface water bodies as well as to assess the impact of radioactivity to human health. Respective analyte maximum contaminant levels (MCLs) as defined by the Environmental Protection Agency (EPA) are used to determine potential impact (EPA, 2009).

While the current DOE project solely samples the Clinch River, this TDEC DoR-OR project builds upon DOE sampling by looking at specific confluences of exit-pathway streams and the Clinch River, many of which have not been intensively monitored in the past. Samples and flow measurements were taken at these streams with the intent to provide a more representative evaluation of the loading of contaminants to the Clinch River. Additional co-sampling was also performed at three of the DOE Clinch River sites (i.e. CRK 16, 32, 58). As done by DOE, all sites will be compared to criteria defined by EPA and the state of Tennessee to determine stream impact (EPA, 2009; TDEC, 2019).

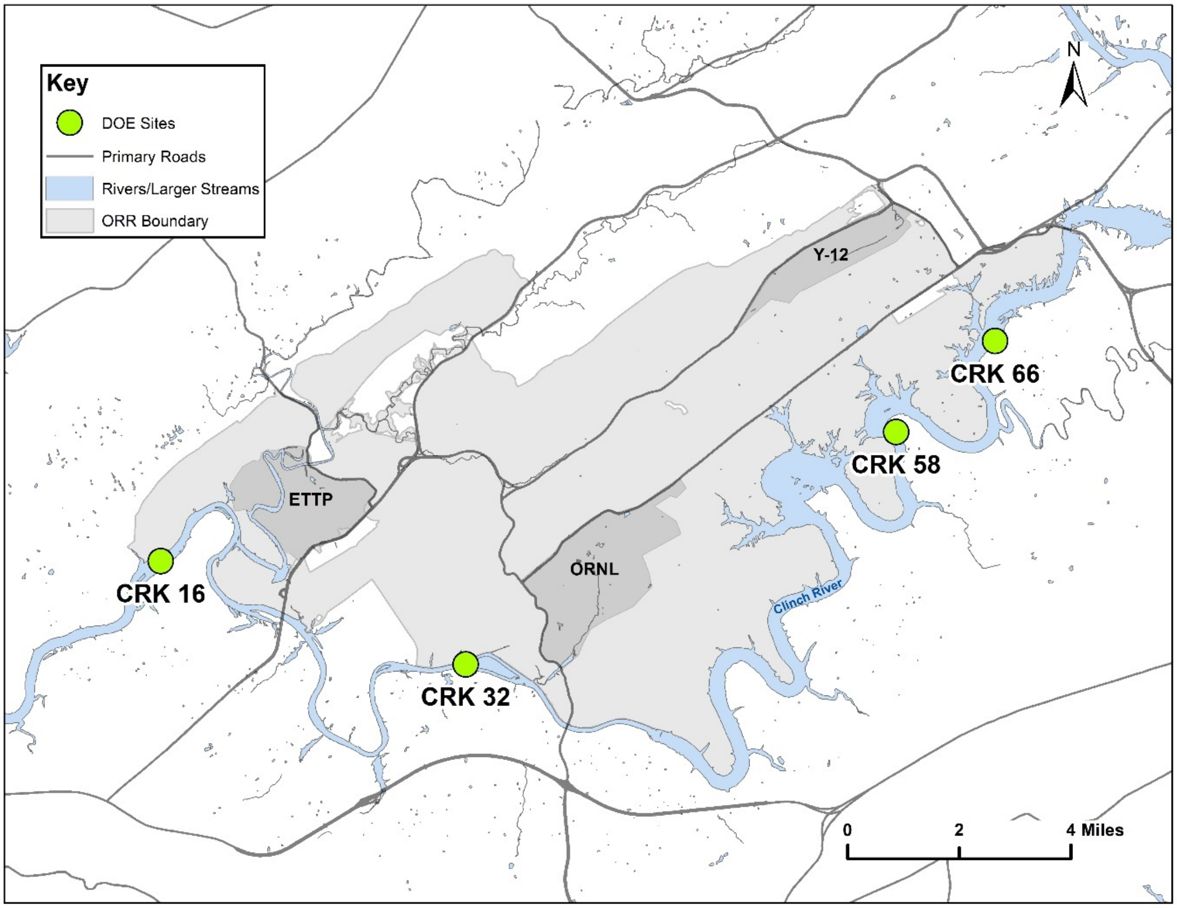


**Figure 5.1.1: Map showing current DOE sampling sites**

### 5.1.2 Problem Statements

This project will supplement DOE's study of the Clinch River to better understand impact to human health. It is estimated, based on 2017 US census data, that nearly 1.2 million people live in the counties surrounding the ORR (DOE, 2017). A large portion of these people have the potential of being influenced by streams that drain the ORR. All of the exit-pathway streams on the ORR eventually flow into the Clinch River. In turn, the Clinch River ultimately flows into the Tennessee River. Twelve water supplies are located on these rivers within 170 river miles downstream of White Oak Creek (DOE, 1992). The Clinch River alone provides drinking water and water for industrial use to many municipalities near and downstream of the ORR. These include Anderson County, Knox County, Roane County, the City of Clinton, the City of Kingston, the City of Norris, and the City of Oak Ridge. The Clinch River surface waters are also used for facilities at the Y-12 National Security Complex (Y-12), the Oak Ridge National Laboratory (ORNL), and the East Tennessee Technology Park (ETTP). Thus, it is important to monitor these exit pathway streams, as well as the Clinch River, to better understand the ORR's impact on this widely used resource.

As seen now and historically, these ORR exit-pathway streams and the Clinch River have been and are currently subject to contaminant releases from activities at ETTP, ORNL, and Y-12. These releases can be detrimental to the environment and to human health.

Identified concerns include but are not limited to the following:

- From 1950 to 1963, Y-12 released approximately 100 metric tons of elemental mercury to East Fork Poplar Creek by spills and leakage from subsurface drains, building foundations, and contaminated soil, as well as purposed discharge of wastewater containing mercury (Turner and Southworth, 1999).
- East Fork Poplar Creek is believed to contribute approximately 0.2 metric tons of mercury to the Clinch River each year (DOE, 1992).
- Besides mercury, other metals that have been found in ORR exit pathway streams at levels greater than background are cadmium, chromium, lead, nickel, silver and zirconium (DOE, 1992).
- ORNL has been releasing low-level radioactive liquid wastes to the Clinch River via White Oak Creek since 1943 (Pickering, 1970).
- The Clinch River received approximately 665 curies of cesium-137 (Cs-137) from White Oak Creek between 1954 and 1959 (DOE, 1992).
- Elevated levels of radioactive strontium have been seen in White Oak Creek after a 2015 ruptured pipe mobilized the contaminant at the Process Waste Treatment Complex (DOE, 2018).

Monitoring exit-pathway streams will help to assess what locations on the ORR are contributing to surface water pollution and provide insight to help protect human health and the environment, especially for the important resource of the Clinch River.

### 5.1.3 Goals

The goal of this Ambient Surface Water Monitoring is to evaluate the impact of contamination to several ORR exit-pathway streams (East Fork Poplar Creek, East Fork Walker Branch, Grassy Creek, McCoy Branch, Mitchell Branch, Melton Branch, Poplar Creek, Raccoon Creek, and Scarboro Creek) and the Clinch River (see Figure 5.1.2). While streams such as East Fork Poplar Creek and Mitchell Branch have been widely monitored, this project seeks to investigate additional streams that aren't sampled as frequently. This project ultimately seeks to understand each respective stream's contribution or loading of contaminants to the Clinch River. An assessment of each stream's impact, including the Clinch River, will be performed by comparing results to EPA defined maximum contaminant levels (EPA, 2009). In all, this project will help to define areas of concern on the ORR that may be significantly impacting the surface water resources of Tennessee citizens.

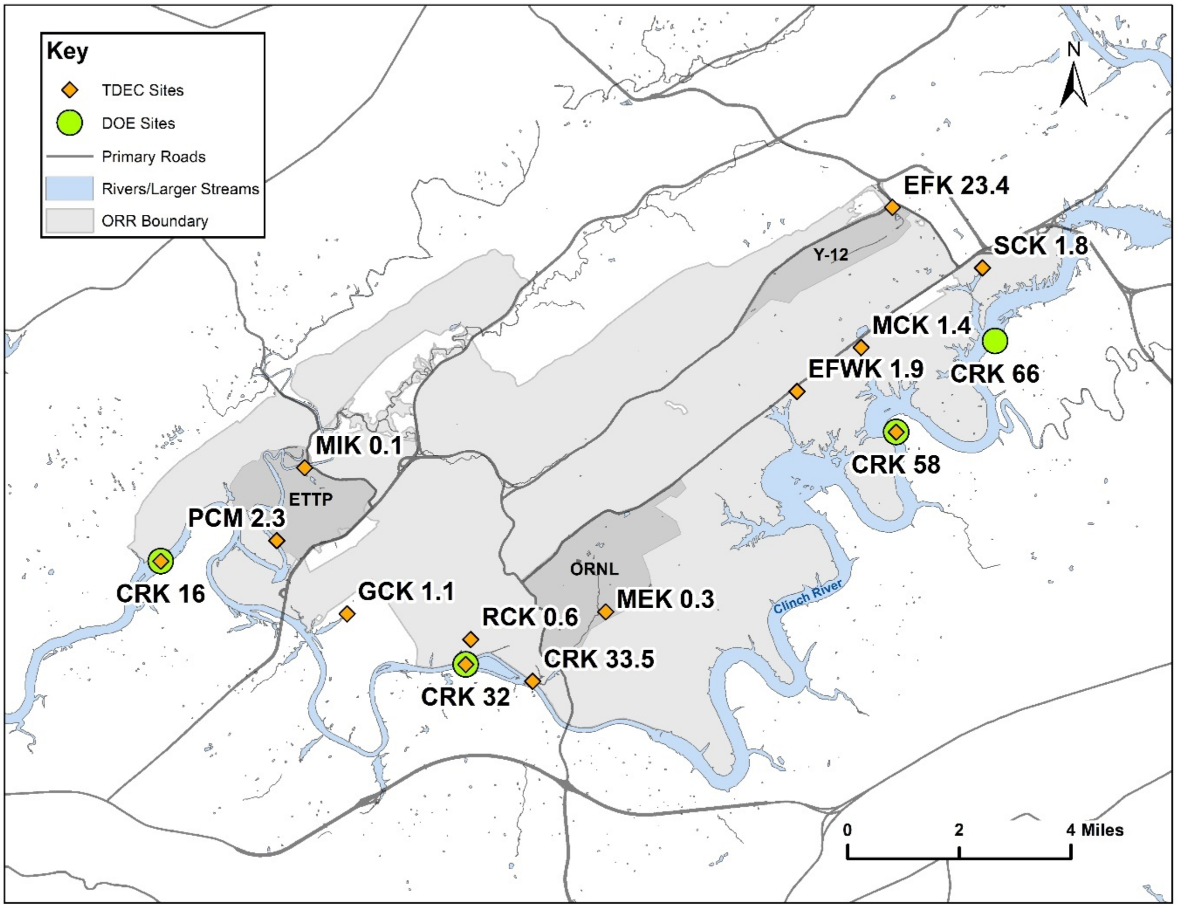


**Figure 5.1.2: Map showing TDEC and DOE sampling sites**

To accomplish this goal, several objectives were completed. These objectives include:

1) Collect surface water samples quarterly at selected exit-pathway streams and the Clinch River (see Figure 5.1.2).
    a) Samples were collected and analyzed for analytes including but not limited to gross alpha, gross beta, tritium, and mercury at each site.
    b) Three sites near the confluence of White Oak Creek and the Clinch River were additionally sampled for radioactive strontium.

    c) The Poplar Creek site had an additional suite of contaminants including several inorganic ions, metals, and radionuclides.
    d) Clinch River sites were co-sampled quarterly with DOE when possible.

2) Physical water parameters (e.g. conductivity, dissolved oxygen, pH, and temperature) were measured at each site at time of sampling.
3) A cross-sectional transect was taken at each stream, and the stream flow rates were measured at time of sampling (excludes Clinch River and Poplar Creek samples).;

### 5.1.4 Scope

The scope of this project is to characterize stream conditions and assess contaminant flux through sampling, stream flow measurements, and analysis of surface water from nine different exit-pathway streams that drain the ORR to the Clinch River. A segment of the Clinch River will also be assessed spanning from the Knox County water intake at Clinch River Kilometer (CRK) 58 downstream to CRK 16.1, downstream of all ORR inputs.

### 5.1.5 Methods, Materials, Metrics

*Sample Collection*

Surface water samples were collected quarterly at 13 different sites both on exit-pathway streams and on the Clinch River. Samples were collected and analyzed for gross alpha (α), gross beta (β), tritium ($^3$H), and mercury at each site. Additional samples were collected for inorganic ions, metals, strontium-89/90 (Sr), and technetium-99 (Tc) at selected sites (see Table 5.1.1). Quality assurance/quality control (QA/QC) samples were also collected as necessary.

*Field Parameter Measurements*

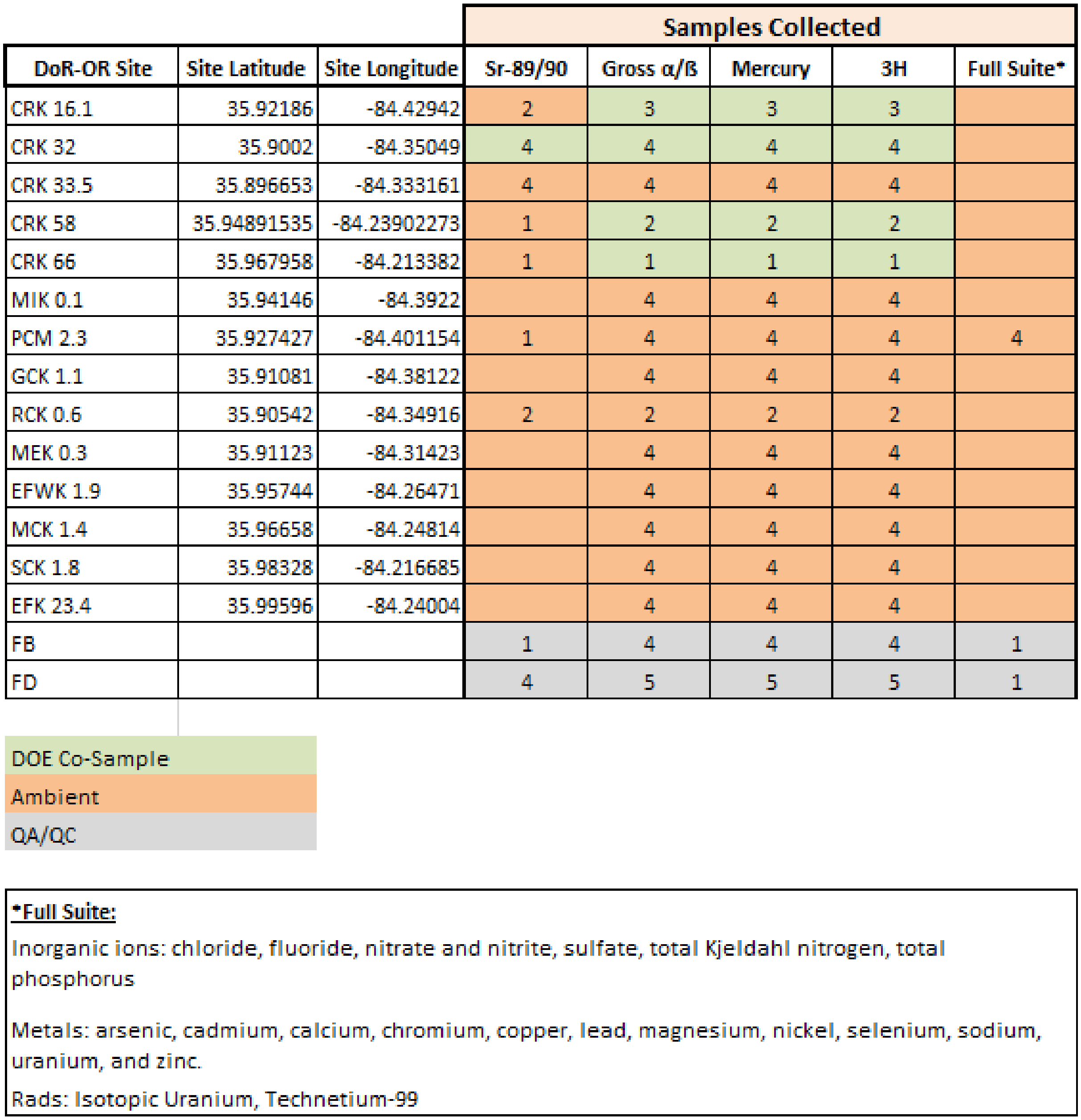
At each site, physical water parameters were collected during the time of sampling. Physical parameters were measured using a multiple parameter water quality meter. Parameters of conductivity (µS/cm), dissolved oxygen (mg/L), pH, and temperature (°C) were recorded along with time of measurement.

*Stream Flow Measurements*

Stream flow measurements were taken at each stream at the time of sampling. This was accomplished by measuring the cross-sectional transect perpendicular to the flow of the stream as well as measuring the flow rate using a FlowTracker2® instrument. The FlowTracker2® instrument allows for an accurate measurement of a stream's cross-section.

Results from the flow measurements were implemented into Sontek Flowtracker software to best characterize the stream flow. Clinch River and Poplar Creek sites were excluded from stream flow measurements.

**Table 5.1.1: Site locations, descriptions, and list of analytes**



| | | | Samples Collected | | | | |
|---|---|---|---|---|---|---|---|
| DoR-OR Site | Site Latitude | Site Longitude | Sr-89/90 | Gross α/ß | Mercury | 3H | Full Suite* |
| CRK 16.1 | 35.92186 | -84.42942 | 2 | 3 | 3 | 3 | |
| CRK 32 | 35.9002 | -84.35049 | 4 | 4 | 4 | 4 | |
| CRK 33.5 | 35.896653 | -84.333161 | 4 | 4 | 4 | 4 | |
| CRK 58 | 35.94891535 | -84.23902273 | 1 | 2 | 2 | 2 | |
| CRK 66 | 35.967958 | -84.213382 | 1 | 1 | 1 | 1 | |
| MIK 0.1 | 35.94146 | -84.3922 | | 4 | 4 | 4 | |
| PCM 2.3 | 35.927427 | -84.401154 | 1 | 4 | 4 | 4 | 4 |
| GCK 1.1 | 35.91081 | -84.38122 | | 4 | 4 | 4 | |
| RCK 0.6 | 35.90542 | -84.34916 | 2 | 2 | 2 | 2 | |
| MEK 0.3 | 35.91123 | -84.31423 | | 4 | 4 | 4 | |
| EFWK 1.9 | 35.95744 | -84.26471 | | 4 | 4 | 4 | |
| MCK 1.4 | 35.96658 | -84.24814 | | 4 | 4 | 4 | |
| SCK 1.8 | 35.98328 | -84.216685 | | 4 | 4 | 4 | |
| EFK 23.4 | 35.99596 | -84.24004 | | 4 | 4 | 4 | |
| FB | | | 1 | 4 | 4 | 4 | 1 |
| FD | | | 4 | 5 | 5 | 5 | 1 |

🟩 DOE Co-Sample
🟧 Ambient
⬜ QA/QC

***Full Suite:**

Inorganic ions: chloride, fluoride, nitrate and nitrite, sulfate, total Kjeldahl nitrogen, total phosphorus

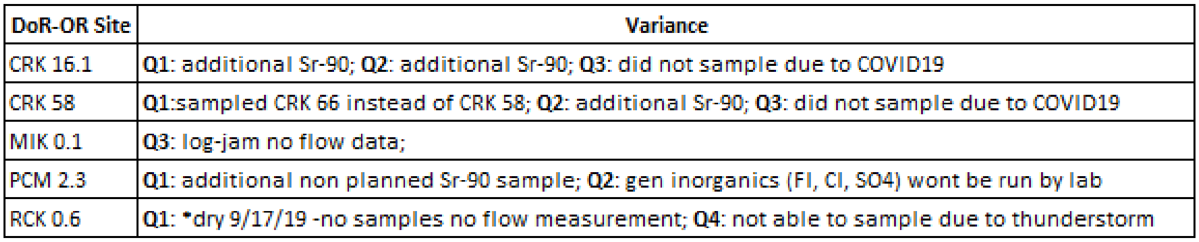
Metals: arsenic, cadmium, calcium, chromium, copper, lead, magnesium, nickel, selenium, sodium, uranium, and zinc.

Rads: Isotopic Uranium, Technetium-99

### 5.1.6 Deviations from the Plan

A few deviations from the plan occurred. For specific deviations, see Table 5.1.2 below.

**Table 5.1.2: Description of deviations from plan by quarter (e.g. Q1 = 1st quarter)**



| DoR-OR Site | Variance |
|---|---|
| CRK 16.1 | **Q1**: additional Sr-90; **Q2**: additional Sr-90; **Q3**: did not sample due to COVID19 |
| CRK 58 | **Q1**:sampled CRK 66 instead of CRK 58; **Q2**: additional Sr-90; **Q3**: did not sample due to COVID19 |
| MIK 0.1 | **Q3**: log-jam no flow data; |
| PCM 2.3 | **Q1**: additional non planned Sr-90 sample; **Q2**: gen inorganics (Fl, Cl, SO4) wont be run by lab |
| RCK 0.6 | **Q1**: *dry 9/17/19 -no samples no flow measurement; **Q4**: not able to sample due to thunderstorm |

### 5.1.7 Results and Analysis

Samples were collected at sites quarterly. Data summaries of sampled constituents are shown below. See tables 5.1.3 through 5.1.6 for quarterly sampling results. Poplar Creek was sampled for additional constituents beyond those sampled at other sites. Results for these additional constituents are shown in tables 5.1.7 through 5.1.9. Table values highlighted in red indicate exceedance of EPA MCLs or TN water quality criteria. A yellow highlight indicates that a value is close to the MCL, within rounding.

## Table 5.1.3: Results from Quarter 1 (July – September)

| DoR-OR Site | Sr-89 (pCi/L) | Sr-90 (pCi/L) | Gross α (pCi/L) | Gross ß (pCi/L) | Tritium (pCi/L) | Mercury (ug/L) | Flow (L/s) | Temperature (C) | pH | Dissolved Oxygen (mg/L) | Conductivity (uS/cm) | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CRK 16.1 | -1.1 | 0.65 | -0.21 | 1.6 | 2 | 0.00345 | * | 21.7 | 7.92 | 8.02 | 281.2 | 9/23/2019 |
| CRK 32 | 1.26 | 0.33 | -0.22 | 1.1 | 14 | 0.00096 | * | 20.2 | 7.92 | 6.76 | 282.1 | 9/23/2019 |
| CRK 33.5 | -0.21 | 50 | 10.4 | 106.7 | 6467 | 0.00235 | * | 20.7 | 7.74 | 5.26 | 300.5 | 9/23/2019 |
| CRK 58 | * | * | * | * | * | * | * | * | * | * | * | * |
| CRK 66 | -0.04 | 0.48 | 0.51 | -0.7 | -13 | 0.00108 | * | 25 | 8.42 | 10.96 | 282 | 9/23/2019 |
| MIK 0.1 | * | * | 6.2 | 19.4 | 111 | 0.00772 | 9.5 | 21.5 | 7.78 | 5.99 | 484.5 | 8/7/2019 |
| PCM 2.3 | 1.9 | -0.54 | 0.56 | 15 | 50 | 0.0588 | * | 24.2 | 7.95 | 6.72 | 292.2 | 8/7/2019 |
| GCK 1.1 | * | * | -0.43 | 0.4 | 316 | 0.00089 | 6.1 | 20.9 | 8.26 | 7.91 | 328.6 | 8/7/2019 |
| RCK 0.6 | * | * | * | * | * | * | * | * | * | * | * | * |
| MEK 0.3 | * | * | 2.27 | 37 | 14781 | 0.00112 | 1.2 | 21.6 | 7.89 | 6.83 | 426.5 | 9/17/2019 |
| EFWK 1.9 | * | * | -0.11 | 3.7 | 116 | 0.0009 | 19.9 | 18.8 | 8.07 | 8.49 | 369.2 | 9/10/2019 |
| MCK 1.4 | * | * | -0.3 | 1.9 | 35 | 0.00116 | 5.5 | 24.7 | 7.81 | 7.21 | 239.1 | 9/10/2019 |
| SCK 1.8 | * | * | 0.13 | 0.2 | 73 | 0.00189 | 23.8 | 19 | 8.12 | 8.21 | 372.5 | 8/13/2019 |
| EFK 23.4 | * | * | 4.6 | 6.7 | 126 | 0.146 | 97.6 | 23.5 | 8.31 | 8.71 | 398.2 | 8/13/2019 |

## Table 5.1.4: Results from Quarter 2 (October – December)

| DoR-OR Site | Sr-89 (pCi/L) | Sr-90 (pCi/L) | Gross α (pCi/L) | Gross ß (pCi/L) | Tritium (pCi/L) | Mercury (ug/L) | Flow (L/s) | Temperature (C) | pH | Dissolved Oxygen (mg/L) | Conductivity (uS/cm) | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CRK 16.1 | 0.34 | 0.06 | 0.69 | 2.5 | -31 | 0.00776 | * | 11.7 | 8.05 | 9.16 | 272.3 | 12/16/2019 |
| CRK 32 | -1.6 | 1.48 | -0.05 | 2.3 | 11 | U | * | 12.2 | 8.31 | 9.37 | 278.6 | 12/16/2019 |
| CRK 33.5 | 1.6 | 13.8 | 3.24 | 33 | 665 | 0.0147 | * | 10 | 7.82 | 8.36 | 377.9 | 12/16/2019 |
| CRK 58 | 1.8 | -0.29 | -0.04 | 0.7 | -68 | U | * | 12.6 | 8.57 | 8.99 | 285.1 | 12/16/2019 |
| MIK 0.1 | * | * | 10.7 | 19.9 | 100 | 0.00769 | 7.3 | 10.7 | 7.54 | 7.24 | 509.3 | 11/19/2019 |
| PCM 2.3 | * | * | 0.6 | 28.7 | 74 | 0.141 | * | 8.2 | 7.79 | 8.17 | 326.5 | 11/19/2019 |
| GCK 1.1 | * | * | 0.61 | 1 | 334 | 0.00232 | 8.2 | 7.3 | 8.1 | 10.45 | 313.1 | 11/19/2019 |
| RCK 0.6 | -1.2 | 1.3 | -0.32 | -1.8 | 178 | 0.00199 | 4.5 | 13 | 7.54 | 8.52 | 338.4 | 10/28/2019 |
| MEK 0.3 | * | * | 7.7 | 70.8 | 3596 | 0.0013 | 16.2 | 15.7 | 7.36 | 7.99 | 346.4 | 10/28/2019 |
| EFWK 1.9 | * | * | 1.19 | -1.1 | 92 | 0.00267 | 16.8 | 9.1 | 8.04 | 9.95 | 263.9 | 12/5/2019 |
| MCK 1.4 | * | * | 0.28 | -0.08 | 48 | U | 42.5 | 12.1 | 8.34 | 9.6 | 262.7 | 12/5/2019 |
| SCK 1.8 | * | * | -0.4 | 2.3 | 33 | 0.00152 | 35.1 | 10.1 | 8.31 | 10.18 | 397 | 11/4/2019 |
| EFK 23.4 | * | * | 14.7 | 8.6 | 127 | 0.142 | 72.5 | 13.7 | 7.8 | 10.01 | 474.3 | 11/4/2019 |

## Table 5.1.5: Results from Quarter 3 (January – March)

| DoR-OR Site | Sr-89 (pCi/L) | Sr-90 (pCi/L) | Gross α (pCi/L) | Gross ß (pCi/L) | Tritium (pCi/L) | Mercury (ug/L) | Flow (L/s) | Temperature (C) | pH | Dissolved Oxygen (mg/L) | Conductivity (uS/cm) | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CRK 16.1 | * | * | * | * | * | * | * | * | * | * | * | * |
| CRK 32 | 1.6 | 1.14 | 0.1 | 4.4 | -21 | 0.00106 | * | 11.9 | 7.75 | 9.94 | 243.2 | 3/23/2020 |
| CRK 33.5 | 2.94 | 23 | 5.52 | 65.4 | 1363 | 0.00681 | * | 13.3 | 7.65 | 9.73 | 214.1 | 3/23/2020 |
| CRK 58 | * | * | * | * | * | * | * | * | * | * | * | * |
| MIK 0.1 | * | * | 5.51 | 7.2 | 75 | 0.00421 | * | 13.1 | 7.69 | 10.16 | 267.1 | 3/4/2020 |
| PCM 2.3 | * | * | 0.73 | 0.8 | 21 | 0.00168 | * | 12.9 | 7.65 | 9.82 | 127.2 | 3/4/2020 |
| GCK 1.1 | * | * | 0.15 | -0.5 | 396 | 0.00134 | 224.2 | 12.2 | 7.68 | 10.52 | 148.3 | 3/4/2020 |
| RCK 0.6 | 0.31 | 0.01 | -0.45 | 2 | 109 | 0.00183 | 42.4 | 13.4 | 7.95 | 10.16 | 287.4 | 3/18/2020 |
| MEK 0.3 | * | * | 2.8 | 33.6 | 1615 | 0.000565 | 169.9 | 14.4 | 8.17 | 10.8 | 231.2 | 3/18/2020 |
| EFWK 1.9 | * | * | 0.75 | 1.2 | 167 | 0.00105 | 61.5 | 13.2 | 7.78 | 10.06 | 248.6 | 3/18/2020 |
| MCK 1.4 | * | * | -0.19 | 0.6 | 98 | 0.00078 | 77.3 | 11.1 | 7.56 | 10.54 | 257.1 | 3/18/2020 |
| SCK 1.8 | * | * | 0.4 | 0.5 | 49 | 0.00642 | 198.8 | 14.5 | 7.99 | 9.97 | 294.7 | 2/25/2020 |
| EFK 23.4 | * | * | 21.5 | 10.8 | 95 | 1.6 | 245.6 | 14.3 | 8.21 | 10.78 | 397.4 | 2/25/2020 |

## Table 5.1.6: Results from Quarter 4 (April – June)

| DoR-OR Site | Sr-89 (pCi/L) | Sr-90 (pCi/L) | Gross α (pCi/L) | Gross ß (pCi/L) | Tritium (pCi/L) | Mercury (ug/L) | Flow (L/s) | Temperature (C) | pH | Dissolved Oxygen (mg/L) | Conductivity (uS/cm) | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CRK 16.1 | * | * | 0.39 | 0.5 | -30 | 0.0115 | * | 20.7 | 7.84 | 7.82 | 259.8 | 6/17/2020 |
| CRK 32 | Pending | Pending | 0.24 | 0.4 | 29 | 0.000934 | * | 19.6 | 7.5 | 7.26 | 256.5 | 6/15/2020 |
| CRK 33.5 | Pending | Pending | 8.8 | 118.3 | 6367 | 0.00397 | * | 19.5 | 7.54 | 5.72 | 257.7 | 6/22/2020 |
| CRK 58 | * | * | -0.45 | 2.8 | 50 | 0.00208 | * | 27.2 | 8.72 | 11.64 | 249.3 | 6/22/2020 |
| MIK 0.1 | * | * | 6.62 | 12 | 47 | 0.00666 | 12.0 | 19.3 | 7.53 | 9.07 | 417.3 | 6/17/2020 |
| PCM 2.3 | * | * | 0.09 | 16.6 | 46 | 0.0603 | * | 23.4 | 7.54 | 7.54 | 278.2 | 6/17/2020 |
| GCK 1.1 | * | * | 0.56 | 1.2 | 360 | 0.00258 | 5.9 | 16.3 | 7.5 | 8.66 | 304.3 | 6/17/2020 |
| RCK 0.6 | * | * | * | * | * | * | * | * | * | * | * | * |
| MEK 0.3 | * | * | 2.09 | 27.4 | 3849 | 0.00187 | 21.3 | 19.1 | 7.28 | 8.21 | 732 | 6/15/2020 |
| EFWK 1.9 | * | * | 0.66 | -0.2 | 117 | 0.0016 | 2.9 | 16 | 7.48 | 8.76 | 317.6 | 6/15/2020 |
| MCK 1.4 | * | * | 0.65 | 0.8 | 97 | 0.00467 | 17.7 | 19.8 | 7.6 | 7.25 | 256 | 6/15/2020 |
| SCK 1.8 | * | * | 0.33 | 2 | 32 | 0.00313 | 37.9 | 19.5 | 8.11 | 8.77 | 370.6 | 6/22/2020 |
| EFK 23.4 | * | * | 4.96 | 8.3 | 114 | 0.131 | 73.4 | 22 | 7.84 | 9.4 | 382.7 | 6/22/2020 |

## Table 5.1.7: PCM 2.3 Anions and Nutrients Results

| DoR-OR Site | Chloride (mg/L) | Fluoride (mg/L) | Sulfate (mg/L) | Phosphorus (mg/L) | Total Kjeldahl Nitrogen (mg/L) | Inorganic nitrogen (nitrate and nitrite) (mg/L) | Quarter | Date |
|---|---|---|---|---|---|---|---|---|
| PCM 2.3 | * | * | * | * | * | * | 1 | 8/7/2019 |
| PCM 2.3 | * | * | * | * | * | * | 2 | 11/19/2019 |
| PCM 2.3 | 2.38 | 0.0618 | 10.5 | 0.0718 | U | 0.248 | 3 | 3/4/2020 |
| PCM 2.3 | 5.02 | 0.113 | 15.5 | 0.0758 | 0.194 | 0.481 | 4 | 6/17/2020 |

## Table 5.1.8: PCM 2.3 Cations and Metals Results

| DoR-OR Site | Calcium (mg/L) | Magnesium (mg/L) | Sodium (mg/L) | Arsenic (ug/L) | Cadmium (ug/L) | Chromium (ug/L) | Copper (ug/L) | Lead (ug/L) | Nickel (ug/L) | Selenium (ug/L) | Uranium (ug/L) | Zinc (ug/L) | Quarter | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PCM 2.3 | 38.3 | 10 | 6.71 | 1.46 | U | U | 1.24 | 0.579 | 1.6 | U | 2.23 | 3.85 | 1 | 8/7/2019 |
| PCM 2.3 | 44.6 | 10.9 | 7.21 | 0.829 | 0.161 | 1.67 | 1.8 | 1.13 | 2.17 | 0.896 | 3.28 | Pending | 2 | 11/19/2019 |
| PCM 2.3 | 13.4 | 3.6 | 1.66 | 282 | U | U | 0.958 | 0.833 | 1.22 | U | U | 3.93 | 3 | 3/4/2020 |
| PCM 2.3 | 35.8 | 0.164 | 9.89 | U | U | U | 0.814 | 0.424 | 1.25 | U | 0.306 | 3.55 | 4 | 6/17/2020 |

## Table 5.1.9: PCM 2.3 Radionuclide Results

| DoR-OR Site | Technetium-99 (pCi/L) | Uranium-234 (pCi/L) | Uranium-235 (pCi/L) | Uranium-238 (pCi/L) | Quarter | Date |
|---|---|---|---|---|---|---|
| PCM 2.3 | 12.18 | 0.58 | 0.18 | 0.66 | 1 | 8/7/2019 |
| PCM 2.3 | 22.66 | 20.6 | 0.96 | 0.302 | 2 | 11/19/2019 |
| PCM 2.3 | 1.35 | 0.348 | 0.067 | 0.39 | 3 | 3/4/2020 |
| PCM 2.3 | Pending | Pending | Pending | Pending | 4 | 6/17/2020 |

### *Stream Flow*

Stream flow was measured at several exit-pathway streams. Flow measurements were taken each quarter (four times) at most sites. Due to conflicts and conditions (see Table 5.1.2), sites MIK 0.1 and RCK 0.6 only were measured three and two times, respectively. Of these few flow measurements at each site, EFK 23.4 had the highest average flow of 122 L/s and MIK had the lowest mean flow of 9.6 L/s. The maximum flows for all sites were in late February and early March. Descriptive statistics of the flow measurements are shown below in Table 5.1.10 and Figure 5.1.3.

**Table 5.1.10: Flow Measurements in Liters per Second**

| Station | Min. Flow | Max Flow | Mean Flow | Quarters Measured |
|---|---|---|---|---|
| EFK 23.4 | 72.5 | 245.6 | 122.3 | 4 |
| SCK 1.8 | 23.8 | 198.8 | 73.9 | 4 |
| GCK 1.1 | 5.9 | 224.2 | 61.1 | 4 |
| MEK 0.3 | 1.2 | 169.9 | 52.2 | 4 |
| MCK 1.4 | 5.5 | 77.3 | 35.7 | 4 |
| EFWK 1.9 | 2.9 | 61.5 | 25.3 | 4 |
| RCK 0.6 | 4.5 | 42.4 | 23.5 | 2 |
| MIK 0.1 | 7.3 | 12.0 | 9.6 | 3 |

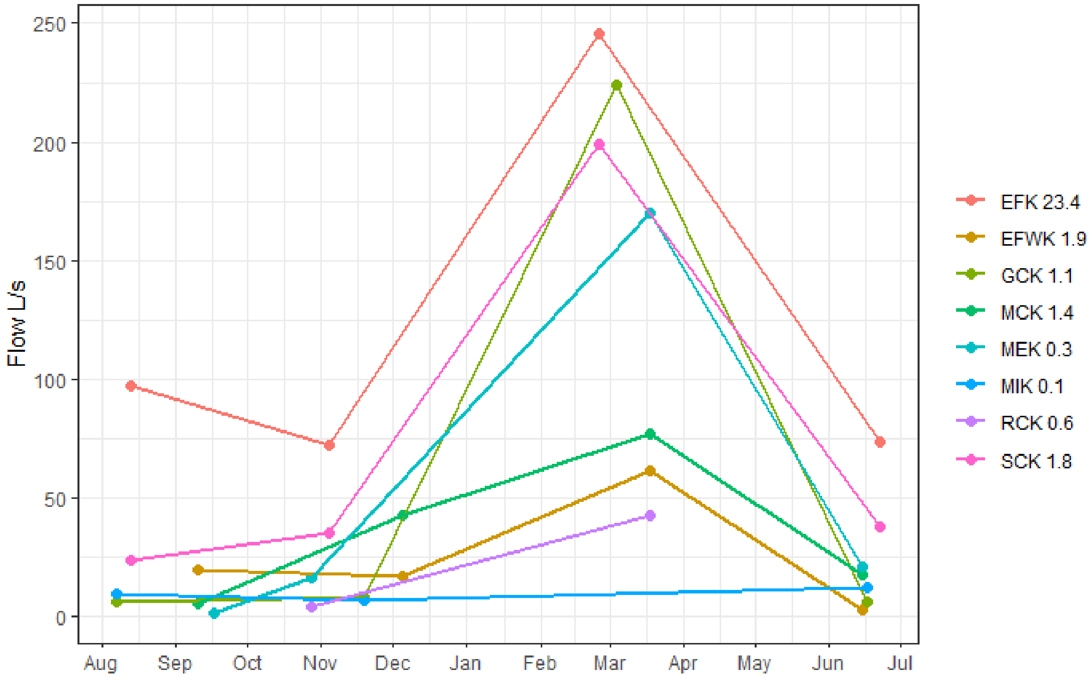


**Figure 5.1.3: Flow measurements for each station in L/s**

*Mercury Flux*

With stream flow measurements and complementary mercury concentrations for each site, mercury flux was able to be calculated to give an approximated mass per year loaded from each stream. These values are only approximate as they are based on only a few measurements and samples. However, these values can provide insight into possible loading potential from each stream. EFK 23.4 has by far the highest flux of mercury based on available data. It potentially loads nearly 3.4 kilograms of mercury to the Clinch River each year. Scarboro Creek loads nearly 12 grams of mercury to the Clinch each year. Other sites load around 1 to 2 grams of mercury to the Clinch (Table 5.1.11).

**Table 5.1.11: Mercury Flux**

| Station | Grams Mercury/Year | Kilograms Mercury/Year | N |
|---|---|---|---|
| EFK 23.4 | 3368.1 | 3.368 | 4 |
| EFWK 1.9 | 1.0 | 0.0010 | 4 |
| GCK 1.1 | 2.7 | 0.0027 | 4 |
| MCK 1.4 | 1.9 | 0.0019 | 4 |
| MEK 0.3 | 1.2 | 0.0012 | 4 |
| MIK 0.1 | 2.2 | 0.0022 | 3 |
| RCK 0.6 | 0.9 | 0.0009 | 2 |
| SCK 1.8 | 11.8 | 0.0118 | 4 |

Specific discussion on analytical results for each stream sampled is provided in the following sections of this project report.

## Clinch River (CRK)

Of all the samples collected for the Clinch River, a few constituents were consistently high or above TN or EPA screening levels (see Tables 5.1.3 to 5.1.6). In particular, CRK 33.5 frequently yielded high radiological activities. CRK 33.5 was consistently high, well above the EPA drinking water MCL of 8 pCi/L, for Sr-90. Similarly, this site consistently yielded high gross beta particle activities, often well above 50 pCi/L. Tritium values were also relatively high, upwards of 6,467 pCi/L, yet well below EPA's drinking water criterion. This site is at the mouth of White Oak Creek, which has historically been a very contaminated stream. In particular, Sr-90 contamination from a 2015 ruptured pipe at the Process Waste Treatment Complex may be a primary cause of these increased Sr-90 levels (DOE, 2018). The site immediately downstream (CRK 32) has elevated Sr-90 and gross beta relative to other CRK sites, but it is below EPA defined criteria. A decrease in Sr-90 and gross beta activity from CRK 33.5 to CRK 32 has been identified as shown in Figures 5.1.4 and 5.1.5 below. This is likely due to dilution of the Clinch River downstream of the mouth of White Oak Creek. All other Clinch River Sites were below criteria for Sr-90, gross alpha/beta activity, tritium, and mercury.

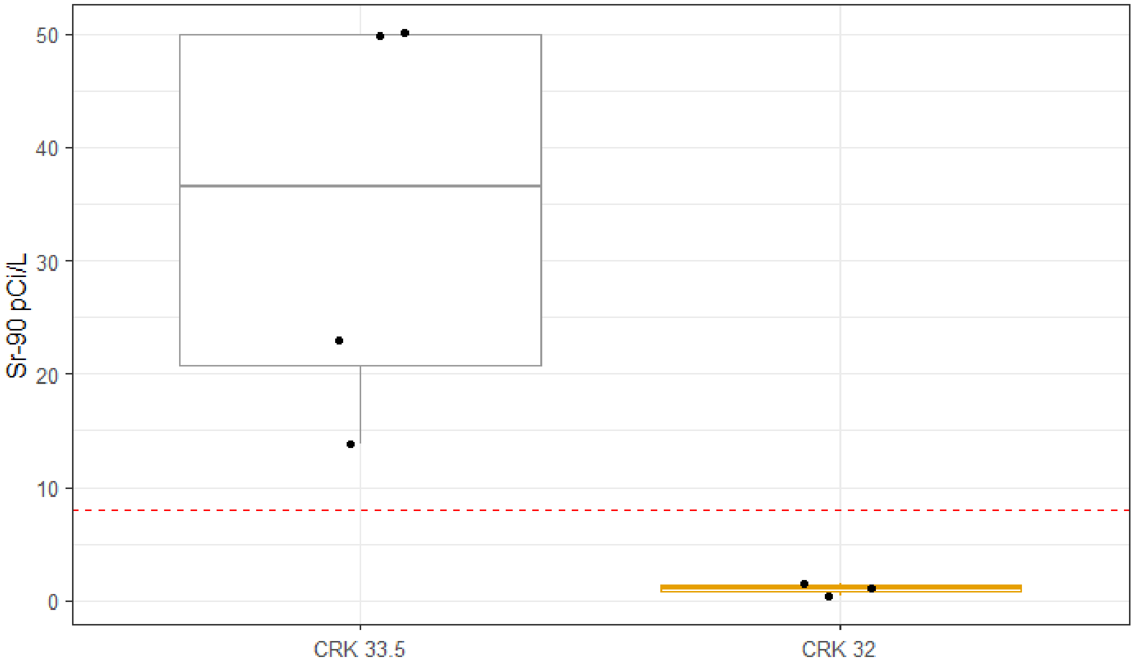


**Figure 5.1.4: Sr-90 measurements from July 2019 through June 2020 at CRK 33.5 and downstream CRK 32. Red dashed line is the EPA MCL of 8 Pci/L.**

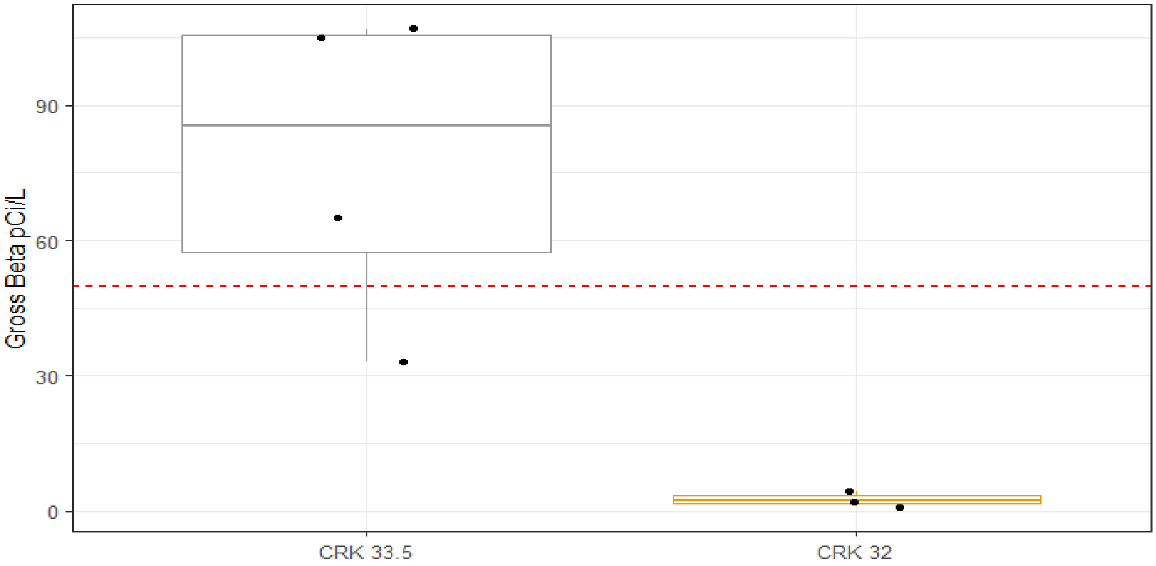


**Figure 5.1.5: Gross beta activity measurements from July 2019 through June 2020 at CRK 33.5 and downstream CRK 32. Red dashed line is the DOE threshold used to trigger further identification of specific beta emitting species.**

### Mitchell Branch (MIK)

Mitchell Branch was below EPA and TN criteria for Sr-90, gross alpha/beta activity, tritium, and mercury. Gross alpha activity was highest at 10.7 pCi/L, approaching the 15 pCi/L EPA MCL in November 2019. Gross beta activity was also relatively high compared to other streams on the ORR at 19.9 pCi/L. However, gross beta is below DOE's threshold for further investigation.

### Poplar Creek (PCM)

Poplar Creek was primarily below criteria for constituents sampled. However, PCM 2.3 exceeded the TN water and organism criterion of 0.051 µg/L for mercury in three out of four quarters sampled. These mercury exceedances were only slightly higher than this criterion as shown in Figure 5.1.6.

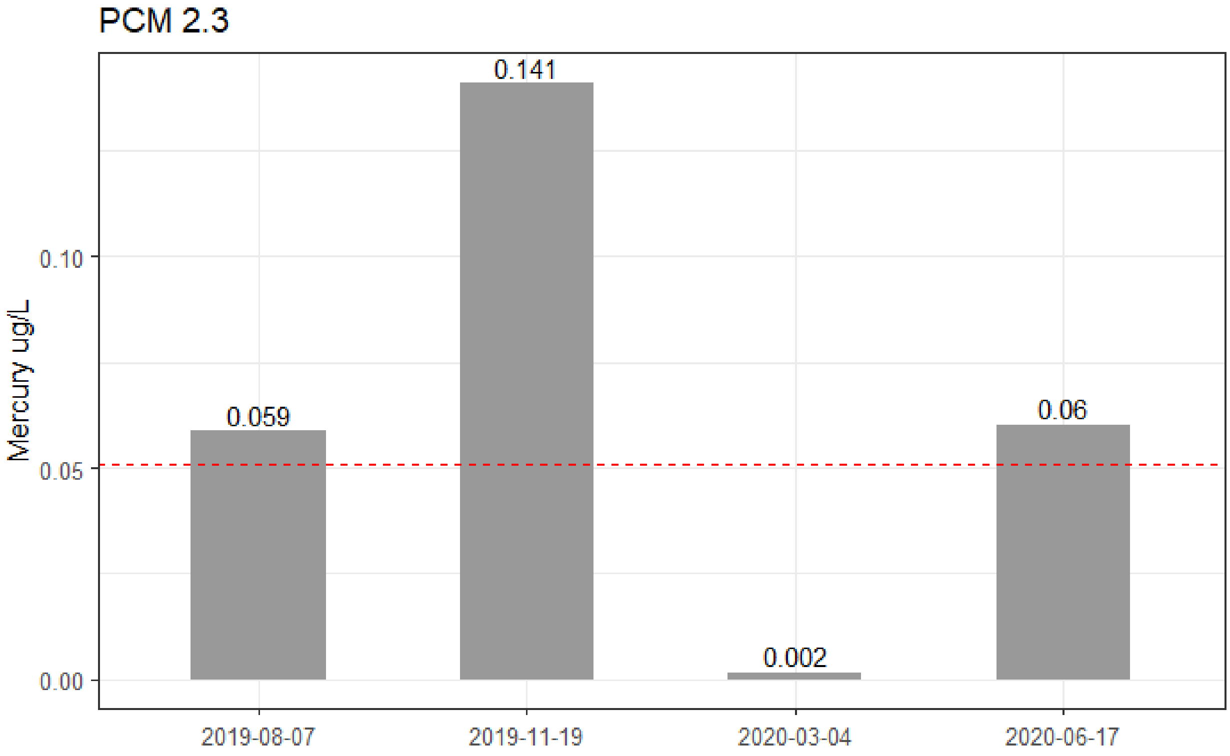


**Figure 5.1.6: Mercury concentrations at PCM 2.3. Red dashed line represents TN criterion for water and organisms of 0.051 µg/L.**

Additionally, Poplar Creek was sampled for constituents beyond those sampled at other sites. Of these constituents, high levels of arsenic and uranium-234 were identified (See Tables 5.1.7 to 5.1.9). Arsenic was 282 µg/L, which is 28 times greater than the TN criterion of 10 µg/L for water and organisms. Uranium-234 was very high at 20.6 pCi/L. This high uranium value may be due to demolition work upstream at ETTP's exposure units (EU) 19 and 13.

### Grassy Creek (GCK)

Grassy Creek was relatively low in all constituents sampled. Tritium was only slightly elevated compared to other streams but was very low relative to the 20,000 pCi/L drinking water MCL.

### Raccoon Creek (RCK)

Of the two times Raccoon Creek was sampled, all constituents sampled were well under defined criteria by EPA and TN.

### Melton Branch (MEK)

Melton Branch was relatively high in alpha activity, beta activity, and tritium activity. These activities were nearly approaching EPA and TN criteria, but not did not exceed them. This site was quite low in mercury concentrations. Alpha activity was highest at 7.7 pCi/L. Beta activity was highest at 70.8 pCi/L, which is above the 50 pCi/L threshold often used by DOE to trigger further isotopic investigation. Tritium was highest at 14,781 pCi/L which is approaching the EPA MCL of 20,000 pCi/L.

### East Fork Walker Branch (EFWK)

East Fork Walker Branch was below EPA and TN criteria for Sr-90, gross alpha/beta activity, tritium, and mercury.

### McCoy Branch (MCK)

McCoy Branch was below EPA and TN criteria for Sr-90, gross alpha/beta activity, tritium, and mercury.

### Scarboro Creek (SCK)

Scarboro Creek was below EPA and TN criteria for Sr-90, gross alpha/beta activity, tritium, and mercury.

### East Fork Poplar Creek (EFK)

EFK 23.4 was consistently high in gross alpha activity, often above or near the EPA MCL. Gross alpha was the highest at 21.5 pCi/L in February 2020. Mercury was nearly double the TN criterion of 0.051 µg/L for water and organisms with some larger exceedances (see Figure

5.1.7). The largest increase was in February 2020 where mercury increased to 1.6 µg/L, or nearly 32 times the criterion for TN water and organisms.

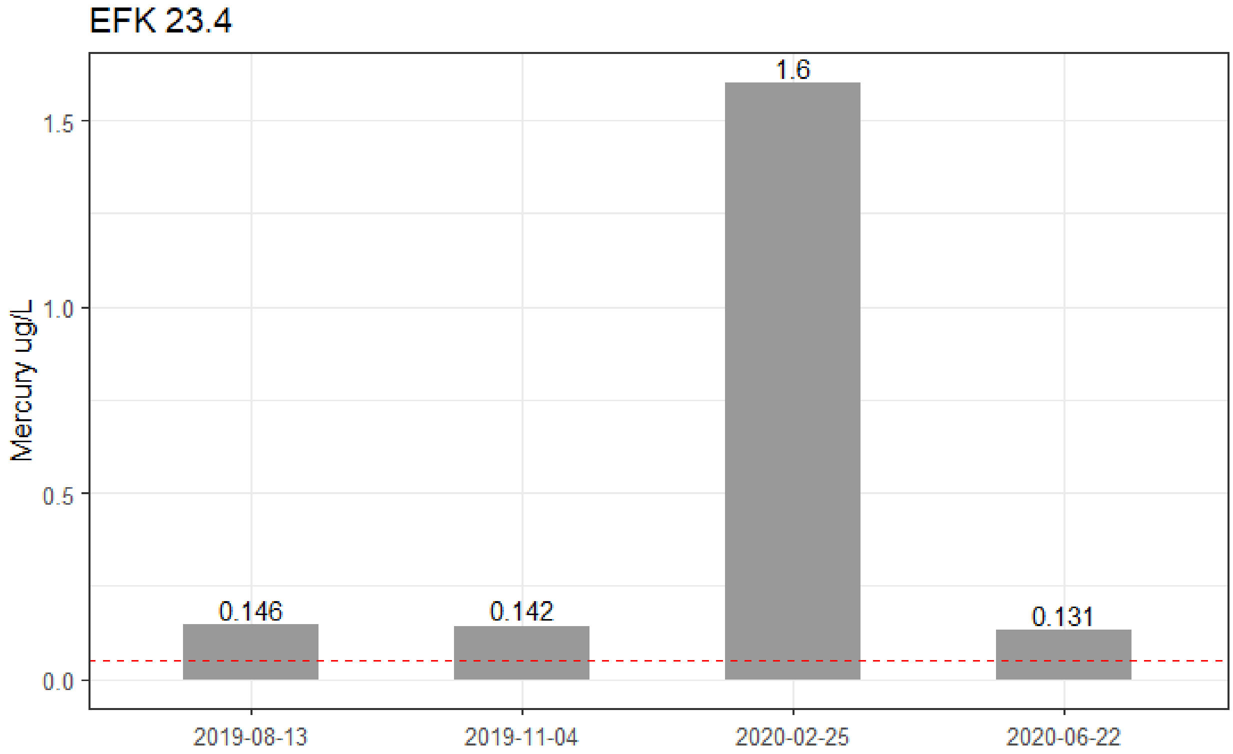


**Figure 5.1.7: Mercury concentrations at EFK 23.4. Red dashed line represents TN criterion for water and organisms of 0.051 µg/L.**

### 5.1.8 Conclusions

Several ORR exit-pathway streams were investigated for metals and radionuclides. This project sought to understand the loading potential of mercury for many exit-pathway streams that drain the ORR into the Clinch River. Many of the smaller, historically less studied streams (e.g., East Fork Walker Branch, Grassy Creek, McCoy Branch, Raccoon Creek, Scarboro Creek) were relatively low in mercury concentrations. Loading rates from these streams were relatively low, only contributing a few grams of mercury to the Clinch River each year. Of these streams, Scarboro Creek had the highest loading of mercury with an estimated 11.8 grams to the Clinch River each year. This is likely due to the higher flows seen in Scarboro Creek relative to the other smaller streams. These streams generally do not appear to be major contributors of mercury loading to the Clinch River. Streams such as East Fork Poplar Creek, Melton Branch, Mitchell Branch, and Poplar Creek have relatively high mercury concentrations, at times exceeding the TN defined criterion for water and organisms of 0.051 µg/L. These higher mercury concentration streams tend to be located within ORR plant boundaries, while the other streams are not as predominantly located. East

Fork Poplar Creek is consistently high in mercury concentrations, often above the TN criterion for water and organisms. East Fork Poplar Creek had the highest loading of mercury compared to the other sites studied, contributing an estimated 3.4 kilograms of mercury to the Clinch River each year. High flow events in the late winter and early spring seem to increase loading of mercury. Radionuclides (gross alpha, gross beta, and tritium) were also analyzed for all streams. The smaller streams (e.g., East Fork Walker Branch, Grassy Creek, McCoy Branch, Raccoon Creek, Scarboro Creek) had relatively low activities. The larger streams such as East Fork Poplar Creek, Melton Branch, Mitchell Branch, and Poplar Creek seem to have elevated activity levels relative to the smaller streams. Again, this is likely due to the proximity of these streams to ORR plant locations, where they are closer to contamination sources and remediation efforts. East Fork Poplar Creek yielded relatively high gross alpha activities, occasionally exceeding the EPA drinking water criteria. Melton Branch is relatively high in alpha and beta activity and in tritium, but the stream tends to be slightly below the defined EPA criteria for these constituents. Mitchell Branch generally has relatively higher gross alpha activity and gross beta activity. However, neither of these constituents exceeded EPA defined criteria. In addition to those constituents sampled at all sites, Poplar Creek was sampled for additional metals and radionuclides. Infrequently, high concentrations of arsenic, upwards of 282 µg/L, were identified in Poplar Creek. Also, uranium-234 was also infrequently identified; however, one result was over 20 pCi/L (see Tables 5.1.7 to 5.1.9). In conclusion, several ORR streams are impaired with mercury and radionuclides which ultimately flow to the Clinch River. Streams more predominately located within ORR plant boundaries tend to be more impaired with these contaminants than streams that are farther from the plant boundaries.

### 5.1.9 Recommendations

A few of the streams in this study had elevated metals and radionuclide contamination. Until all areas of extensive anthropogenic-point and non-point source contamination on the ORR are fully remediated, the potential exists for pollution to contaminate surface waters on the ORR as well as downstream offsite aquatic systems. Accordingly, it is prudent for this project to continue assessing ORR exit pathway stream and Clinch River surface water conditions, perhaps focusing on those streams that are more contaminated. In addition, it is recommended that flow measurements continue to be taken in conjunction with surface water sampling to assess the loading of contaminants from the ORR into the Clinch River, a major resource for many Tennessee citizens.

### 5.1.10 References

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## 5.2 AMBIENT SURFACE WATER PARAMETERS

### 5.2.1 Background

The Oak Ridge Reservation (ORR) is a complex National Priority List (NPL) site. Built in the 1940's, the federally-owned 37,000-acre reservation includes three Department of Energy (DOE) facilities created as integral parts of the Manhattan Project. The three site facilities are the Oak Ridge National Laboratory (ORNL), the Y-12 National Security Complex (Y-12), and the East Tennessee Technology Park (ETTP), formerly the K-25 Plant. Activities at site facilities have resulted in the discharge of hazardous substances (metals, organics, and radioactive materials) leading to the contamination of waterbodies at the ORR NPL site and in the surrounding areas.

An ambient surface water parameters project has been implemented each year since 2005. Due to the presence in some areas of anthropogenic point- and non-point source contamination on the ORR, there exists the potential for contamination to impact surface water on the ORR. To assess the degree of surface water impact relative to this potential contamination displacement, stream monitoring data will be collected monthly to establish a database of physical stream parameters (conductivity, pH, temperature, and dissolved oxygen).

### 5.2.2 Problem Statements

ORR exit pathway streams are subject to contaminant releases from activities at ETTP, ORNL, and Y-12; these contaminant releases have been detrimental to stream health in the past and present. Identified issues include:

- From 1950 to 1963, Y-12 released approximately 100 metric tons of elemental mercury to East Fork Poplar Creek (EFPC) by spills and leakage from subsurface drains, building foundations, contaminated soil, and purposed discharge of wastewater containing mercury (Turner and Southworth, 1999).
- EFPC is believed to contribute approximately 0.2 metric tons of mercury to the Clinch River each year (DOE, 1992).
- Besides mercury, other metals that have been found in ORR exit pathway streams at levels greater than background are cadmium, chromium, lead, nickel, silver, and zirconium (DOE, 1992).
- Water supply facilities, serving an estimated population of 200,000 persons, on the Tennessee River downstream of White Oak Creek have the potential of being influenced by streams that drain the ORR (DOE, 1992).

- ORNL has been releasing low-level radioactive liquid wastes to the Clinch River via White Oak Creek since 1943 (Pickering, 1970).
- The Clinch River received approximately 665 curies of cesium-137 (Cs-137) from White Oak Creek from 1954 to 1959 (DOE, 1992).

### 5.2.3 Goals

- Create a database/baseline of surface water conditions on and around the ORR.
- Assess site remediation efforts through long-term monitoring of surface water.
- Record ambient conditions that can be used for comparisons in the event of accidents that may have impacted surface water bodies.

### 5.2.4 Scope

Due to the presence in some areas of anthropogenic point- and non-point source contamination on the ORR and the potential for contamination to impact surface water parameters, this project is limited to collecting and recording physical stream parameter measurements of ambient surface water of the exit pathway streams that drain the ORR to establish a baseline of conditions on and around the ORR.

### 5.2.5 Methods, Materials, Metrics

The surface water physical parameters of temperature, pH, conductivity, and dissolved oxygen were measured monthly with a YSI Professional Plus multi-parameter water quality instrument. Field monitoring followed the 2018 Tennessee Department of Environment and Conservation (TDEC), Division of Water Resources (DWR), *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water* (TDEC, 2018).

**Table 5.2.1: Monitoring Locations**

| Site DWR Name | DOE-O Site Description | DOE-O Site | Site Latitude | Site 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 |
| FECO67I12 | Mill Branch Mile 1.0 | MBK 1.6 | 35.98886 | -84.28935 |

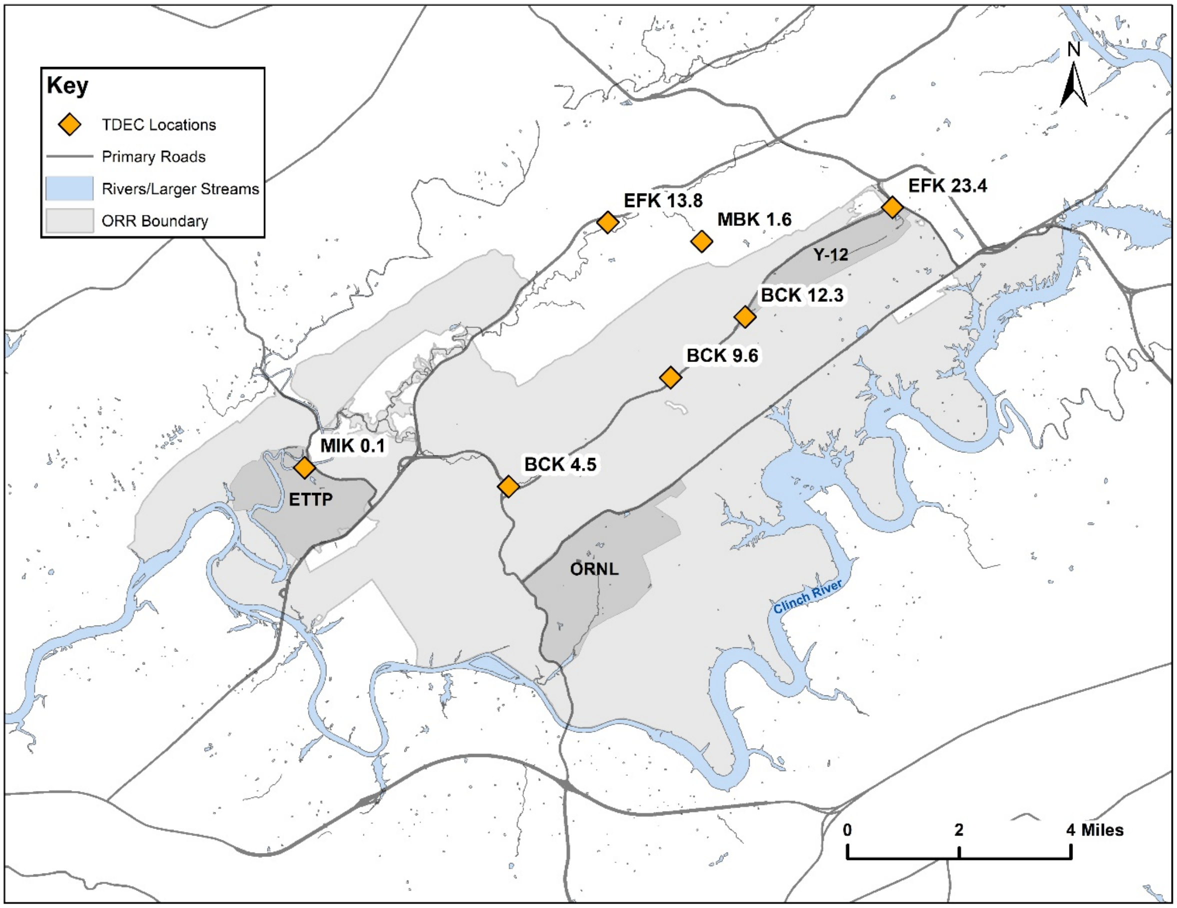

**Figure 5.2.1: Map of surface water parameter locations.**

### 5.2.6 Deviations from the Plan

Due to COVID-19 shutdowns, surface water physical parameters were not measured in the months of April and May 2020. Parameters were measured at all sites in all other months from July 2019 to June 2020.

### 5.2.7 Results and Analysis

Field parameters including conductivity, dissolved oxygen, pH, and temperature were collected monthly from the seven monitoring locations (Figure 5.2.1). 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. Significant differences among streams will be analyzed and discussed below.

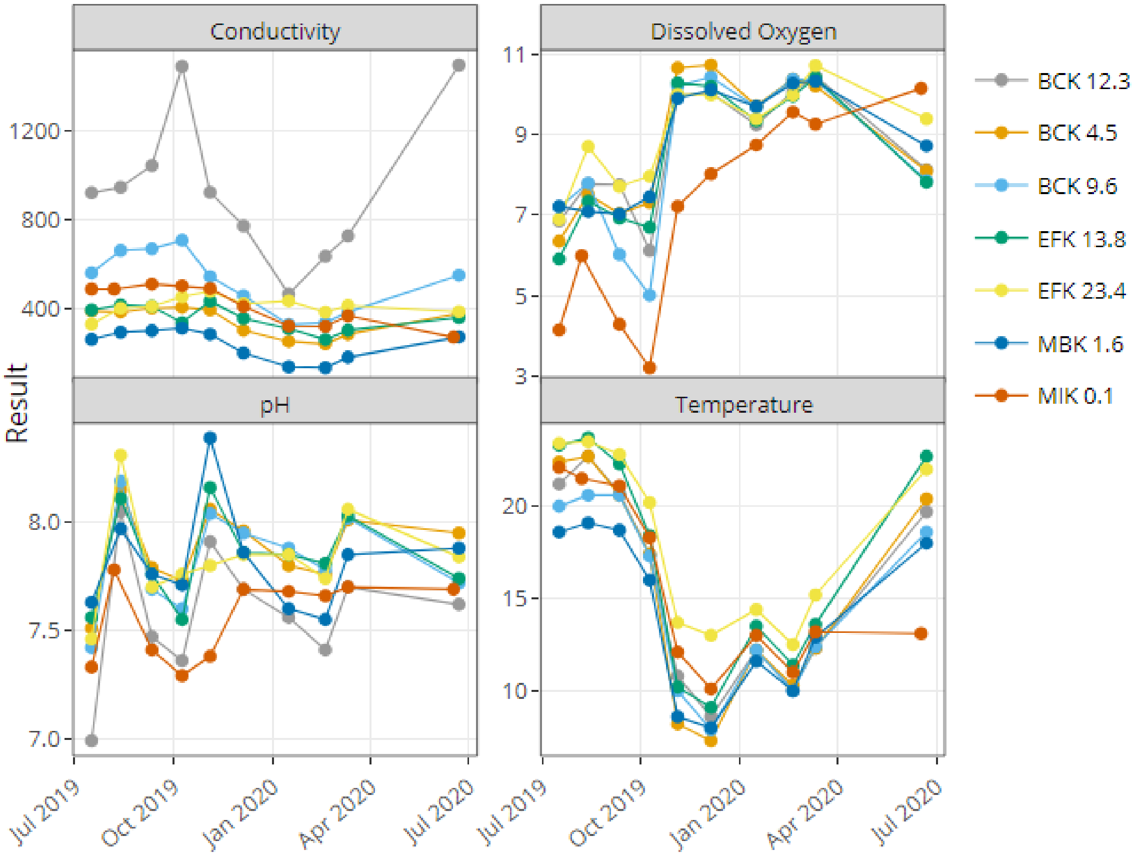

**Figure 5.2.2: Field parameter results from July 2019 through June 2020. Units for conductivity, dissolved oxygen, pH, and temperature are µS/cm, mg/L, std. unit, and °C, respectively.**

One of the field parameters with significant differences among streams was conductivity. Mean conductivity values from measurements collected July 2019 to June 2020 ranged from 939 to 234 µS/cm, among all of the monitoring sites. Bear Creek sites BCK 12.3 and BCK 9.6 had the highest mean conductivity values of 939 and 517 µS/cm, respectively. Further downstream, BCK 4.5 had a lower mean value of 340 µS/cm. At EFPC, site EFK 23.4, near the eastern border of the Y-12 Security Complex, had a mean conductivity of 408 µS/cm. Downstream of EFK 23.4, site EFK 13.8 had a lower mean value of 355 µS/cm. The Mitchell Branch site MIK 0.1 at ETTP had a mean conductivity value of 414 µS/cm. Mill Branch (MBK 1.6), an ecological reference site, had the lowest conductivity among all streams measured with a mean value of 234 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 of the Tukey test 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 5.2.2). This finding is consistent with historical comparisons of these streams.

**Table 5.2.2: Results of Tukey comparison of means test for conductivity**

| Site | Mean Conductivity (µS/cm) |
|---|---|
| BCK 12.3* | 938.9 |
| BCK 9.6† | 516.9 |
| MIK 0.1†‡ | 413.6 |
| EFK 23.4†‡ | 407.8 |
| EFK 13.8†‡ | 354.6 |
| BCK 4.5†‡ | 340.0 |
| MBK 1.6‡ | 234.3 |

**, †, ‡, 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 values were also evaluated from measurements collected July 2019 to June 2020. Mean values of dissolved oxygen ranged from 9.1 to 7.1 mg/L. East Fork Poplar Creek, site EFK (23.4), had the highest oxygen concentration among all sites. The ETTP Mitchell Branch site, MIK 0.1, had the lowest mean concentration of dissolved oxygen. In general, streams were quite similar in dissolved oxygen concentrations.

An ANOVA was performed to see if any significant differences exist among streams for dissolved oxygen concentrations. Results from the ANOVA indicated that no streams were statistically significantly different ($p < 0.05$) in dissolved oxygen concentrations. Mean dissolved oxygen concentrations for each site are shown below (Table 5.2.3).

**Table 5.2.3: Results of Tukey comparison of means test for dissolved oxygen**

| Site | Mean Dissolved Oxygen (mg/L) |
|---|---|
| EFK 23.4 | 9.1 |
| BCK 4.5 | 8.8 |
| MBK 1.6 | 8.8 |
| BCK 12.3 | 8.6 |
| BCK 9.6 | 8.5 |
| EFK 13.8 | 8.5 |
| MIK 0.1 | 7.1 |

Mitchell Branch (MIK 0.1) tends to have lower dissolved oxygen levels during the months of July through October, 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 23.4 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. Perhaps, in addition to water temperature, an oxygen demanding contaminant is loaded to Mitchell Branch from increased runoff during these hotter and wetter months. More research is needed to fully understand why Mitchell Branch tends to have these lower dissolved oxygen concentrations.

The field parameter of pH was analyzed for measurements collected July 2019 to June 2020. Mean pH values ranged from 7.87 to 7.56 among all sites. In Bear Creek, pH was slightly increased downstream with sites BCK 12.3, BCK 9.6, and BCK 4.5 having mean values of 7.58, 7.83, and 7.87, respectively. East Fork Poplar Creek was consistently 7.84 at EFK 23.4 and EFK 13.8. Mill Branch MBK 1.6 had a mean pH of 7.82 and Mitchell Branch MIK 0.1 had a mean pH of 7.56. An ANOVA and post hoc Tukey test indicated two distinct groupings. Site BCK 4.5 was significantly different than MIK 0.1. All other sites were not statistically different from one another in pH. (see Table 5.2.4).

**Table 5.2.4: Results of Tukey comparison of means test for pH**

| Site | Mean pH (Std. Unit) |
|---|---|
| BCK 4.5* | 7.87 |
| EFK 13.8*† | 7.84 |
| EFK 23.4*† | 7.84 |
| BCK 9.6*† | 7.83 |
| MBK 1.6*† | 7.82 |
| BCK 12.3*† | 7.58 |
| MIK 0.1† | 7.56 |

**, † 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.*

Lastly, temperature data were evaluated for all sites measured July 2019 to June 2020. Mean water temperatures ranged from 18.1 to 14.2 degrees Celsius 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 5.2.5).

**Table 5.2.5: Average water temperatures**

| Site | Mean Temperature (°C) |
|---|---|
| EFK 23.4 | 18.1 |
| EFK 13.8 | 16.8 |
| BCK 12.3 | 15.6 |
| MIK 0.1 | 15.6 |
| BCK 4.5 | 15.4 |
| BCK 9.6 | 15.0 |
| MBK 1.6 | 14.2 |

The above-mentioned field parameter data collected July 2019 to June 2020 were also analyzed in conjunction with data collected 2005 to 2019 (Figure 5.2.2).

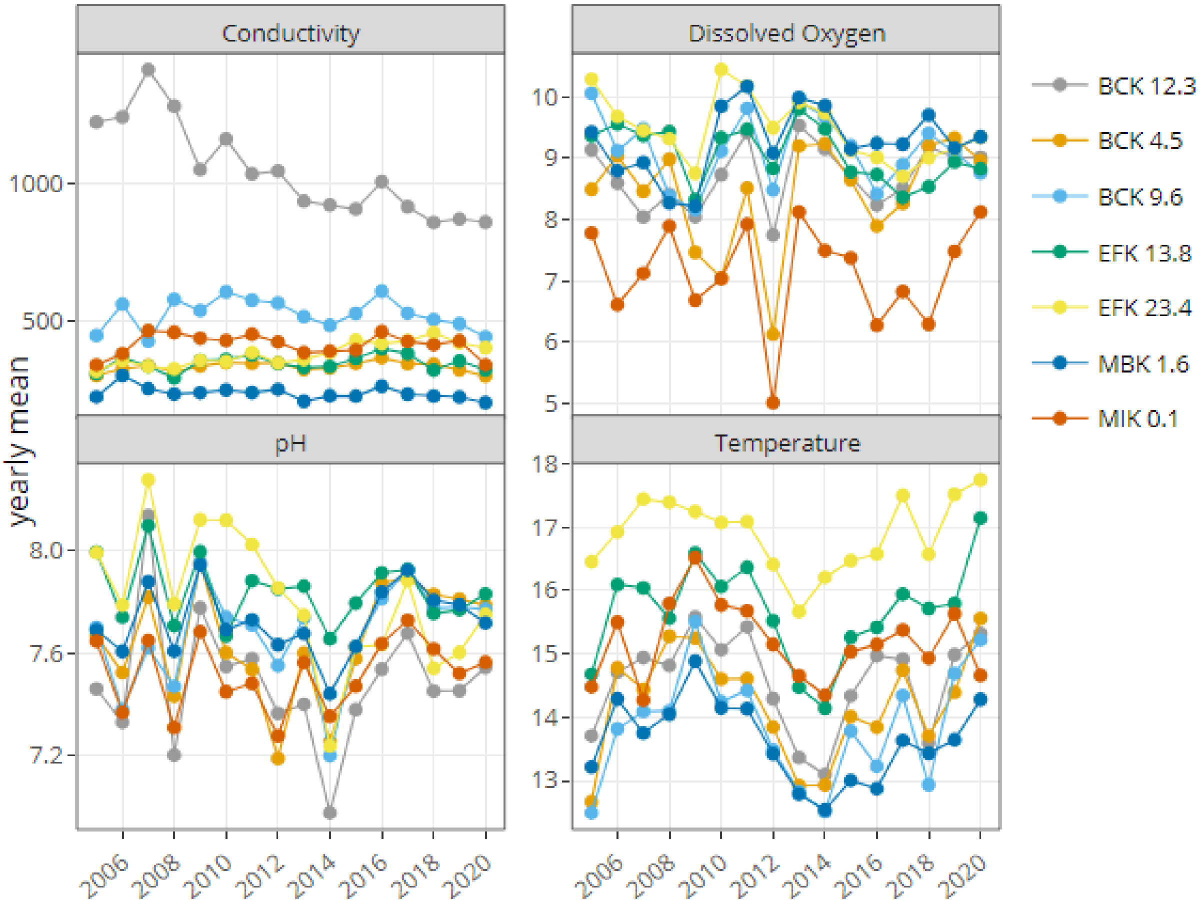

**Figure 5.2.3: Mean annual values for Conductivity, Dissolved Oxygen, pH, and Temperature from 2005 to the present for all sites. Units for conductivity, dissolved oxygen, pH, and temperature are μS/cm, mg/L, std. unit, and °C, respectively.**

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 four field parameters at three different stations.

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 0.787, 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 32 μS/cm annually. While a negative trend is found over all data from 2005 to the present, the last three years have been steady at around 860 μS/cm with little variance. Similarly, a statistically significant positive correlation was found with mean annual conductivity and time for EFK 23.4 with $p < 0.05$. The coefficient of determination ($R^2$) was 0.746, which indicates the regression fits the data well. This trend illustrates that conductivity has increased with time since 2005 for EFK 23.4. The slope of the regression line shows that this increase is occurring at roughly 8 μS/cm annually (Figure 5.2.4).

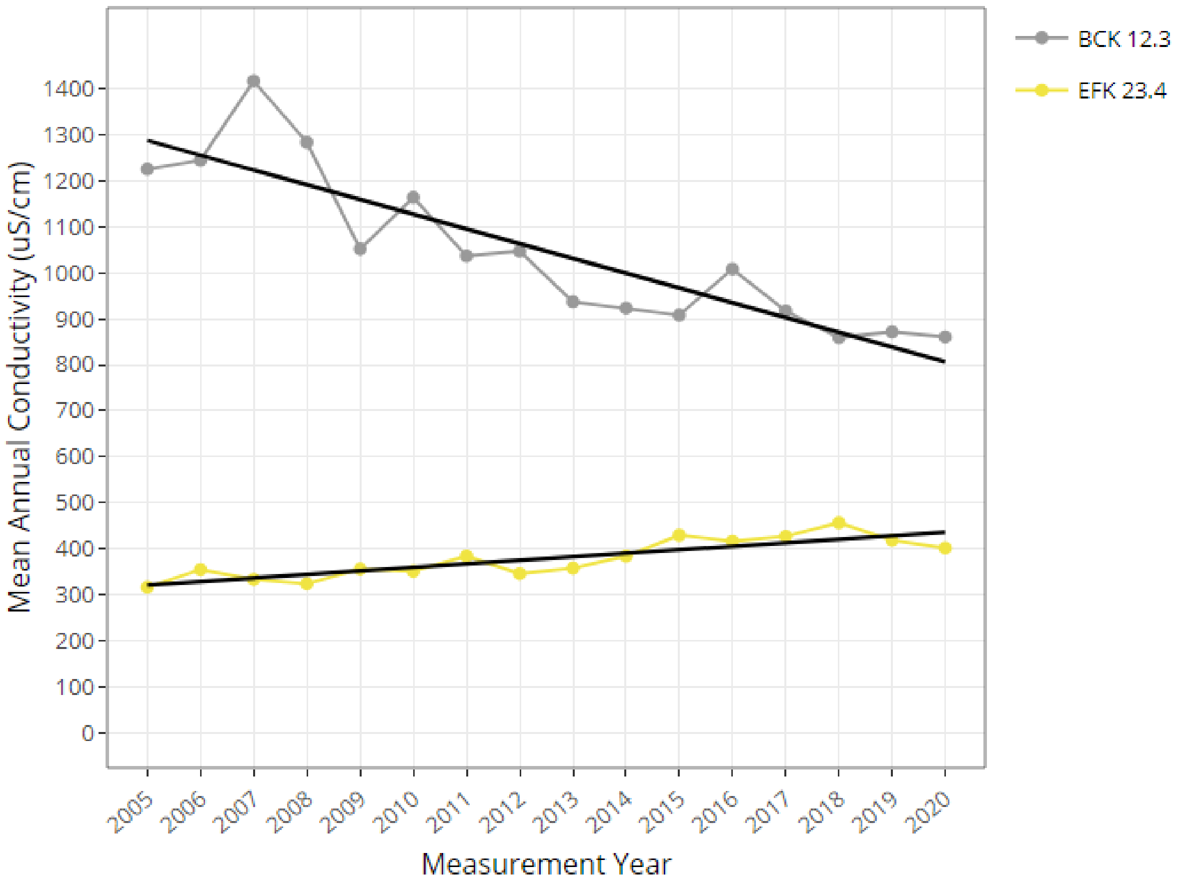

**Figure 5.2.4: Linear regression of mean annual conductivity with respect to time for sites Bear Creek (BCK 12.3) and East Fork Poplar Creek (EFK 23.4)**

A statistically significant negative correlation was found between mean annual dissolved oxygen and time for EFK 23.4. Site EFK 13.8 had a significant negative correlation between mean annual pH and time. The coefficient of determination ($R^2$) for these correlations were 0.269 and 0.340, respectively. Although these parameters are significantly correlated with time, the respective $R^2$ values represent relatively poor fits, indicating variability from the linear model (Figure 5.2.5).

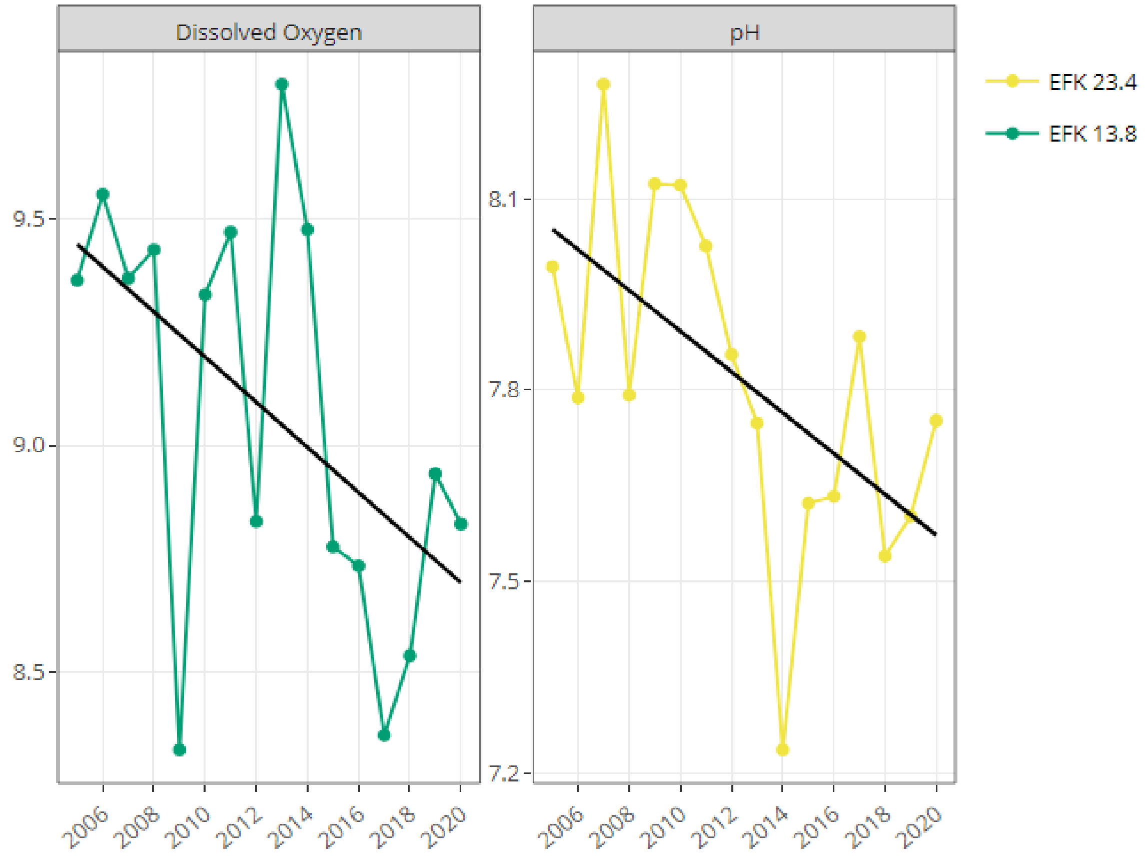

**Figure 5.2.5: Linear regression of mean annual values for Dissolved Oxygen (left) and pH (right) from 2005 to the present for EFK 23.4 (yellow) and EFK 13.8 (green). Units for dissolved oxygen and pH are mg/L and std. unit, respectively.**

### 5.2.8 Conclusions

Field parameters including conductivity, dissolved oxygen, pH, and temperature were collected monthly from the seven monitoring locations. These data serve to populate a database and baseline for surface water conditions for many streams in the ORR as well as to help assess impact of remediation efforts and identify accidental releases.

Of these measurements, all readings were within the State of Tennessee Water Quality Criteria (TDEC, 2019). While there is no existing State of Tennessee Water Quality Criteria for conductivity, Bear Creek site BCK 12.3 was found to be statistically significantly higher than all other streams. Despite this higher conductivity, historical data (2005-2020) suggests that BCK 12.3 has a predicted decreasing trend in conductivity of roughly 32 µS/cm annually. In all, this stream is still quite high in conductivity, but is decreasing with time. Recent years have shown no decrease in conductivity. 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 Security Complex which contained high concentrations of metals (e.g., calcium, magnesium, sodium, potassium, and aluminum) as well as high concentrations of trace metals (Brooks, 2001). The decrease in conductivity at BCK 12.3 since 2005 may be the result of attenuation of contaminant sources in the area of the S-3 ponds and the Y-12 West End Water Treatment Facility. On East Fork Poplar Creek, site EFK 23.4 has shown a steadily increasing trend of conductivity which is on average roughly 8 µS/cm annually. The reason(s) for this increase have not yet been determined.

### 5.2.9 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 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 23.4 and the downward trend of conductivity at Bear Creek site BCK 12.3.

### 5.2.10 References

DOE (1992). Federal Facility Agreement (FFA). Appendices for the Oak Ridge Reservation. Oak Ridge Site Description – UCOR, Appendix B (2017 revision). DOE/OR-1014. U. S. Department of Energy. Retrieved from http://www.ucor.com/docs/ffa/appendices/AppendixB.pdf

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Pickering, R. (1970). Composition of Water in Clinch River, Tennessee River, and White Oak Creek as Related to Disposal of Low-Level Radioactive Liquid Wastes. (Geological Survey Professional Paper No. 433–J). Retrieved from https://pubs.usgs.gov/pp/0433j/report.pdf

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TDEC (2019). Rules of The Tennessee Department of Environment and Conservation, General Water Quality Criteria. Retrieved from https://publications.tnsosfiles.com/rules/0400/0400-40/0400-40-03.20190911.pdf

Turner, R. R., & Southworth, G.R. (1999). Mercury-Contaminated Industrial and Mining Sites in North America: an Overview with Selected Case Studies. In R. Ebinhaus, R. R. Turner, L. D. de Lacerda, O. Vasilev, & W. Salomons (Eds.), Environmental Science: Mercury Contaminated Sites. Springer-Verlag.

## 5.3 RAIN EVENT

### 5.3.1 Background

Rainwater and groundwater are not static. They accumulate, pool, and enter basements, basins, and soil during excavations, D&D activities, and remedial actions (RA). Most of this water accumulation contains at least one contaminant that needs to be treated before it is discharged to the environment. DOE collects storm water samples for compliance with the National Pollutant Discharge Elimination System (NPDES) and collects samples at potentially affected areas before and during remedial activities. Beginning in 2018, DOE has created and operated treatment systems for the remediation of accumulated water. DoR-OR, in cooperation with DOE and its contractors, conducted random oversight of sampling activities at the treatment systems and of their storm water sampling program. In addition to performing sampling oversight, DoR-OR reviews the analytical results from the treatment systems provided by DOE. The overall goal of the program is to monitor DOE efforts in preventing contamination from leaving the Oak Ridge Reservation (ORR).

### 5.3.2 Problem Statements

- Contamination from legacy and ongoing activities can be disturbed and transported beyond the physical boundaries of the ORR by D&D or RA activities during a rain event.
- Water can accumulate in D&D or RA areas through entry into basins, sumps, basements, or during soil remediation activities. Accumulated water may become contaminated and dispersed into the environment.

### 5.3.3 Goals

The goal of this project is to obtain data to evaluate DOE’s remedial actions and D&D activities. This evaluation will help guide future cleanup decisions. Actions to achieve this goal follow:

- Monitor storm drains (SD) near remediation activities to gather data for the evaluation of D&D activities.
- Use split and or independent sampling to monitor releases into the environment.
- Observe sampling activities associated with D&D and RA activities.
- Review DOE sampling results.

### 5.3.4 Scope

The scope of this project is to assess, monitor, observe and analyze data pertaining to rain events and accumulated water treatment systems associated with DOE's remedial actions.

### 5.3.5 Methods, Materials, Metrics

Sampling of the treatment systems was conducted when the treatment systems had accumulated enough treated water for release. Sampling for the storm events follow basic guidelines of the EPA NPDES Storm Water Sampling Guidance Document (EPA 833-8-90-001 July 1992). The stormwater guidance which triggers monitoring is a 1" rainfall in a 24-hour period, preceded by at least 72 hours of dry weather. DOE contractors notified DoR-OR staff when a sampling event was taking place. If available, DoR-OR staff members conducted biased oversight of the sampling events using UCOR's *Surface Water Sampling _ Manual and Automated SOP Guidance* document as a reference.

Upon notification of a DOE sampling event, staff members gathered any necessary Personal Protective Equipment (PPE) and proceeded to the sampling area. If the sampling event was a rain event, DoR-OR agreed to find the contractor sampling team in the field, so that there was no delay to the contractor. Each sampling event observation was as close to the sampling point as possible, while avoiding any interference with the DOE sampling process.

The treatment systems at ETTP and Y-12 use holding tanks for the treated water until sampling and analysis is completed. During the observation of the treatment systems, if possible, observations were made from the catwalk of the tank. Following the guidelines presented in the *Surface Water Sampling _ Manual and Automated SOP* document, attention was paid to the order that samples were taken, sampling procedures, sampling tools and equipment used, and disposal of excess liquids.

If two DoR-OR staff members were present for oversight of DOE activities, one staff member would observe the sampling, while the other staff member would observe the transport, labeling, bagging and storage of the samples. If any action was observed to be a variance from the reference document, it was noted in the field book and a discussion was held with the field samplers before further action was taken.

At TDEC's request beginning in October 2019, DOE provided sampling results to TDEC for each treatment system and rain event sampling conducted to monitor CERCLA actions at ETTP. Results provided to TDEC for the treatment systems at ETTP were compared to the central neutralization facility (CNF) National Pollution Discharge Elimination System (NPDES) permit and State of Tennessee Ambient Water Quality Criteria (AWQC).

TDEC requested and received the sampling results from the Y-12 treatment system in early 2020. The provided sampling results covered the time frame from November 1, 2019 through January 27, 2020. These results were reviewed.

### 5.3.6 Deviations from the Plan

There were three situations that prohibited DoR-OR from making observations from the catwalk, DoR-OR arrived after sampling had begun, the health physicist was not comfortable with DoR-OR entering the work area, and certain tanks had a small catwalk which limited access to the sample point. During the sampling events where DoR-OR was not able to access the catwalk, a point was found that allowed DoR-OR to observe the sampling as close as possible.

Due to budget constraints TDEC was unable to conduct the planned split or independent sampling as outlined in the environmental monitoring plan.

### 5.3.7 Results and Analysis

Sampling of the Tc-99 treatment system began in May 2018. A total of 67 sampling events occurred between May 2018 and March 2020. TDEC did not begin observation of the sampling events until March 2019. Of the 67 total sampling events, TDEC observed ~13% of the events. Sampling at K-832 began in June 2019 and concluded in March 2020. Over this time frame, ~107 sampling events occurred. TDEC began observation of the sampling in August 2019. TDEC observed ~16% of the K-832 sampling events.

Within the storm sampling events, there were five storm sampling events reported by DOE for the third and fourth quarter 2019 and the first quarter of 2020. TDEC observed ~ 40% of these sampling events.

All provided sampling results from ETTP sampling events were reviewed against the Tennessee Code Annotated (TCA) Rule 0400-40-03 for the lowest discharge limits allowed. If a contaminant of concern is not listed in the TCA, the DOE discharge limit was used for review. Most of the contaminant analysis results were below their associated detection limits.

The contaminants of concern at the Tc-99 treatment system were Tc-99, mercury, hexavalent chrome and PCBs. Table 5.3.1 shows the highest reported results with applicable discharge limits.

**Table 5.3.1**

| | |
|---|---|
| **Tc-99** | |
| DOE Discharge Limit | 11000 pCi/L |
| Highest Reported Results | 42.8 pCi/L |
| **Mercury** | |
| Water & Organisms | 0.05 µg/L |
| Highest Reported Results | 0.00112 µg/L |
| **Hexavalent Chrome** | |
| Criterion Continuous Concentration | 11 µg/L |
| Highest Reported Results | Undetected |

PCB results throughout the sample period were reported as a U value (undetected value). Throughout all sampling the PCB detection limit was in the 0.03 µg/L range. The Water & Organisms Criteria and the Organisms Only Criteria limit is 0.00064 µg/L. Tennessee Code Annotated Rule 0400-40-03-.05(8) states "All chemical data reported under this rule shall be generated using "sufficiently sensitive" analytical methods approved under 40 C.F.R. part 136 (2018) or required under 40 C.F.R. chapter I, subchapter N or O (2018)." The EPA test method listed in 40 C.F.R. part 136 for PCBs is EPA-608.3, and this is the method that was used for sample analysis. While the detection limit was above the Water & Organisms Criteria and the Organisms Only Criteria limit, the criteria for 0400-40-03-.05(8) were met.

Contaminants of concern at the K-832 Treatment System were arsenic, chromium, mercury, and nickel. Table 5.3.2 shows the highest reported results with applicable discharge limits.

**Table 5.3.2**

| | |
|---|---|
| **Arsenic** | |
| Water & Organism | 10 µg/L |
| Highest Reported Results | 7.47 µg/L |
| **Chromium** | |
| Safe Drinking Water Act | 100 µg/L |
| Highest Reported Results | 3 µg/L |
| **Mercury** | |
| Water & Organism | 0.05 µg/L |
| Highest Reported Results | 0.0403 µg/L |
| **Nickel** | |
| Criterion Continuous Concentration | 52 µg/L |
| Highest Reported Results | 1.53 µg/L |

### 5.3.8 Conclusions

TDEC requested the Standard Operating Procedure (SOP) reference document used for the sampling events. Due to delays caused by the requested document going through the release protocol, TDEC received the document in March of 2020. After reviewing the reference document, TDEC reviewed trip reports and field logbooks for any discrepancy from the reference document. TDEC staff then began using the requirements in the provided SOP in its observations of the sampling events.

TDEC found no discrepancies from the SOP that samplers were working under.

During the period from July 31, 2019 to June 1, 2020, no areas of concern were noted during the observations of the sampling programs.

While the wide gap between the undetected PCB results and the Water & Organisms Criteria and the Organisms Only Criteria discharge limit is concerning, compliance with TCA regulations have been met.

### 5.3.9 Recommendations

TDEC found no exceedances in sampled rainwater or discharged accumulated water following treatment. As remedial activities continue and move to new locations on the ORR, there is the potential for negative impact on the environment from water that has accumulated in buildings or ponded in areas of contamination. TDEC recommends continued oversight of rain event and discharged water at locations at Y-12 and ORNL where contaminants and contaminant mobility issues may be variable.

### 5.3.10 References

UCOR Surface Water Sampling – Manual and Automated (2018) PROC-ES-2203

Rules of the Tennessee Department of Environment and Conservation. General Water Quality Criteria 0400-40-03

## 5.4 SURFACE WATER SAMPLING AT THE EMWMF

### 5.4.1 Background

The Environmental Management Waste Management Facility (EMWMF) was constructed for the disposal of low-level radioactive waste (LLRW) and hazardous waste (HW) generated by remedial activities on the Oak Ridge Reservation (ORR) and is operated under the authority of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). While the facility holds no permit from any state agency, it is required to comply with applicable or relevant and appropriate requirements contained in the CERCLA ROD (DOE, 1999) and substantive requirements of DOE directives developed to address responsibilities delegated to the agency by the Atomic Energy Act of 1946.

Currently, the only authorized discharge from EMWMF is contact water and uncontaminated storm water. Contact water is derived from precipitation that falls into an active cell, contacts waste and collects in the disposal cells above the leachate collection system. The contact water is routinely pumped from the disposal cells to holding ponds and tanks where it is then sampled. Based on the results, it is either treated or released to a storm water sedimentation basin which discharges to a tributary of Bear Creek known as North Tributary 5 (NT-5).

The EMWMF cells were designed with a 5% slope along the centerline of each disposal cell to direct storm water and leachate to the southern (lower) end of the cells (Williams, 2004). This design feature, along with the abundant rainfall in the region, and low porosity native soils used as a protective layer over the leachate collections system, resulted in excessive pooling of the contact water at the lower end of the cells (Williams, 2004). Heavy rainfall the first year of operations resulted in the storm water and associated leachate overflowing the cell berms, releasing contaminants to adjacent land, and into the NT-5 tributary. To avoid similar incidents, the allowable release limits at the contact water ponds were relaxed and the compliance point for radionuclides subsequently moved from the ponds/tanks to the discharge from the storm water sedimentation basin.

For radionuclides, the limits on releases from the holding ponds/tanks to the sedimentation basin are currently based on requirements contained in DOE Order 5400.5 which restricts the release of liquid wastes containing radionuclides to an average concentration equivalent to a dose of 100 mrem/year. The limit for discharges from the sedimentation basin to NT-5 are based on state regulation (TDEC 0400-20-11-.16{2}) restricting concentrations of radioactive material released from LLRW disposal facilities to the general environment in groundwater, surface water, air, soil, plants, or animals to an annual dose equivalent of 25 mrem/year. Neither dose limit is currently considered protective under CERCLA, based on EPA guidance in OSWER Directive 9285.6-20 (June 13, 2014). The issue is currently being addressed as a part of an FFA dispute on the related Focused Feasibility Study (FFS) for *Water Management for the Disposal of CERCLA Waste on the Oak Ridge Reservation, Oak Ridge, Tennessee* (DOE/OR/01-2664&D2).

For contaminants other than radionuclides, the point of compliance is the contact water ponds, where Tennessee ambient water quality criteria (AWQC) for fish and wildlife has served as the limit for the releases of contact water to the sediment basin and via the basin to Bear Creek through NT-5. Bear Creek's designated uses currently include recreational, which has not been incorporated into the EMWMF release criteria. This issue is also being addressed as part of the FFA dispute on the FFS for Water Management for the Disposal of CERCLA Waste cited above.

### 5.4.2 Problem Statements

Contaminated materials from CERCLA remediation activities are buried and continue to be buried in the EMWMF. Over time, associated mobile contaminants have the potential to migrate from the facility into the environment and be carried by ground and surface waters to off-site locations in concentrations above agreed upon limits.

### 5.4.3 Goals

The Surface Water Monitoring of the EMWMF Project aims to accomplish the following goals.

- To provide assurance through the independent monitoring efforts and evaluation of DOE's data that operations at EMWMF are protective of public health and the environment and meet the remedial actions objectives specified in the EMWMF ROD.
- To verify that DOE discharges into Bear Creek of contaminated storm water (i.e. storm water that has contacted waste and has not been treated), comply with the established limits and operational requirements.
- To provide independent data on discharges from the underdrain and to evaluate its effectiveness in lowering the groundwater table under the landfill.

- To ensure EMWMF is meeting its operational requirements, discharge data collected by EMWMF will be reviewed, quarterly.
- DoR-OR will collect confirmation samples to ensure best practices are used to limit contaminant migration, site visits will be performed to monitor ongoing activities at EMWMF.

### 5.4.4 Scope

The Surface Water Monitoring of the EMWMF Project proposed each of the following tasks.

- Staff will monitor parameters at the EMWMF-2 (underdrain discharge) and EMWMF-3 (Sediment Basin v-weir discharge) sites at least twice weekly with the use of a YSI-Professional Plus water quality instrument or equivalent.
- To ensure contaminants from the cell are not adversely affecting the surrounding environment, water samples will be collected on a routine basis from select sites (Table 5.4.1).
- Sediment samples will be collected from the sediment basin when the bottom is dry and firm (there is no or little water in the sediment basin). These samples will be composited into one sample for analysis.
- Discharge data from EMWMF-2 and EMWMF-3 is measured by DOE on a routine schedule. To ensure EMWMF is meeting its operational requirements TDEC-DoR-OR will review the discharge data received from DOE, quarterly.
- TDEC will collect confirmation samples as referenced by Table 5.4.1 and Figure 5.4.1
- Samples will be collected from the weirs (EMWMF-2 monthly and EMWMF-3 quarterly) as referenced by Figure 5.4.1
- DOE collects samples quarterly from EMWMF-1 (GW-918) and DoR-OR will analyze the samples, received from DOE, semiannually.
- EMWMF-4B will be sampled and analyzed semi-annually.

Table 5.4.1 and Figure 5.4.1 depict monitoring and sampling locations and sample rationale at the EMWMF.

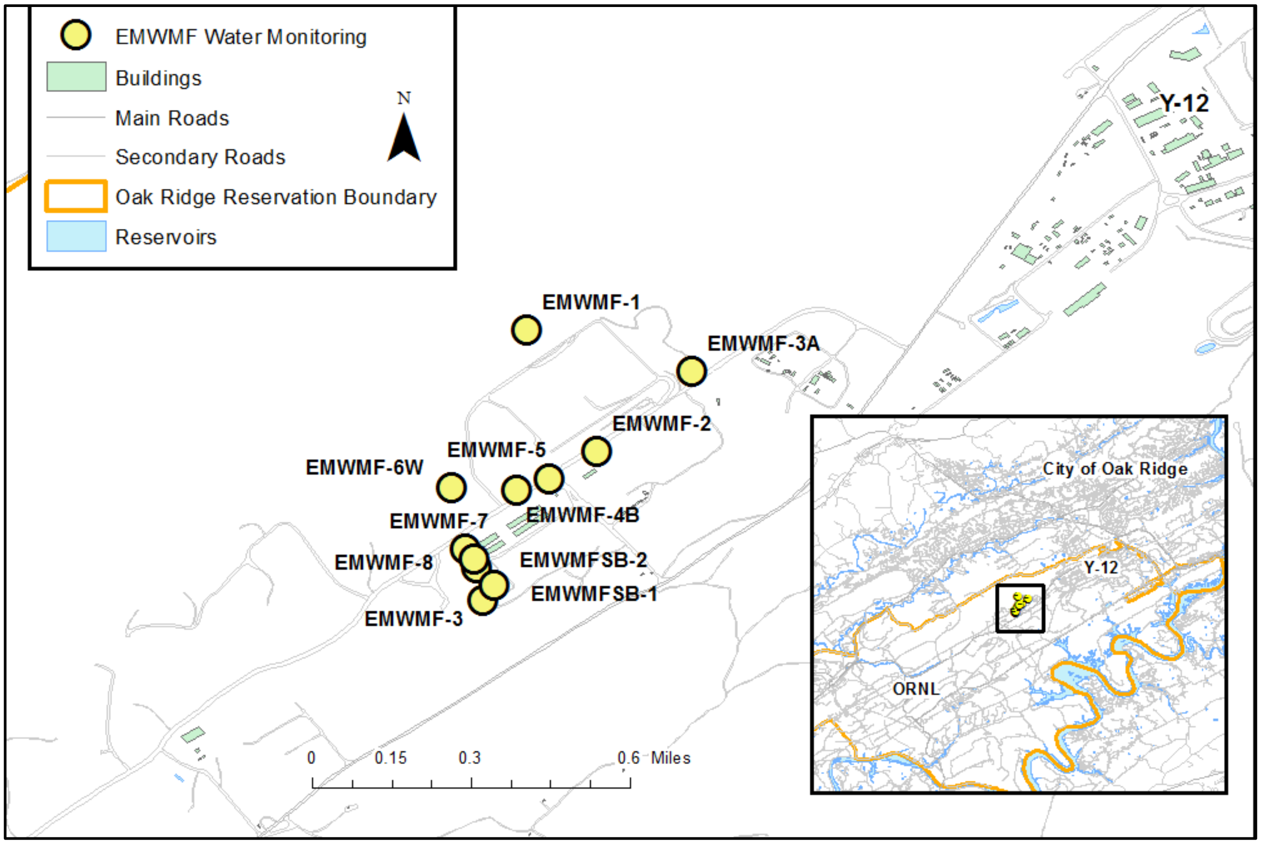


**Figure 5.4.1: Proposed EMWMF Sampling and Monitoring Locations**

**Table 5.4.1: Proposed EMWMF Sampling and Monitoring Locations**

| Station | Sample ID | Frequency | Sampling Rationale |
|---|---|---|---|
| **GW-918** | EMWMF-1 | SemiAnnually | Upgradient well linked to a spring. The spring is the headwaters for both NT-4. This sample is co-sampled with the EMWMF personnel for quality control. |
| **EMWMF Underdrain** | EMWMF-2 | Monthly | NT-4 discharge below the landfill. The underdrain was installed below Cell 3 and it is theorized that if cells 1, 2, and 3 were to leak contaminants, they would first be observed at the underdrain. |
| **Sediment Basin Effluents** | EMWMF-3 | Quarterly | Provides confirmation of contaminant levels being discharged froom the sediment basin. |
| **Sedimentation Basin Sediment** | EMWMFSB-1,<br>EMWMFSB-2 | Annually | This location is only sampled when the sediment basin is dry. The results are used to observe the loading of radionuclides in the sediment of the basin. |
| **Cell 6 Drainage** | EMWMF-4B | SemiAnnually | This location is used as a verification that water collected in Cell 6 (prior to waste placement) is storm water. |

GW - groundwater
EMWMF - Environmental Management Waste Management Facility
NT - North Tributary

## 5.4.5 Methods, Materials, Metrics

### Methods – Field

Twice per week, the Project Lead performed independent monitoring (check and record water quality parameters and sites) shown on Figure 5.4.1.

Water samples (from the locations identified in Table 5.4.1 and Figure 5.4.1) were to be collected in accordance with the Project Plan.

To assess compliance with the radiological limits placed on the outfall of the sedimentation basin, samples will be taken from the discharge from the v-weir at the basin (EMWMF-3), quarterly.

The first results and analysis section, DOE charts for EMWMF-2 and EMWMF-3, focuses on radionuclides that have historically contributed the most to the annual dose quarterly limits for each discharge location.

The second results and analysis section, TDEC charts for EMWMF-2 and EMWMF-3, evaluates the performance of the landfill liner by monitoring parameters and analysis of samples collected from the underdrain (EMWMF-2).

EMWMF-1 (GW-918) was to be co-sampled with DOE as a background well.

Sediment samples are typically collected from the sediment basin during the fall when there is less precipitation and the bottom of the basin is dry and safe to sample.

Groundwater and sediment sampling will follow *TDEC DoR Quality Assurance Project Plan* (2015) and the *Sampling and Analysis Plan* (2016).

**Methods: Lab Methods**

The Tennessee Department of Health Laboratory uses EPA methods for sample analysis. The requested analytical methods for this project are listed below in Table 5.4.2:

**Table 5.4.2: Lab Methods and Analyses**

| Method Designation (EPA method) | Test Name | Analytes |
|---|---|---|
| Method 200.7 | ICP-OES | Metals |
| Method 200.8 | ICP-MS | Metals |
| Method 1631 | Low Level Mercury | Mercury |
| Method 8260B | GC/MS | Volatile Organic Compounds |
| Method 901.1 | Gamma water | Gamma radiation |
| Method ENV-Rad-SOP-401-R.1.3 | Gross Alpha-Beta water by LSC | Gross alpha-beta activity |
| Method 905.0 | Sr-89-90 water | Strontium 89-90 |
| Eichrom Method TCW02 | Technetium-99 water | Technetium-99 |
| Method 906.0 | Tritium water | Tritium |

The results of laboratory analyses were entered into an Excel database for interpretation. Interpretation included construction of tables and graphs illustrating ranges and limits of constituents over the course of the project. Included on the graphs are pertinent water quality criteria from the EPA and TDEC.

### 5.4.6 Deviations from the Plan

**Parameter monitoring and observation visits missed**

Certain weeks there were only one or no monitoring events were completed. This was due to unavoidable schedule changes, changes in priorities, weather, and an addition of a Radiological Work Plan (RWP) at the end of May that requires a Radiation Protection Technician be there to watch and to measure radiological activity from instruments and workers that may come into contact with groundwater or surface water during monitoring at the EMWMF.

**Change in priorities due to loss of sampling budget**

Changes in grant amounts for laboratory analyses forced a reevaluation of locations to sample for analysis.

- Water from GW-918 was not analyzed,
- EMWMF-2 was not sampled,
- EMWMF-3 was not sampled,
- NT-3A was not sampled and,
- Cell 6 (EMWMF-4B) Drainage was not sampled

## 5.4.7 Results and Analysis

### 5.4.7.1 DOE Data -Charts for EMWMF-2 (Underdrain) and EMWMF-3 (V-Wier)

DOE samples and analyzes samples collected from wells, pipes, streams, ponds, tanks and air as part of its written, accepted monitoring requirements. Most sampling is conducted in monthly, quarterly, annual and biennial time periods. Of main interest in this report are samples collected for analysis from two discharge point locations, one surface water and one groundwater. Those sampling points are identified as EMW-VWEIR and EMW-VWUNDRDRAIN, respectively. TDEC uses an alias for these two points, EMW-VWUNDRDRAIN is known in this report as EMWMF-2, (Underdrain), and EMW-VWEIR is known as EMWMF-3 (V-Weir).

DOE's contaminants of concern (COCs) vary for each sampling event depending on the data usage requirements. Fourteen wells are sampled quarterly for "Key COCs": metals, mercury, cyanide, selected anions, pesticides, and isotopic radionuclides consisting of iodine-129, strontium-90, technetium-99, tritium, uranium-233/234, uranium-235/236, and uranium-238. Annually the wells are sampled and analyzed for "Extended COCs" which include volatile organic compounds, along with benzoic acid, five more metals, PCBs, dioxin, and additional radionuclides (carbon-14, cesium-137, chlorine-36, radium-226, and thorium-230). The well samples are analyzed every other year (biennially) for additional analytes – "All COCs": the

EPA 8260 list of 36 compounds, EPA's 8270 list of 45 semi-volatile analytes, 32 metals, PCBs, mercury, 21 pesticides, two herbicides, cyanide, propylene glycol, methanol, dioxin, and 45 radioisotopes.

EMWMF-3, EMWNT-03B, EMWNT-05, the Contact Water Ponds 1 through 4, and the Contact Water Tanks A through D follow the same sampling and analysis regimen as above for annual and biennial samplings. EMWMF-2 is collected bi-monthly; EMWNT-03B and EMWNT-05 are collected quarterly for key COCs. The Contact Water Ponds, and Contact Water Tanks are analyzed for key COCs prior to each release. The details of the analytes and the schedule are delineated in the *Sampling and Analysis Plan/Quality Assurance Project Plan for Environmental Monitoring at the Environmental Management Waste Management Facility, Oak Ridge, Tennessee,* DOE/OR/01-2734&D1/R1.

### DOE Analysis Metals Results Discussion

EMWMF-2 (or EM-VWUNDRDRAIN) is the point of emergence of a drain designed to mitigate groundwater impingement in the geologic buffer underneath landfill cells 2 and 3. EMWMF-2 was built in late 2003 and early 2004. A look at some selected metals is shown in Figures 5.4.2 and 5.4.3. In the first graph, magnesium, sodium, and barium are all slightly increasing in concentration since 2014. Aluminum, barium and iron after early fluctuations are holding steady. Strontium continues to fluctuate but there does seem to be a slight increase over time.

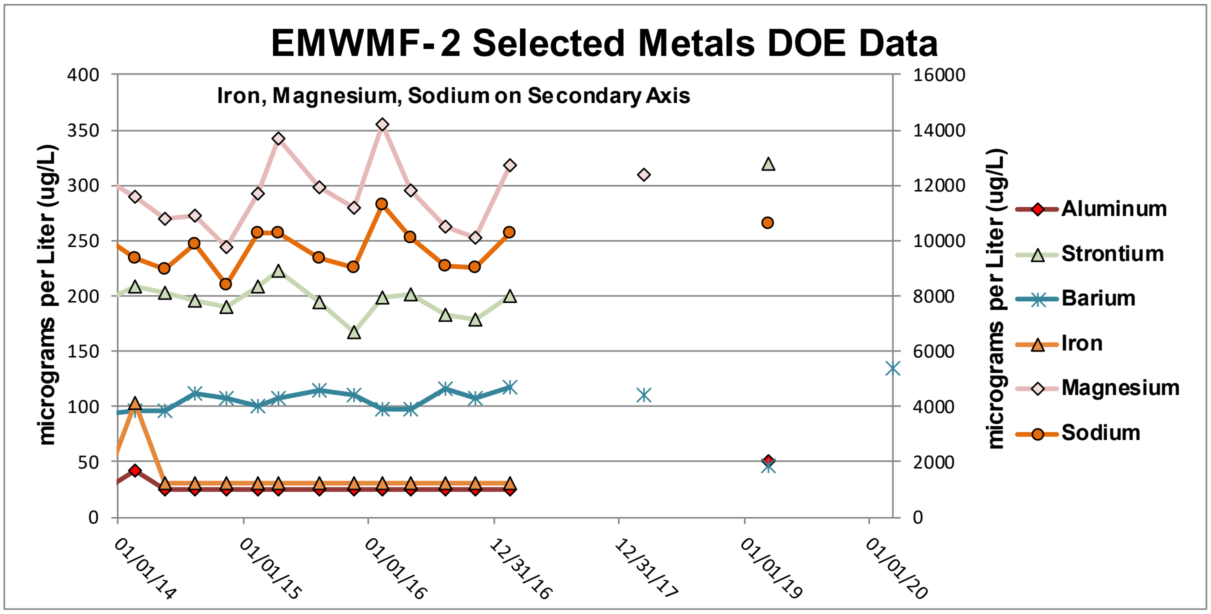


**Figure 5.4.2: EMWMF-2 Selected Metals DOE Data**

Figure 5.4.3 graphs selected metals with lower concentrations: antimony, arsenic, boron, cadmium, vanadium, and zinc. Metals not detected in the analyses are beryllium, chromium, cobalt, lead, lithium, mercury, nickel, and uranium. Metals detected but not graphed are calcium, potassium, and manganese, because they all have large concentrations and are commonly found in soils. All analytes with the exceptions of zinc and boron have become steady. Boron continues to fluctuate in concentration and the trend is steady. Zinc, after settling down, spiked in March 2019 at 105 µg/L. The level of zinc measured in March 2019 is below the Tennessee Ambient Water Quality Criteria and the EPA's criteria (120 µg/L) also. Antimony and arsenic have increased for one sampling event each in 2018. This will need to be watched further in the future.

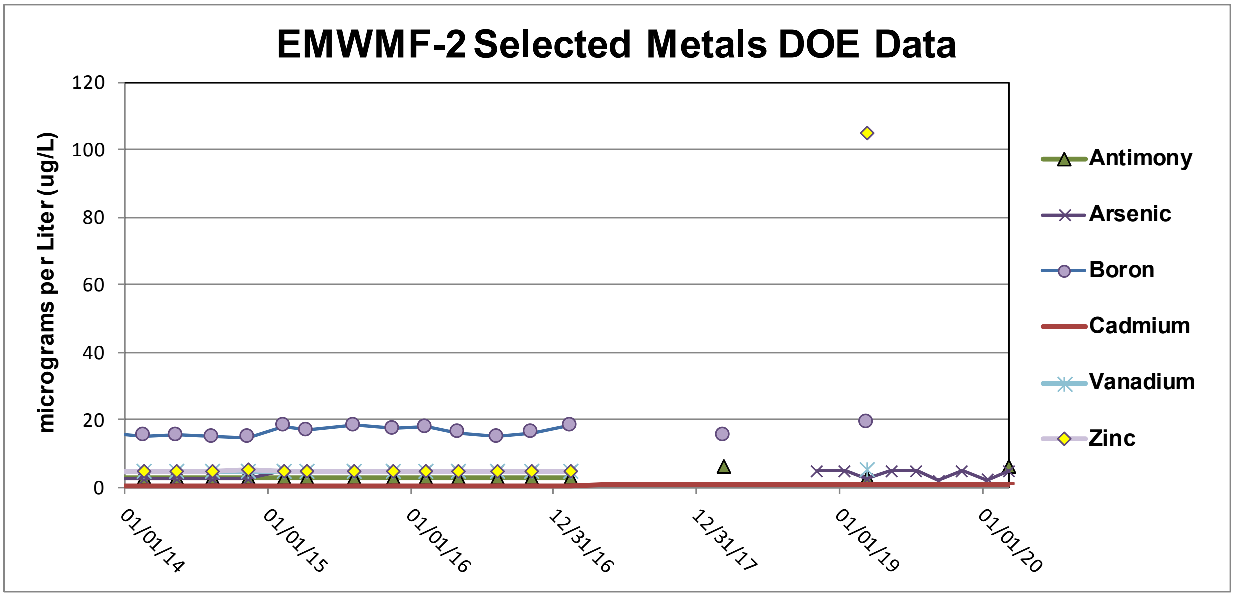


**Figure 5.4.3: EMWMF-2 Selected Metals DOE Data**

The water that reaches the sediment basin consists of water discharged from the contact water ponds, the contact water tanks and what is known as clean stormwater. During storm events, rainwater that falls on the enhanced cover over Cells 1, 2, and 3 is directed straight to the sediment basin by unlined ditches. Water that collects in the clean area of Cell 6 is also discharged to the sediment basin after analysis. All the storm water mixes with the discharged water from the tanks and ponds before flowing into NT-5 and then into Bear Creek. The location that is sampled is named by DOE as EM-VWEIR. TDEC uses the name EMWMF-3.

Four charts below show the relationships between EMWMF-3 selected metals (Figures 5.4.4 through 5.4.7). Metals analysis results with no detectable concentrations are not presented. They are cadmium, cobalt, hafnium, lithium, selenium, silver, thallium and tin. The figures are split into ranges of concentration to better illustrate the make-up of the water being discharged from the sediment basin. Figure 5.4.4 illustrates metals with large concentrations, aluminum, calcium, sodium and iron. All four of these analytes routinely come from the breakdown of soil and rock by percolating water. Calcium is also a component of concrete and the demolition of buildings and slabs at ETTP has increased the amount of concrete and therefore the calcium in the waste cells. Figure 5.4.5 illustrates those metals with concentrations between 200 and 14,000 µg/L. Potassium and magnesium have increased in the samples collected after the start of calendar year 2012 and continue to this day. Figure 5.4.6 shows metal with concentrations less than 30 µg/L. All the metals (in this chart) are somewhat attenuated with the exception of uranium and zinc. Figure 5.4.7 depicts those metals with concentrations less than 18 µg/L. These metals have smaller concentrations, but, as seen, nickel, uranium and vanadium jumped in 2018 along with chromium.

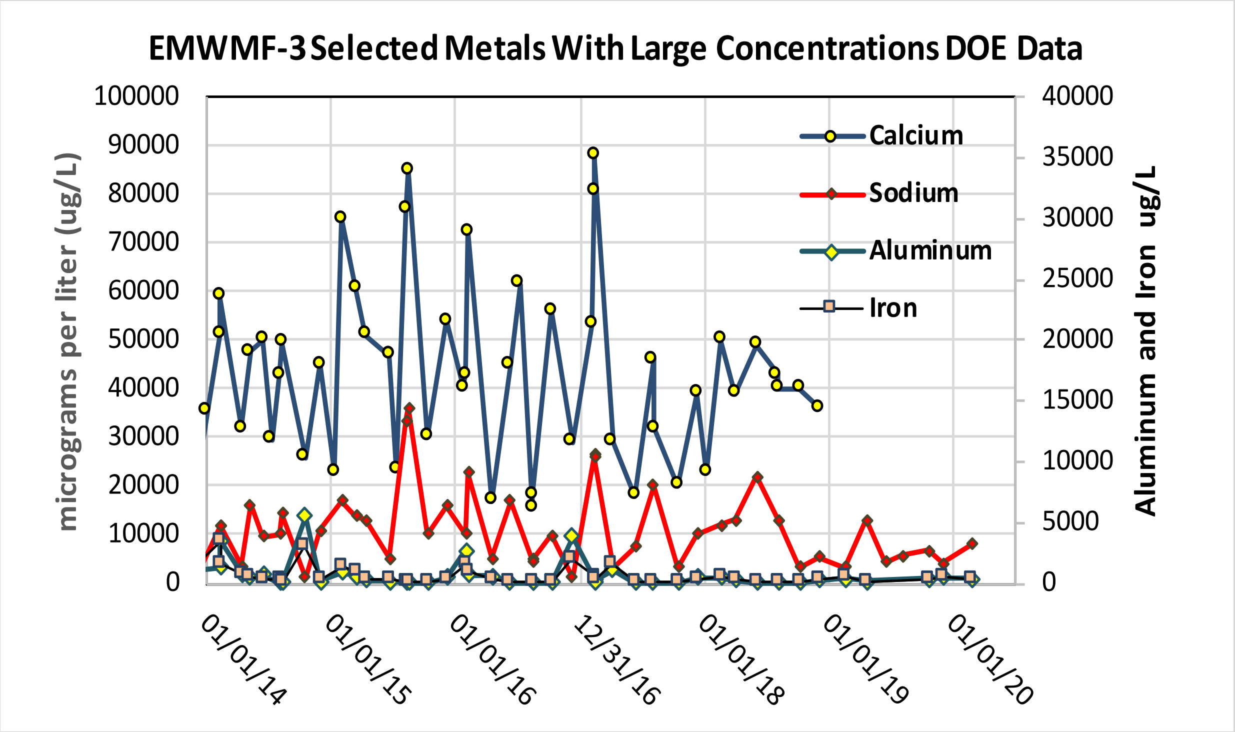


**Figure 5.4.4: EMWMF-3 Selected Metals with Large Concentrations**

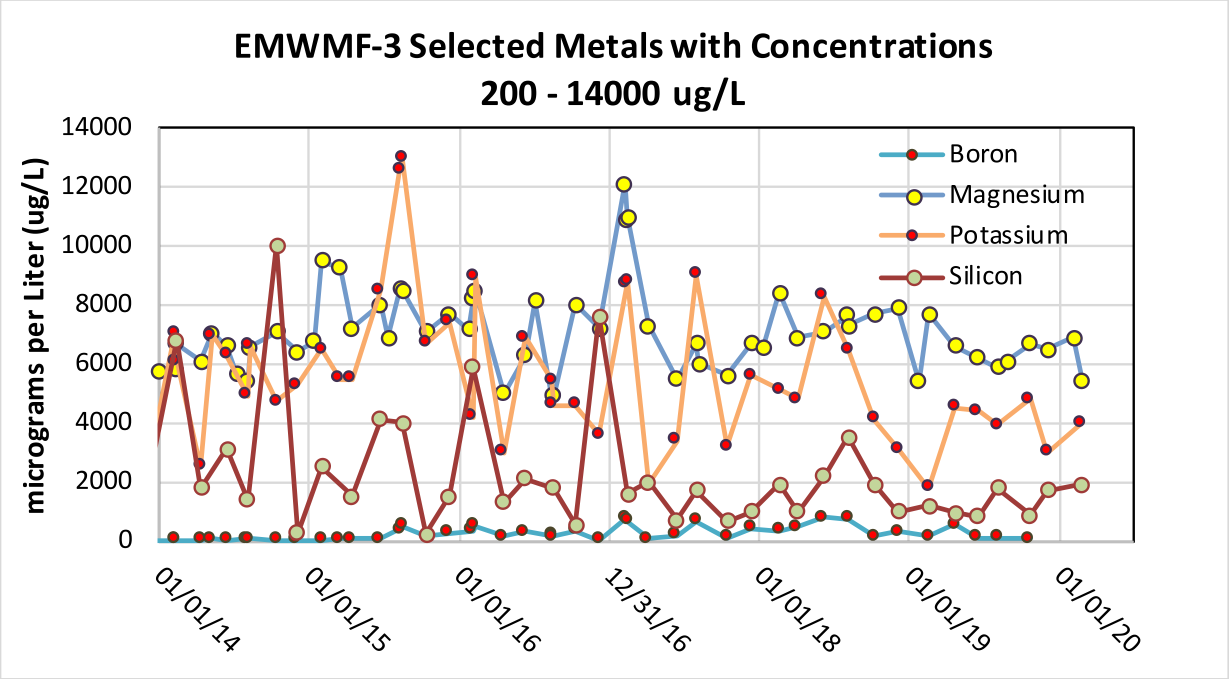


Figure 5.4.5: EMWMF-3 Selected Metals with Concentrations between 200 and 14000 µg/L

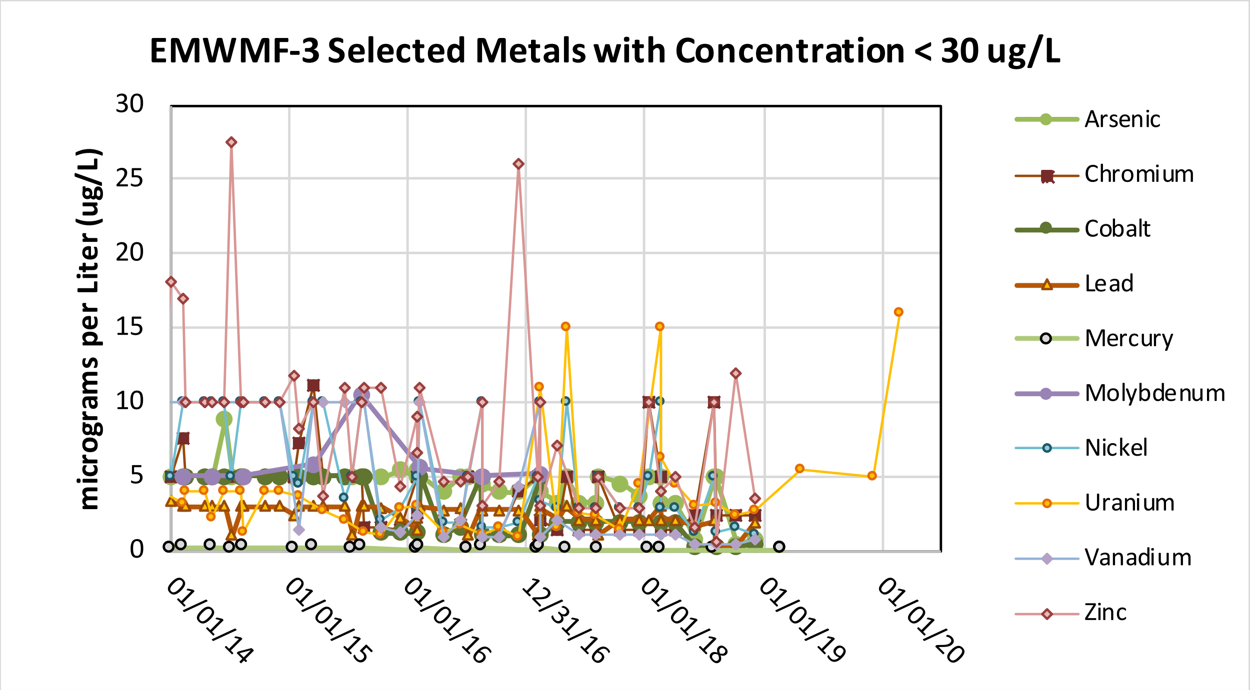


Figure 5.4.6: EMWMF-3 Selected Metals with Concentrations Less Than 30 µg/L

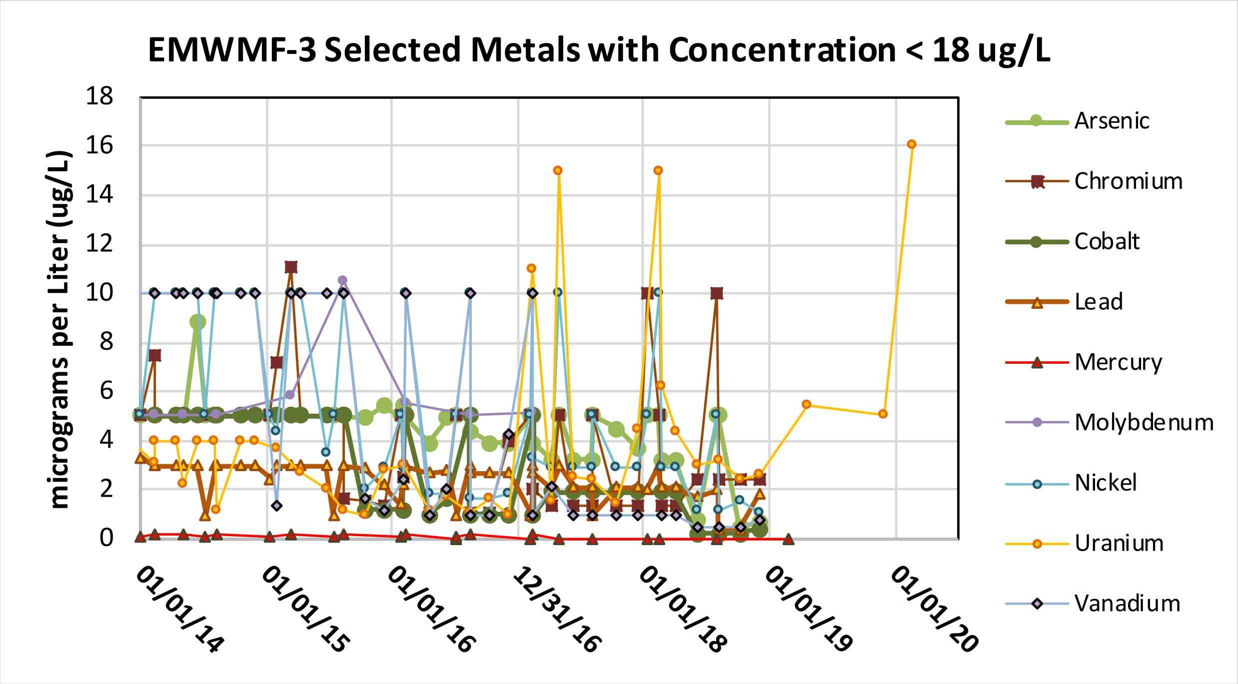


**Figure 5.4.7: EMWMF-3 Selected Metals with Concentrations Less Than 18 µg/L**

### DOE Analysis Radionuclide Results Discussion

Figures 5.4.8 through 5.4.14 depict radionuclide activities in water from EMWMF-2 from March 2004 to March 2020. The four graphs are for isotopic uranium activity (Figure 5.4.8 through 5.4.10), iodine-129, technetium-99, (Figure 5.4.11), strontium-90, and yttrium-90 (Figure 5.4.12) and alpha and beta activity (Figure 5.4.13). The first three graphs show the activities of isotopic uranium; uranium-233/234, uranium-235/236, and uranium-238. All three uranium isotopes are slowly increasing in activity. The activity levels are small and the project quantification level (PQL) as identified in the EMWMF SAP/QAPP {2016&2017) is 0.5 picoCuries per Liter (pCi/L). The detection limits of the analyses are also graphed in the above figures. Instead of using the radiological analytical error to determine the efficacy of the analysis the detection limits of the analysis are used. Numbers above the detection limit (DL) are considered to be real. Many of the later uranium 233/234 results are above its DL. Some of the uranium-235/236 and uranium-238 later results are above their DL. uranium-233/234 and uranium 235/236 are already above the PQL and the last several uranium-238 results are also. It is unclear what is causing the elevated activities therefore, further monitoring is warranted.

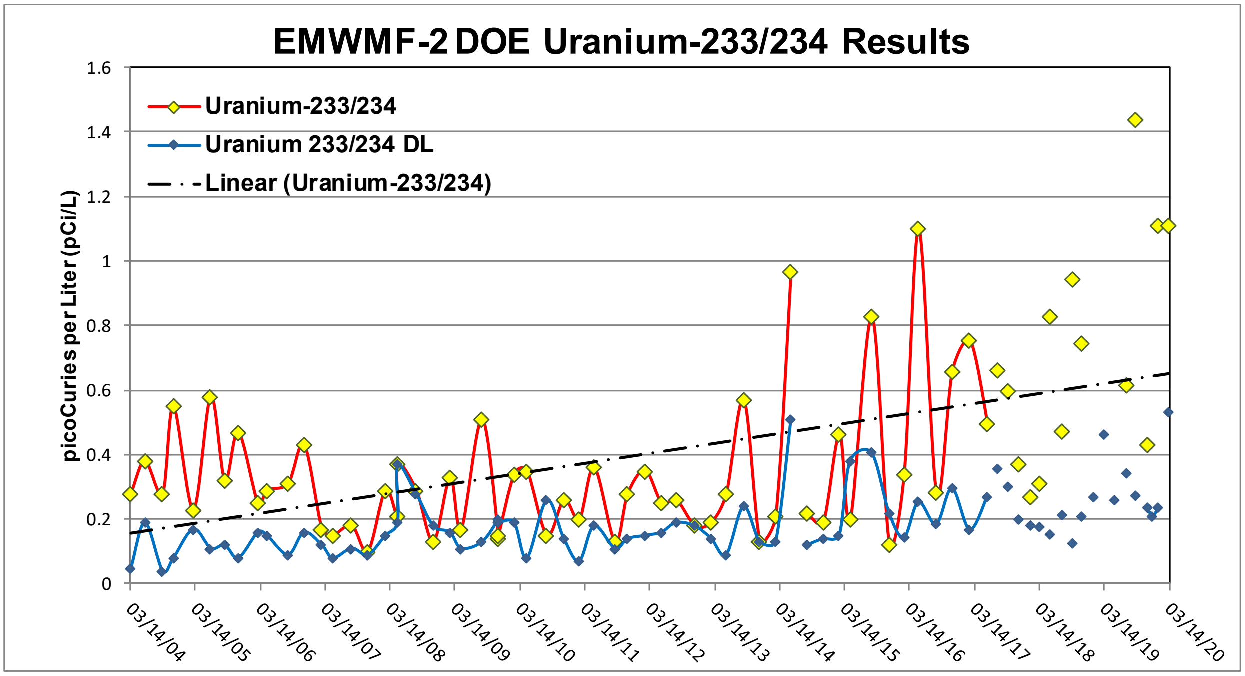


Figure 5.4.8: EMWMF-2 DOE Uranium-233/234 Results

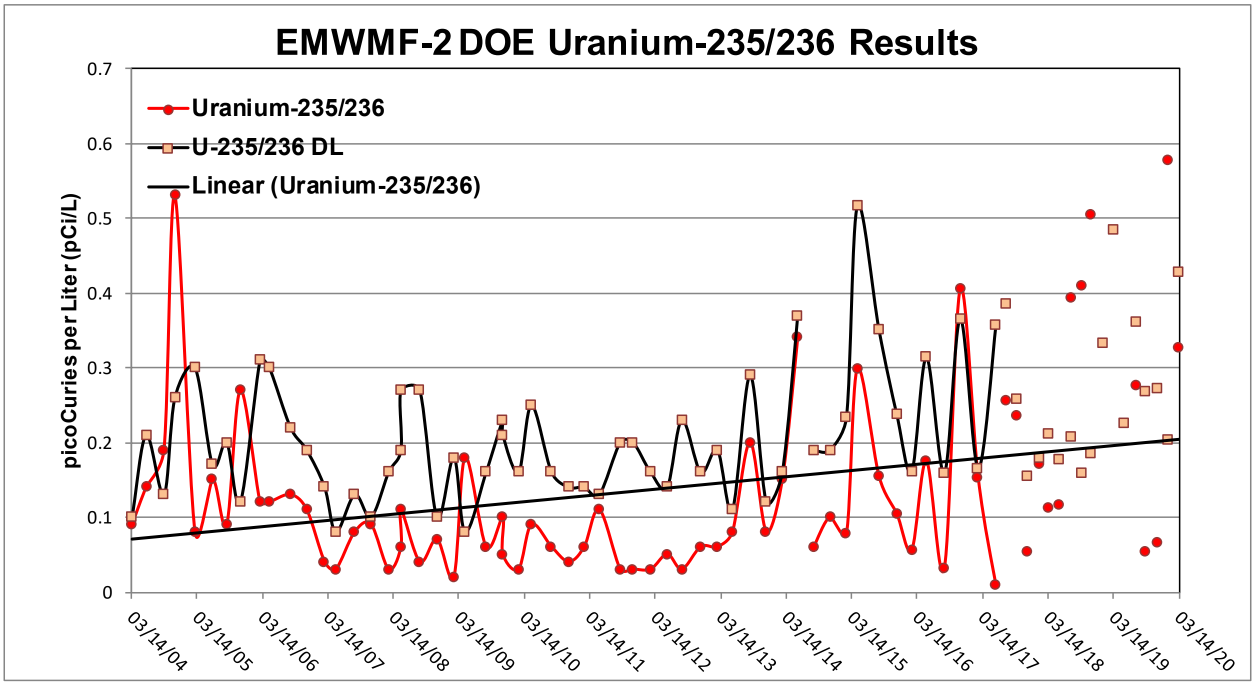


Figure 5.4.9: EMWMF-2 DOE Uranium-235/236 Results

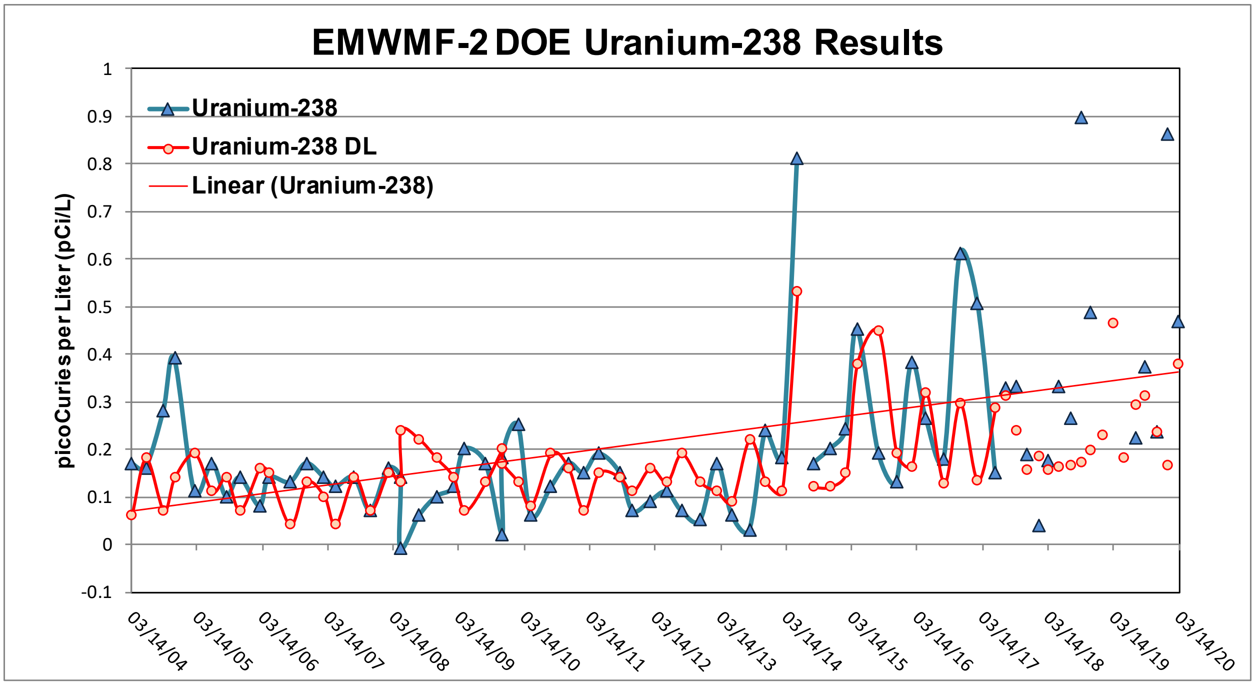


**Figure 5.4.10: EMWMF-2 DOE Uranium-238 Results**

Figure 5.4.11 shows activities of selected radionuclides, iodine-129, and technetium-99. The iodine numbers are steady, but the technetium-99 activities are increasing since 2014. The DLs for the Iodine-129 analyses are mostly below the measured activities, and the DLs for technetium-99 are well below the measured activities since mid-2018. The PQL for technetium-99 is 5 pCi/L and the detections have not reached that number, but the trend indicates that it might within 2 years. Figure 5.4.12 strontium and yttrium show an increasing trend as well. The PQL for strontium-90 is 2 pCi/L and the trend is increasing but could flatten out below the PQL. The DL for the yttrium is consistently above the measured activity illustrating that the yttrium activity measurements are not actual. The DLs for the strontium activities are equal to or below the activities until mid-2019. Then the DLs are above the strontium activities measured.

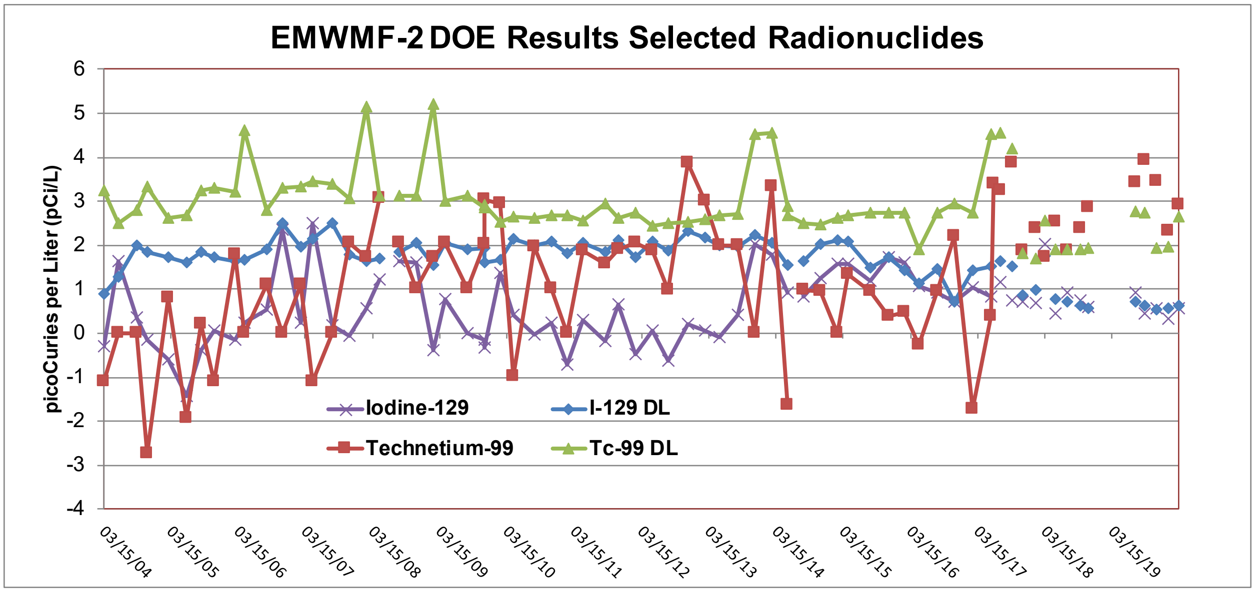


**Figure 5.4.7.11: EMWMF-2 DOE Results Selected Radionuclides**

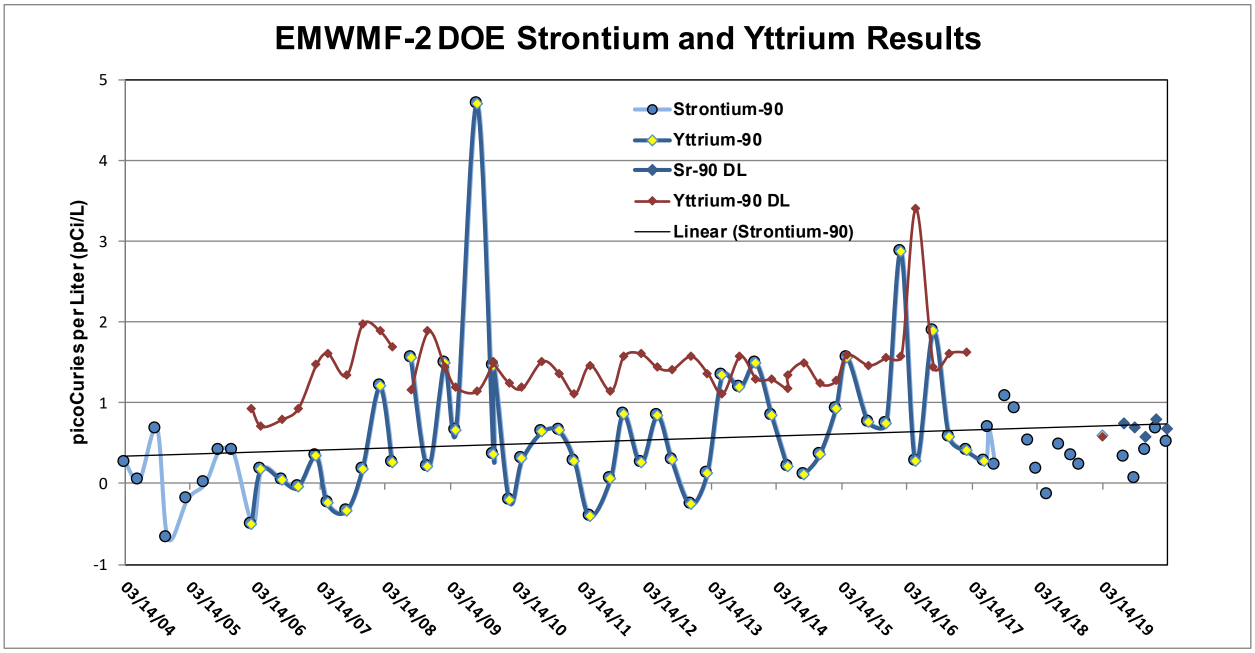


**Figure 5.4.7.12: EMWMF-2 DOE Strontium-90 and Yttrium-90 Results**

Figure 5.4.13 shows the measurements of alpha and beta activities beginning in May 2017. Measuring alpha and beta activities are new additions to the sampling at EMWMF. The beta activity is seeming to be increasing as there is more technetium-99 being placed in the landfill. The alpha activity is somewhat steady but there is an amount of fluctuation with a definite downturn in 2019.

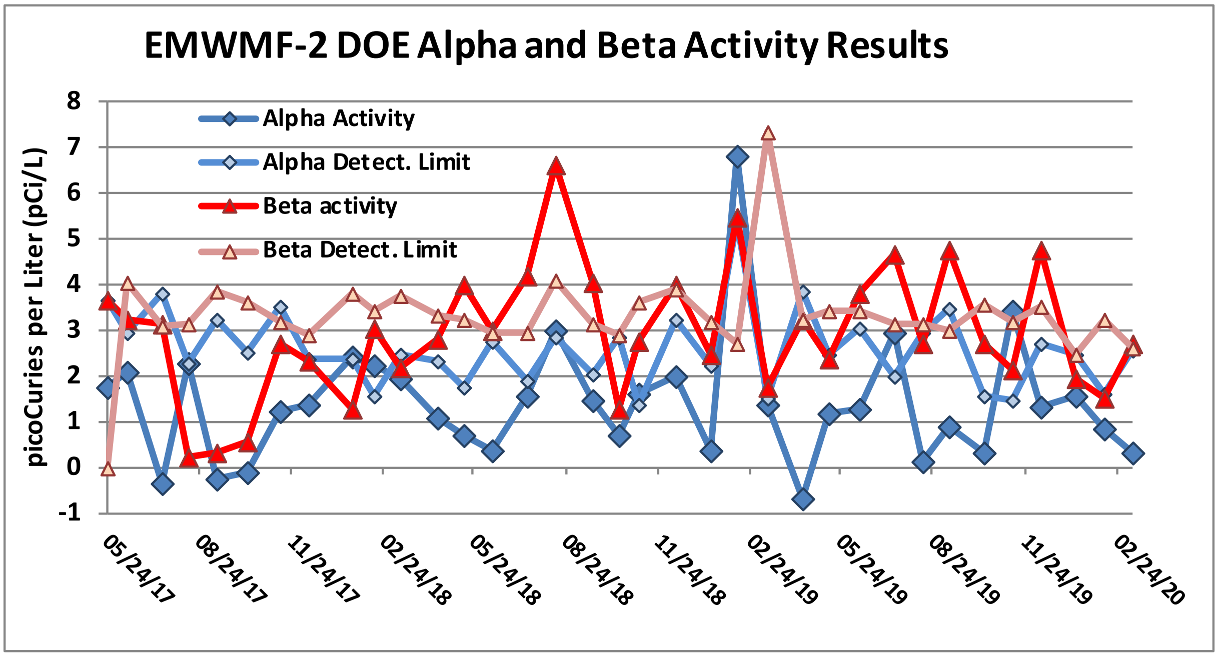


Figure 5.4.13: EMWMF-2 DOE Alpha and Beta Activity Results

Figure 5.4.14 illustrates the comparison between well GW-918 and EMWMF-2 (EM-WVUNDRDRAIN) for isotopes of uranium (233/234, 235/236, and 238).

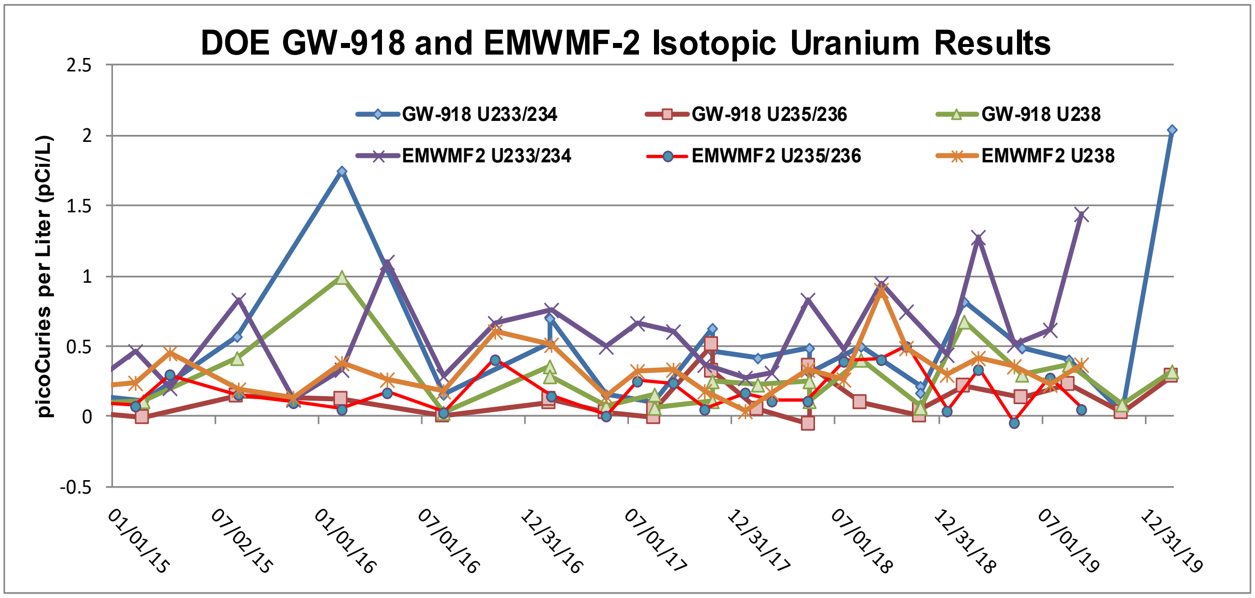


Figure 5.4.14: GW-918 and EMWMF-2 DOE Isotopic Uranium Results

Figures 5.4.15 to Figure 5.4.17 illustrate the radionuclides analyzed by DOE of the effluent from the Sediment Basin. The monitoring station is named EMW-VWEIR by DOE and EMWMF-3 (VWEIR) by TDEC. Continuous sampling at EMWMF-3 began in August of 2002 until the present.

Figure 5.4.15 is a graph of carbon-14, and alpha and beta activity. Beta activity varies a bit (10 to 100 pCi/L) with several outliers of greatly increased activity. The maximum beta activities reported are 1140 pCi/L on Feb. 14, 2007, 1220 pCi/L on Dec. 3, 2019, 637pCi/L on Feb. 4, 2020, and 1240 pCi/L Feb. 25, 2020. Alpha activity varies as well with the maximum alpha activity of 226 pCi/L measured on Feb. 21, 2003. Stacking of alpha and beta results in 2003 is a factor of scale. Samples were collected daily for almost two weeks starting February 16 through March 7, 2003. The last three analysis results fluctuated from 40.8 pCi/L down to 5.08 pCi/L and back to 22.8 pCi/L, which is not unusual for radionuclide analysis. Carbon-14 has a relatively consistent activity until August 2014 when there was more of a range with more activities in the positive side than the negative. This could be due to placing waste from ETTP in the landfill.

Figure 5.4.16 depicts the graphed activities of strontium-90 and technetium-99 from 2002 until March 2020. There was an increase of strontium-90 measured from mid-2004 through mid-2007 with another increase from 2008 through 2009. Since 2009, strontium-90 activity has fallen to almost not detected. The exception is Dec.11, 2018 when the activity was measured at 9.46 pCi/L. The activities measured since are less than 2.0 pCi/L. There are a few instances where the strontium-90 activity increases but then reduces back. Technetium-99 is near not detectable activity from mid-2003 through the beginning of 2014 where it begins to be detected in almost every sampling. In 2016 many of the measurements were lower but in 2018 increased from approximately 20 pCi/L to a maximum of 1150 pCi/L. In November 2019 activities increased to a maximum activity of 8520 pCi/L and has fallen over a month to a range between 400 and 1800 pCi/L through the end of March 2020.

Figure 5.4.17 illustrates uranium isotope results from 2002 until the end of March 2020. Uranium-235/236 activity spikes from the end of July into August 2013 with a maximum activity of 15.6 pCi/L. Another smaller spike in activities is seen from the end of January into April. The maximum activity here is 7.67pCi/L. Another spike is seen from the end of December 2016 till the end of March 2017. The maximum activity for uranium-235/236 was 12.7 pCi/L. The rest of the measurements hover between 1 and 2 pCi/L. Another uranium isotope graphed is uranium-234/235; it is an energetic isotope as can be seen in the graph with spikes in activity mirroring those of uranium-235/236.

Uranium-238 activities from 2003 until 2006 had two large spikes, up to 100 pCi/L, as the landfill was starting with maximum activities at that time. After 2006 to the present the uranium-238 activity rarely exceeds 10 pCi/L.

There are no regulatory numbers yet to compare the analysis results against. DOE uses a rolling sum of fractions to determine the dose to the public from the water released along with the rest of the pathways (air, groundwater, surface water, soil etc.).

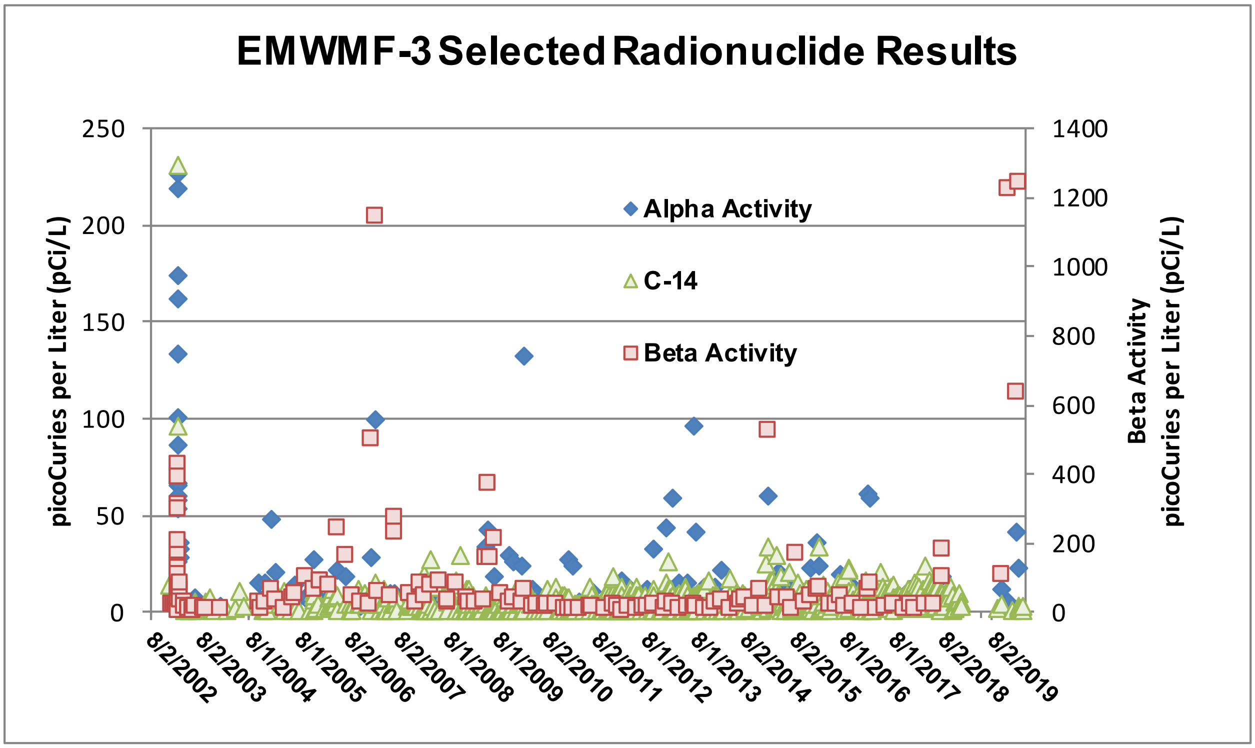


Figure 5.4.15: EMWMF-3 DOE Selected Radionuclides Results

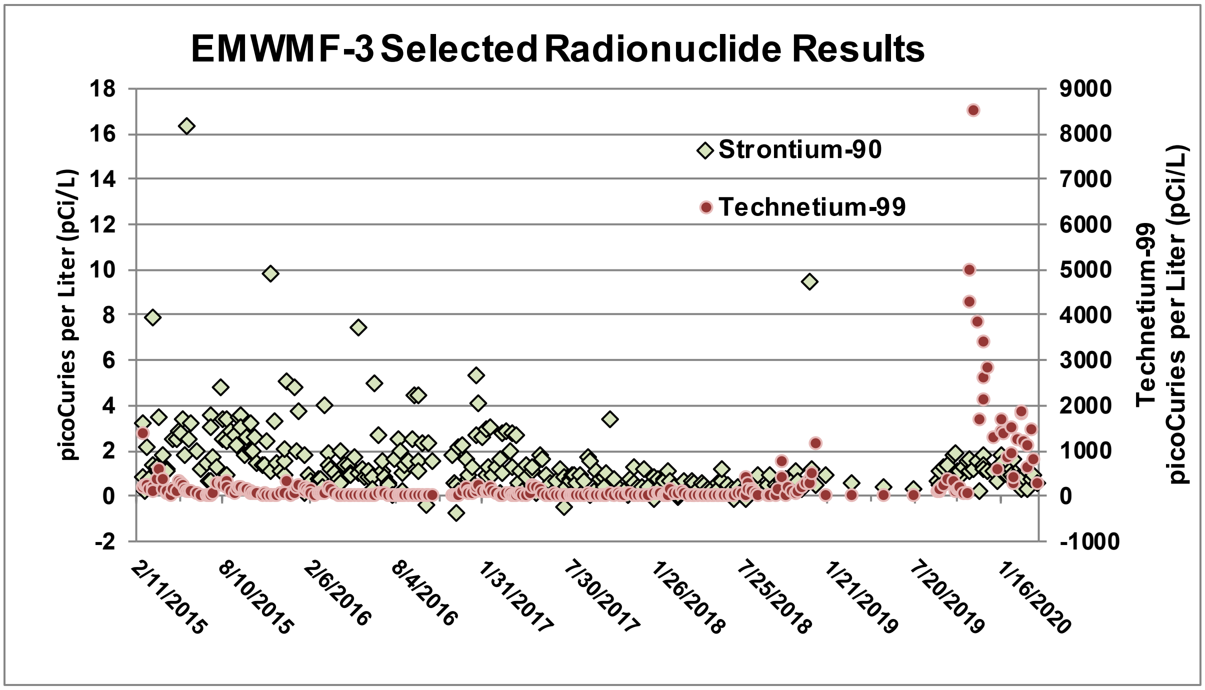


Figure 5.4.16: EMWMF-3 DOE Selected Radionuclides Results

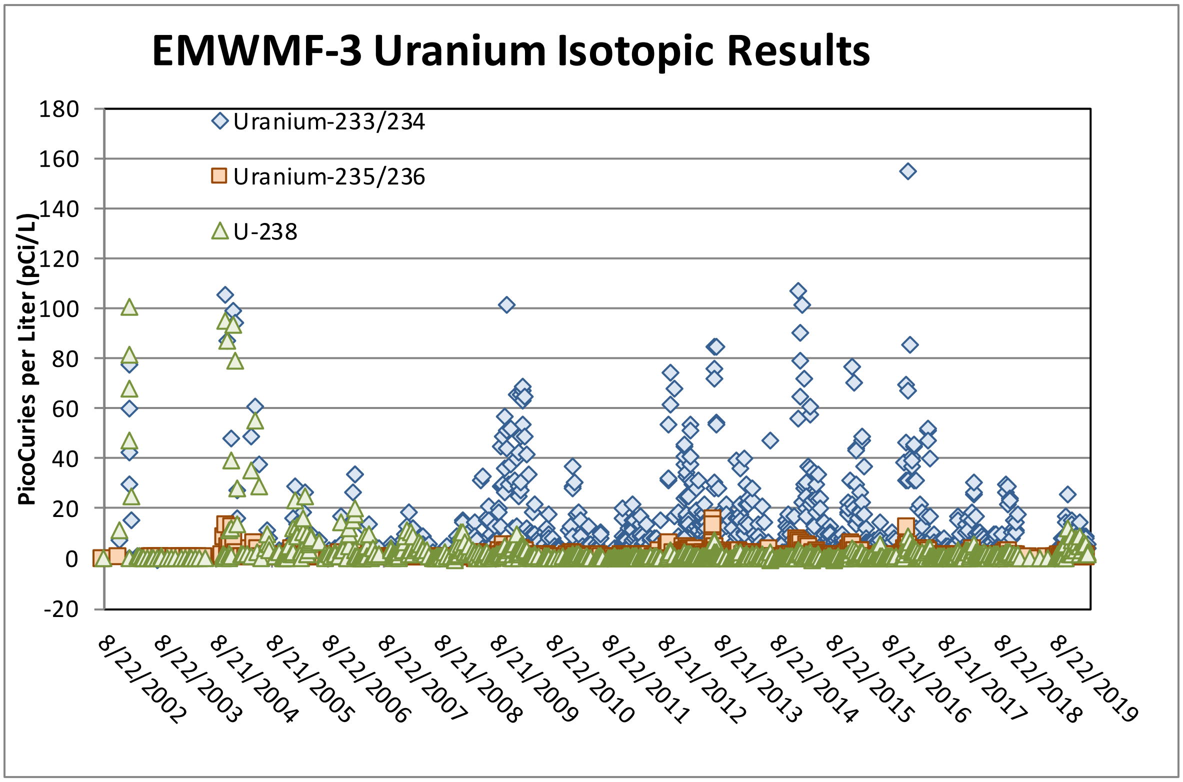


Figure 5.4.17: EMWMF-3 DOE Uranium Isotopic Results

### 5.4.7.2 TDEC Data Charts for EMWMF-2 and EMWMF-3

### Parameters Discussion

Figures 5.4.18 through Figure 5.4.23 illustrate graphically the routine water quality parameters measured at EMWMF-2 and EMWMF-3 on a routine basis. These water quality parameters can signal situations, possibly problems, with the liner, or in the case of EMWMF-3, contaminated stormwater that was previously not identified. The parameters measured are pH, specific conductivity, water temperature, oxidation-reduction potential and the depth of water leaving the weirs.

Figure 5.4.18 depicts the seasonal changes in temperature and conductivity measured since 2012 to the present. This graph shows eight seasonal cycles and the corresponding highs and lows of temperature and conductivity. EMWMF-3 occasionally does not discharge water after extended periods of no precipitation. Those are the zero measurements and since there is no flowing water, no water quality parameters are measured either. The temperature and conductivity of EMWMF-2, UT and UCond on the graph are muted and delayed in relation to EMWMF-3 parameters (VWT and VWCond). Figure 5.4.19 is a depiction of the reporting year's measurements of conductivity and temperature. In September 2018 there was no flow over the weir in EMWMF-3 so there are no measurements from that time.

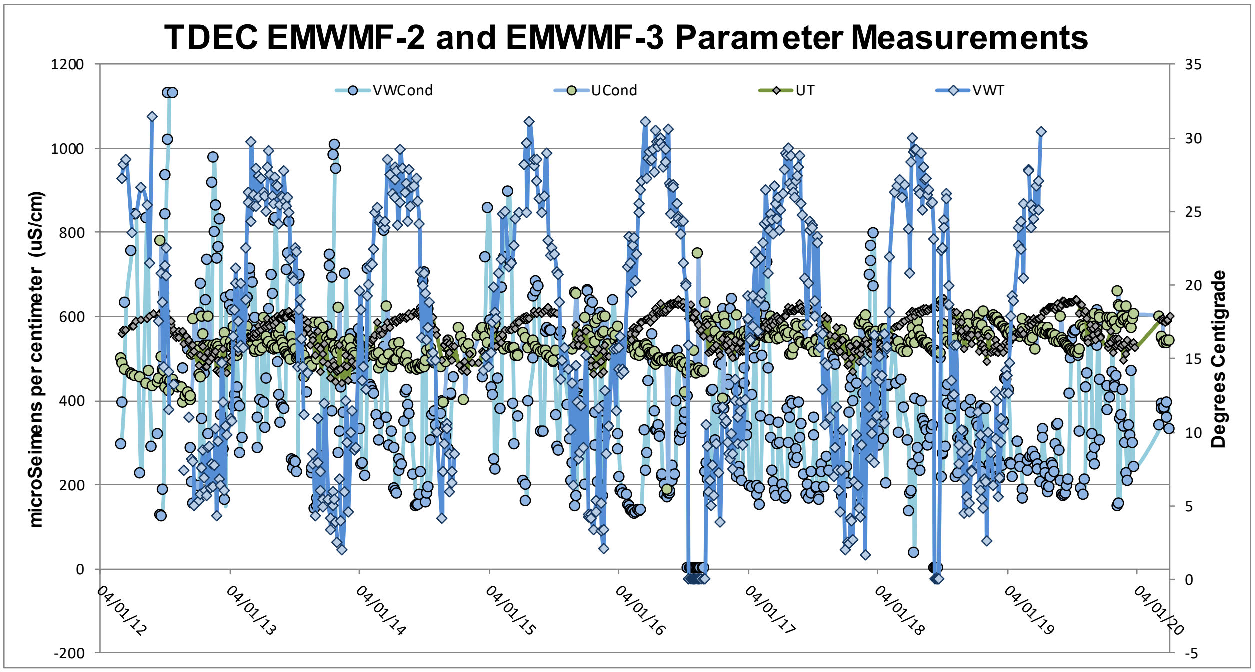


Figure 5.4.18: TDEC EMWMF-2 and EMWMF-3 Parameter Measurements 2012 To the Present

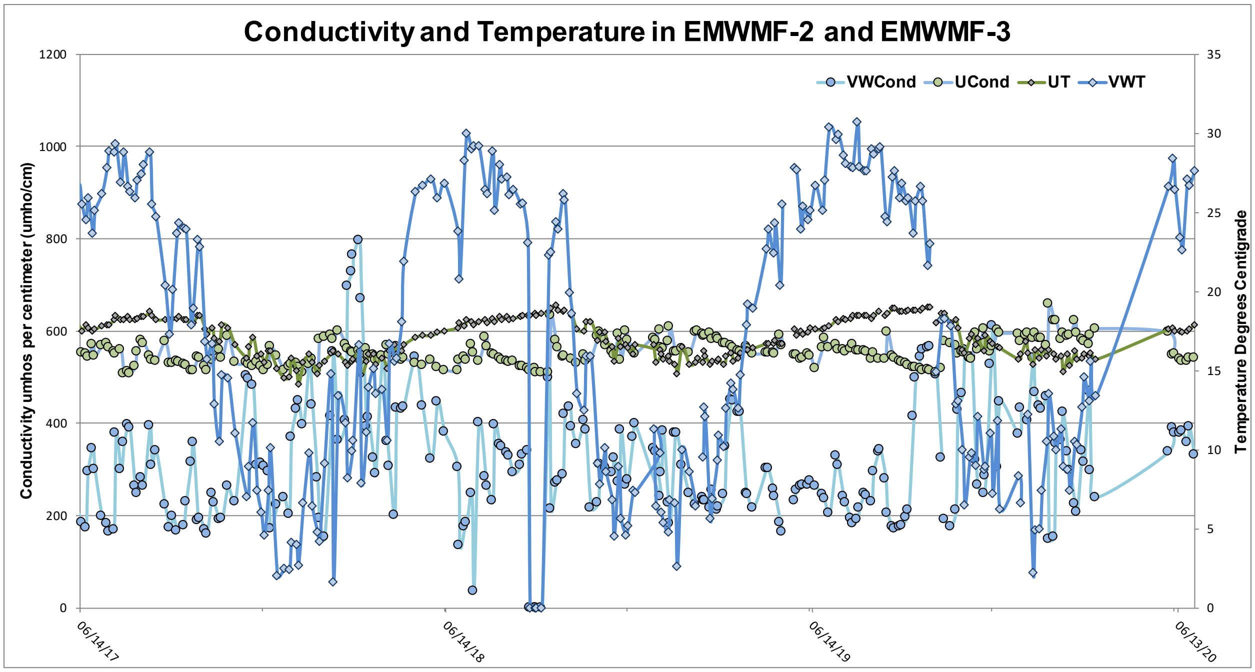


**Figure 5.4.19: FY 2019 Conductivity and Temperature in EMWMF-2 and EMWMF-3**

Figures 5.4.20 through 5.4.23 illustrate graphically the routine water quality parameters measured at EMWMF-2 and EMWMF-3 on a routine basis for the 2020 fiscal year beginning July 1, 2019 and ending June 30, 2020.

Figure 5.4.20 graphs the water temperatures in EMWMF-2 and EMWMF-3 for the 2019 reporting year. In September 2018 after a period of no rain, EMWMF-3 ceased to flow. The temperatures from EMWMF-2 do not have the amplitude as EMWMF-3 due mainly to the fact that water in EMWMF-2 is groundwater. Figure 5.4.21 presents the conductivity measured at both stations. EMWMF-3 is open to the environment, collects water from different sources, and has a variability that the EMWMF-2 water does not. The seasonal variation in the conductivity of the EMWMF-2 water is seen here.

Figure 5.4.22 graphs pH measurements for the reporting year of 2019. Seasonal variability is present for both stations with the range of measurements greater in EMWMF-3. This is to be expected due to the water open to the environment. The drop and corresponding jump in pH in March of 2019 is due to a replacement of the pH probe in the measuring instrument.

Figure 5.4.23 shows the measured depth at the weirs from both EMWMF-2 and EMWMF3. This can be used to determine flow and calculate constituent flux over time. Water in EMWMF-2 was quite stable at 2 inches at the “vee” of the weir. However, during an extremely wet period in February 2019, the water from the weir was unable to drain due to the amount of runoff. Therefore, the measurement of 4.25 inches instead of 2 inches as expected. The water depth going over the weir has been increasing due to the drainage ditch not removing surface water draining from the haul road and the weir. The ditch needs to be cleaned out for the flow measured at the weir to be more than an approximation.

The depth of water flowing from EMWMF-3 is dependent on stormwater (precipitation collected form the uncontaminated areas of the landfill site) and the discharge of contact water from the ponds and tanks on site. Before discharge, the water in the ponds and tanks are analyzed to make sure they meet the agreed upon discharge limits for hexavalent chromium, which are listed in Tennessee Ambient Water Quality Criteria for Fish and Aquatic Life.

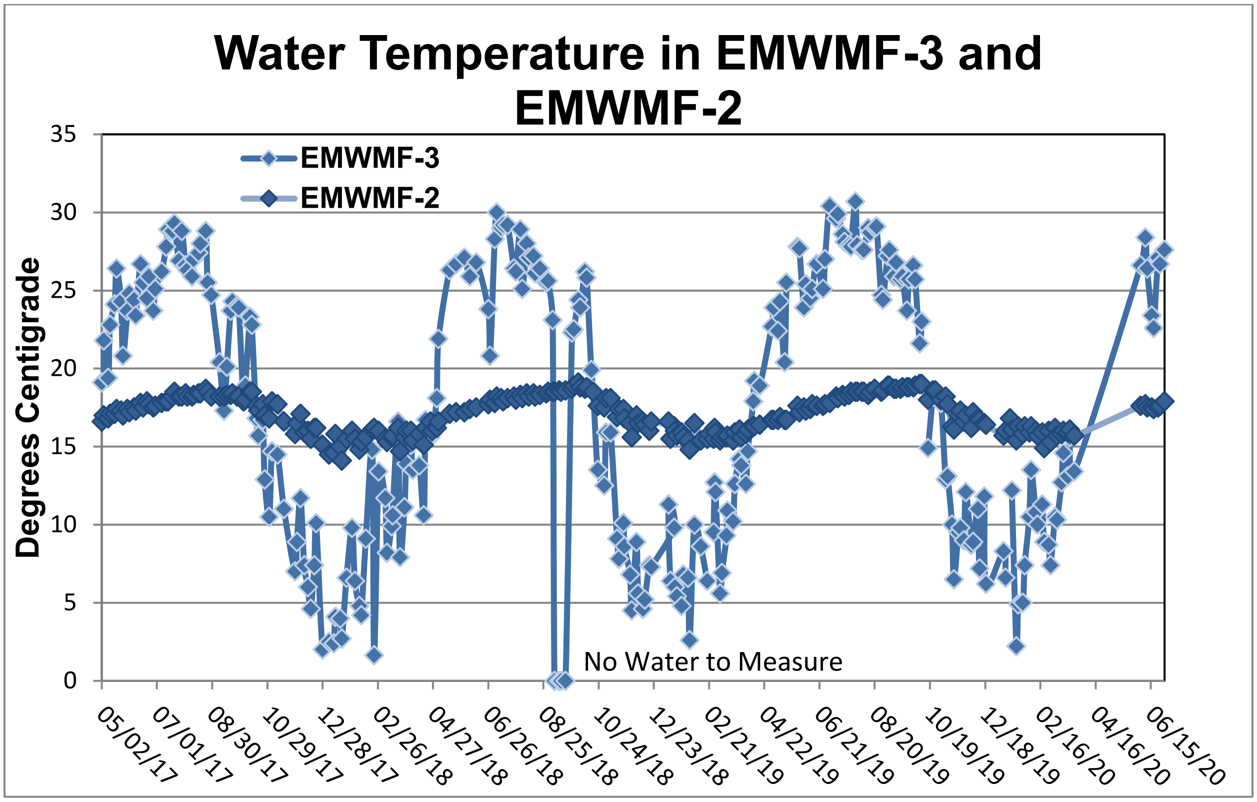


**Figure 5.4.20: Water Temperature in EMWMF-3 and EMWMF-2**

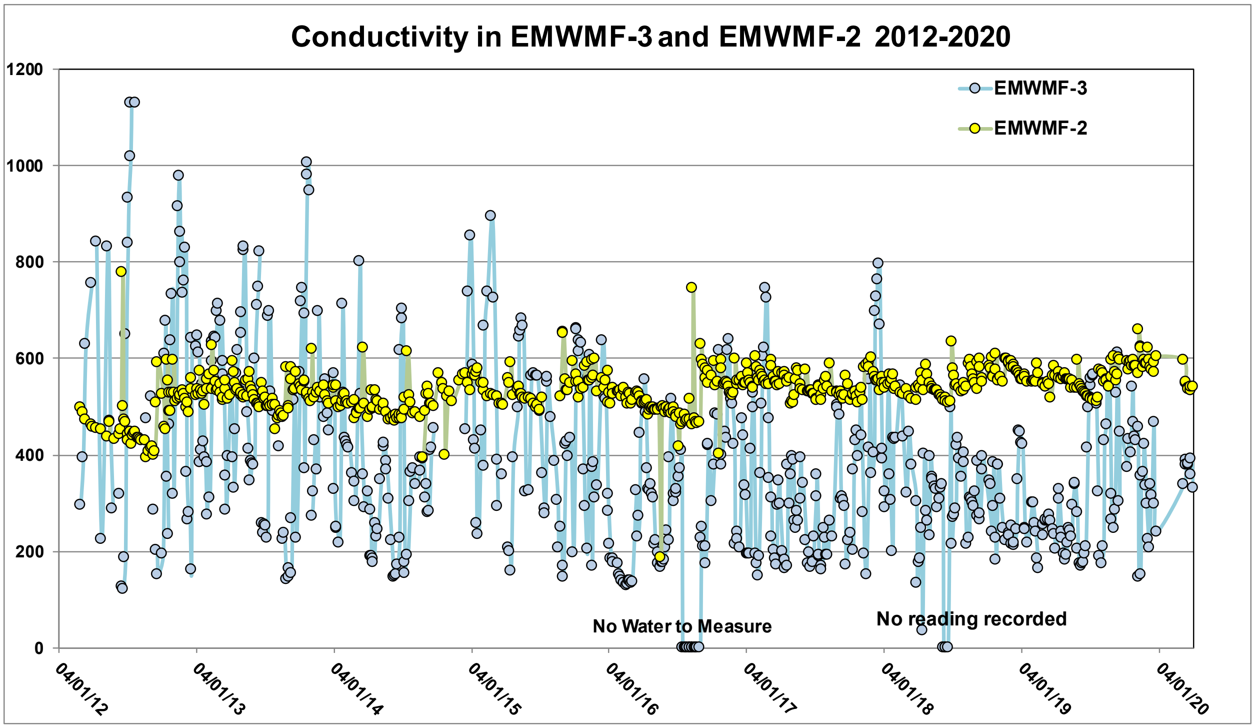


Figure 5.4.21: FY 2019 Conductivity in EMWMF-3 and EMWMF-2

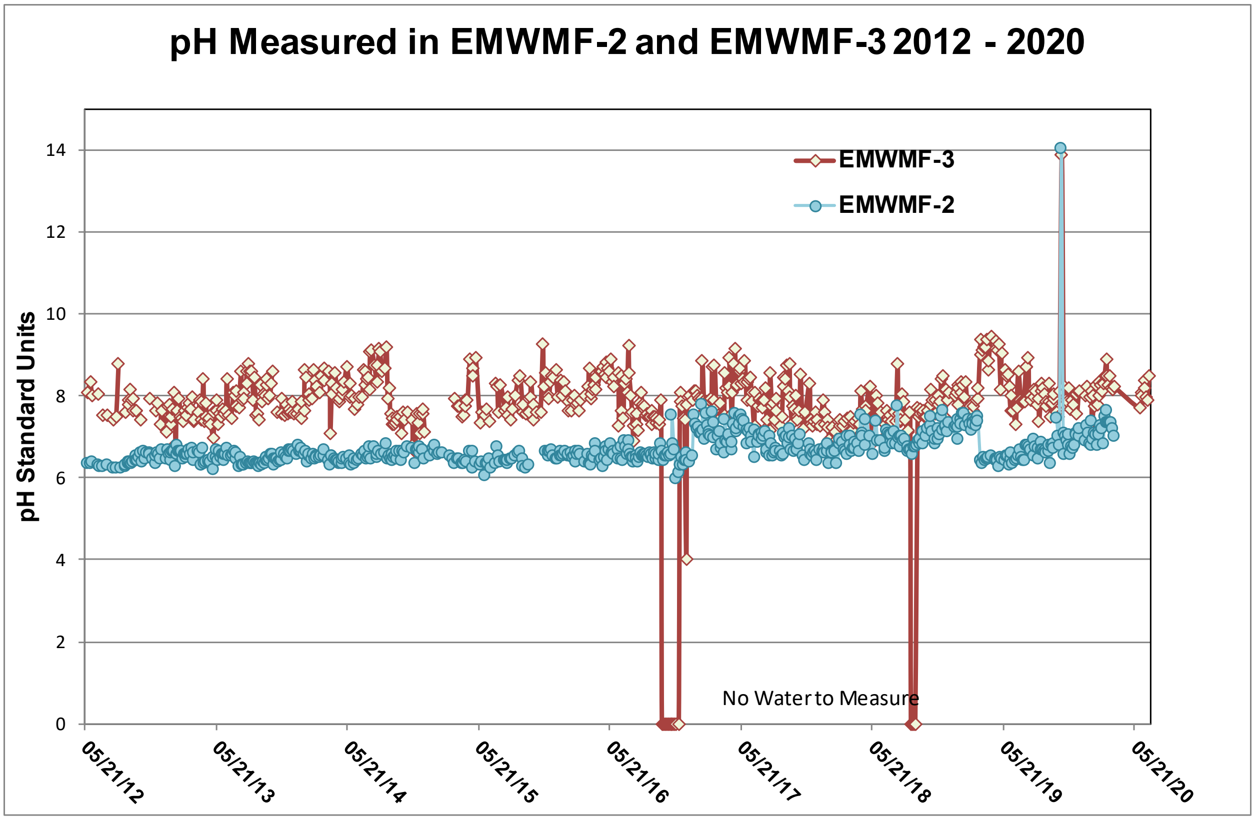


Figure 5.4.22: FY 2019 pH Measured in EMWMF-2 and EMWMF-3

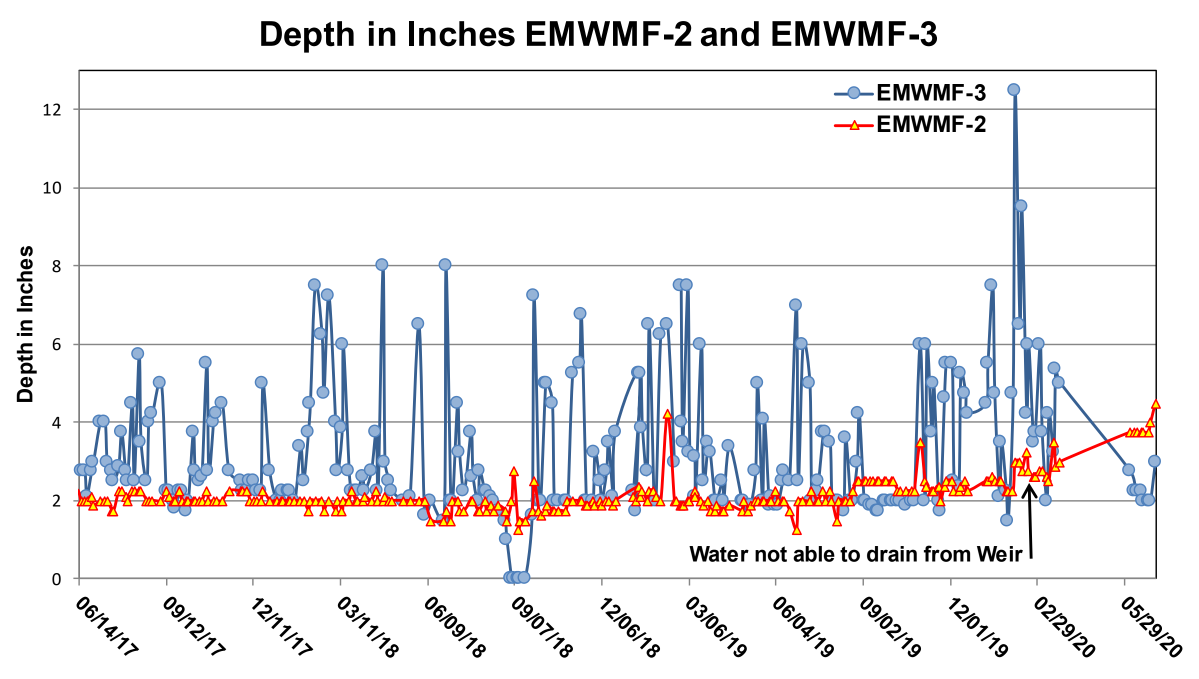


Figure 5.4.23: FY 2019 Water Depth in Inches EMWMF-2 and EMWMF-3

### TDEC Analysis Radionuclide Results Discussion

There was no independent radionuclide verification sampling conducted by TDEC during the State’s 2020 fiscal year due to budgetary constraints during the projects period of performance.

### 5.4.7.3 Sediment Basin Sampling

The primary surface water collection area and discharge point at the EMWMF is at the sediment basin. On September 6, 2018, a composite sample of sediment was collected from the bottom of the sediment basin. There was almost no water in the basin at the time and the bottom was deemed safe to walk on. The bottom clay was dry and cracked in most areas. Two samples were collected with cleaned stainless-steel spoons and were placed into a clean stainless-steel bowl for mixing. Two jars were filled with the composited sediment, one was for metals analysis and the other for radionuclide analysis. The 2018 results and graphs are published in the 2019 Oak Ridge Office Environmental Monitoring Report.

No samples were collected at the sediment basin in 2019-2020, as water continued to be present in the sediment basin and sampling was not safe.

### 5.4.8 Conclusions

Past TDEC sample results compare favorably to DOE's current year results, showing continued detections of low level (insignificant) but increasing contamination (U-238, U233/234, U235) from EMWMF-2 (Underdrain). EMWMF-3 (V-Wier) continues to discharge contaminants but not in concentrations that violate the EMWMF Record of Decision discharge limits.

### 5.4.9 Recommendations

DOE samples the effluents at EMWMF-3 weekly on a flow proportional basis. DoR-OR recommends quarterly sampling and spot sampling based on field observations, to perform continuity checks and determine if significant levels of contaminants are discharged into Bear Creek. Also, DoR-OR recommends sampling of contact water ponds/tanks as they are discharged to the unlined ditch, at EMWMF-5, and then to the sediment basin.

DOE samples EMWMF-2 bi-monthly, while DoR-OR sampled bi-monthly when DOE does not sample. For example, DOE sampled January, March, and May, while DoR-OR sampled February, April and June. The basis for bi-monthly sampling is because EMWMF-2 is the first place that contaminants from the landfill surface and are then discharged to Bear Creek without any treatment. Radionuclides and a short list of metals should be sampled here on a regular basis.

### 5.4.10 References

Environmental Sampling of the Oak Ridge Reservation and its Environs Quality Assurance Project Plan.. Tennessee Department of Environment and Conservation, Division of Remediation Oak Ridge: (2015)

Operating Procedure for Surface Water Sampling.. SESDPROC-201-R4 US-EPA, Region 4, LSASD, Athens, Georgia (2016)

Quality Systems Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water Revision 5, Tennessee Department of Environment and Conservation, Division of Water Resources, (2018)

Procedures for Shipping Samples to Laboratories for Analysis. Draft SOP No. 101 Tennessee Department of Environment and Conservation, Division of Remediation Oak Ridge (2019)

# 6.0 SEDIMENT MONITORING

## 6.1 TRAPPED SEDIMENT

### 6.1.1 Background

Sediment is an important part of aquatic ecosystems. Many aquatic organisms depend on sediment for habitat, sustenance, and reproduction. Anthropogenic chemicals and waste materials, such as metals, radionuclides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and agricultural chemicals that are introduced into aquatic systems often accumulate in sediments. Contaminants may accumulate in sediments because their concentrations are higher than in the water column. Some sediment contaminants may be directly toxic to benthic organisms or may bioaccumulate in the food chain, creating health risks for wildlife and humans. Sediment analysis is an important aspect of environmental quality and impact assessment for rivers, streams, and lakes.

Mill Branch is a tributary of East Fork Poplar Creek and is used as a background stream. NT-5 is the main outfall for the Environmental Management Waste Management Facility (EMWMF); EMWMF is a mixed-waste landfill that has received waste resulting primarily from ETTP decommissioning and demolition activities since 2002. Samples have been analyzed for radiological activity and metals. Past sediment sampling activities by the Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office (DoR-ORO) have shown that Poplar Creek and East Fork Poplar Creek have elevated levels of mercury in sediments. This mercury can be attributed to historical discharges from Y-12 and, to a lesser extent, East Tennessee Technology Park (ETTP).

### 6.1.2 Problem Statements

ORR exit pathway streams are subject to contaminant releases from activities at ETTP, ORNL, and Y-12. These contaminant releases have been detrimental to stream health in the past and present. Identified issues include:

- East Fork Poplar Creek is believed to contribute approximately 0.2 metric tons of mercury to the Clinch River each year. (DOE, 1992)

- Besides mercury, other metals that have been found in ORR exit pathway streams at levels greater than background are cadmium, chromium, lead, nickel, silver and zirconium. (DOE, 1992)

- Water supply facilities, serving an estimated population of 200,000 persons on the Tennessee River downstream of White Oak Creek, have the potential of being influenced by streams that drain the ORR. (DOE, 1992)

- The Clinch River received approximately 665 curies of cesium-13 (Cs-137) from White Oak Creek from 1954 to 1959. (DOE, 1992)

### 6.1.3 Goals

The goals of this project are:

- Gauge stream health through sampling and analysis of suspended sediment.
- Assess site remediation efforts through long-term monitoring of suspended sediment.
- Identify trends in data, based on findings, and use those trends to make recommendations in order to improve sediment quality and the health of affected streams.

### 6.1.4 Scope

This project evaluates the concentrations of potential contaminants in suspended sediments that are currently being transported in East Fork Poplar Creek (EFPC), Mill Branch, and North Tributary 5 (NT-5) by utilizing passive sediment collectors. This project does not have a comparable DOE counterpart at the present time, so it provides independent data to assist in the evaluation of the streams that drain the ORR.

### 6.1.5 Methods, Materials, Metrics

In order to monitor for changes in contaminant flow through sediment transport, passive sediment samplers (traps) were deployed. Sampling is conducted for two major exit pathway streams of the ORR; including but not limited to North Tributary 5 of Bear Creek (NT-5), East Fork Poplar Creek, and Mill Branch (Table 6.1.1, Figure 6.1.1). Mill Branch is a background location. Samples are retrieved from the sediment traps at scheduled intervals throughout the year. Table 6.1.2 provides the deployment dates of the sediment traps.

Sediment samples are analyzed for metals (arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, and uranium) and radiological parameters (gross alpha, gross beta). The metals data is compared to the Consensus-Based Sediment Quality Guidelines (CBSQGs) (MacDonald et al., 2000). Radiological data is compared to data from background locations.

The standard operating protocol used for this project is the TDEC DoR-OR Standard Operating Procedure for Sediment Trap Sampling (TDEC DoR-OR 2017). Suspended sediment samples are collected by using fixed sediment collection devices (traps). Sediment traps are installed in a stream bed and positioned to accommodate the most considerable flow through the body of the trap. Suitable sites are limited in a stream; careful consideration must be given to the selection of installation locations for the sediment traps. To completely immerse the sediment traps, water flow and depth must be sufficient.

Following a collection period (a minimum of four months), the collected sediment is emptied from a sediment trap and is transferred to a clean bucket where the sediment is allowed to settle on ice from 24 to 48 hours. After the sediment has settled, the supernatant water is carefully drawn off from the sample with a peristaltic pump. Sediment samples are spooned from the bucket into sample containers of appropriate size and construction for the requested analyses.

**Table 6.1.1: Sampling Locations**

| Sampling Location | DWR ID | Alt. ID | Sampling Rationale | Latitude | Longitude |
|---|---|---|---|---|---|
| East Fork Poplar Creek km 23.4 | EFPOP014.5AN | EFK 23.4 | Surveillance of suspended sediment at point where EFPC leaves DOE property. | 35.99596 | -84.24004 |
| Mill Branch Mile km 1.6 | FECO67I12 | MBK 1.6 | Surveillance of suspended sediment at a background location. | 35.98886 | -84.28935 |
| North Tributary 5 of Bear Creek | BEAR006.5T0.1AN | NT-5 | Surveillance of suspended sediment downstream of EMWMF | 35.96603 | -84.29024 |
| Bear Creek km 7.6 | BEAR004.7RO | BCK 7.6 | Surveillance of suspended sediment downstream of proposed EMDF | 35.95096 | -84.31395 |
| Bear Creek km 3.3 | BEAR002.0RO | BCK 3.3 | Surveillance of suspended sediment downstream of Y-12 | 35.943538 | -84.349114 |

**Table 6.1.2: Deployment Dates of Sediment Traps**

| Sampling Station | Deployed | Sampled |
|---|---|---|
| EFK 23.4 | 4/12/18 | 7/16/2018 |
| EFK 23.4 | 10/3/18 | 4/15/2019 |
| NT-5 | 9/21/2017 | 7/16/2018 |
| NT-5 | 10/3/18 | 10/7/2019 |
| MBK 1.6 | 6/12/2017 | 7/16/2018 |
| MBK 1.6 | 10/3/18 | 10/7/2019 |
| BCK 3.3 | 2/5/19 | 10/7/2019 |
| BCK 7.6 | 2/5/19 | 10/7/2019 |

Sediment traps were deployed at the following stream locations: East Fork Poplar Creek km 23.4 (EFK 23.4), NT-5, Bear Creek km 7.6 (BCK 7.6), BCK 3.3, and at Mill Branch km 1.6 (MBK 1.6) (Figure 6.1.1).

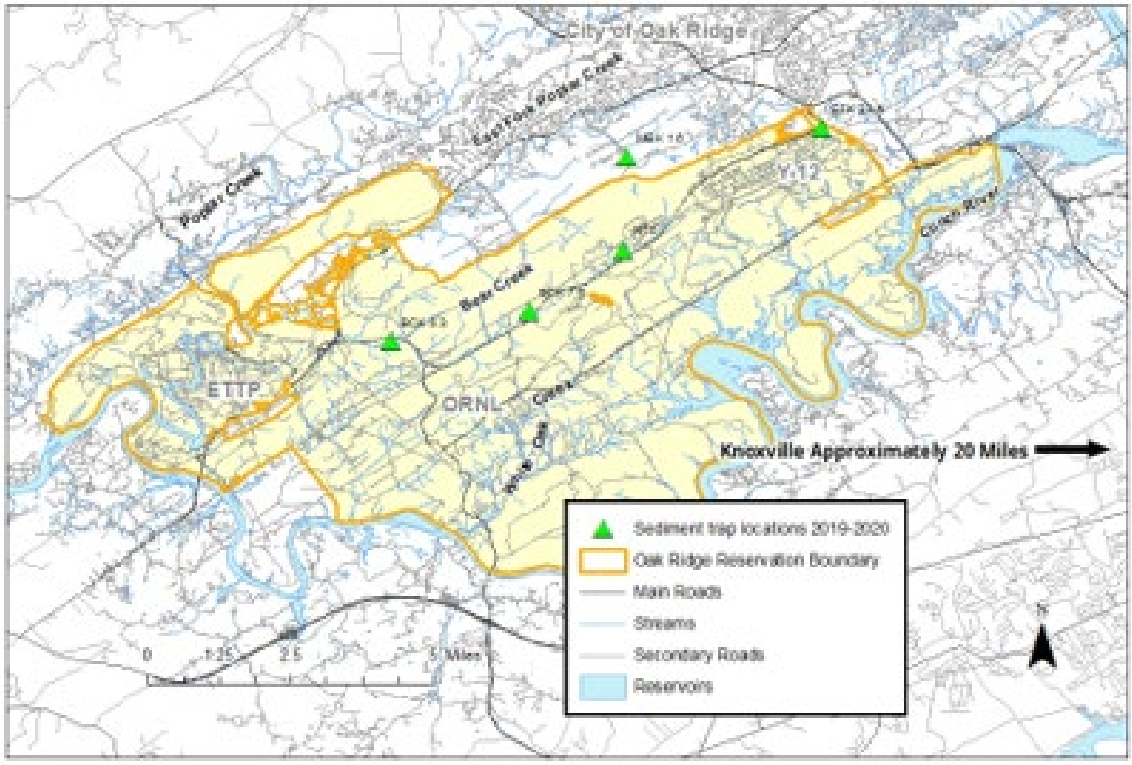


Figure 6.1.1: Sampling Locations

### 6.1.6 Deviations from the Plan

Two new sediment traps were installed at BCK 3.3 and BCK 7.6 on 2/5/19; these installations were not included in the original EMP. These sampling locations were added to provide data for the Bear Creek Valley Assessment Project.

### 6.1.7 Results and Analysis

Trapped sediment results were compared with the Consensus Based Sediment Quality Guidelines (CBSQGs) Probable Effects Concentrations (PECs) for each metal. The PECs are CBSQGs that were established as concentrations of individual chemicals above which adverse effects in sediments are expected to frequently occur (Ingersoll et al. 2000). Adverse effects, in this case, refer to the effects to benthic macroinvertebrate species only (WDNR

2003). The CBSQGs are considered protective of human health and wildlife except where bioaccumulative or carcinogenic organic chemicals, such as PCBs or methylmercury, are involved. In these cases, in addition to CBSQGs, other tools such as human health and ecological risk assessments, bioaccumulation-based guidelines, bioaccumulation studies, and tissue-residue guidelines should be used to assess direct toxicity and food chain effects. The threshold effects concentrations (TECs) are concentrations below which adverse effects are not expected to occur (MacDonald et al. 2000).

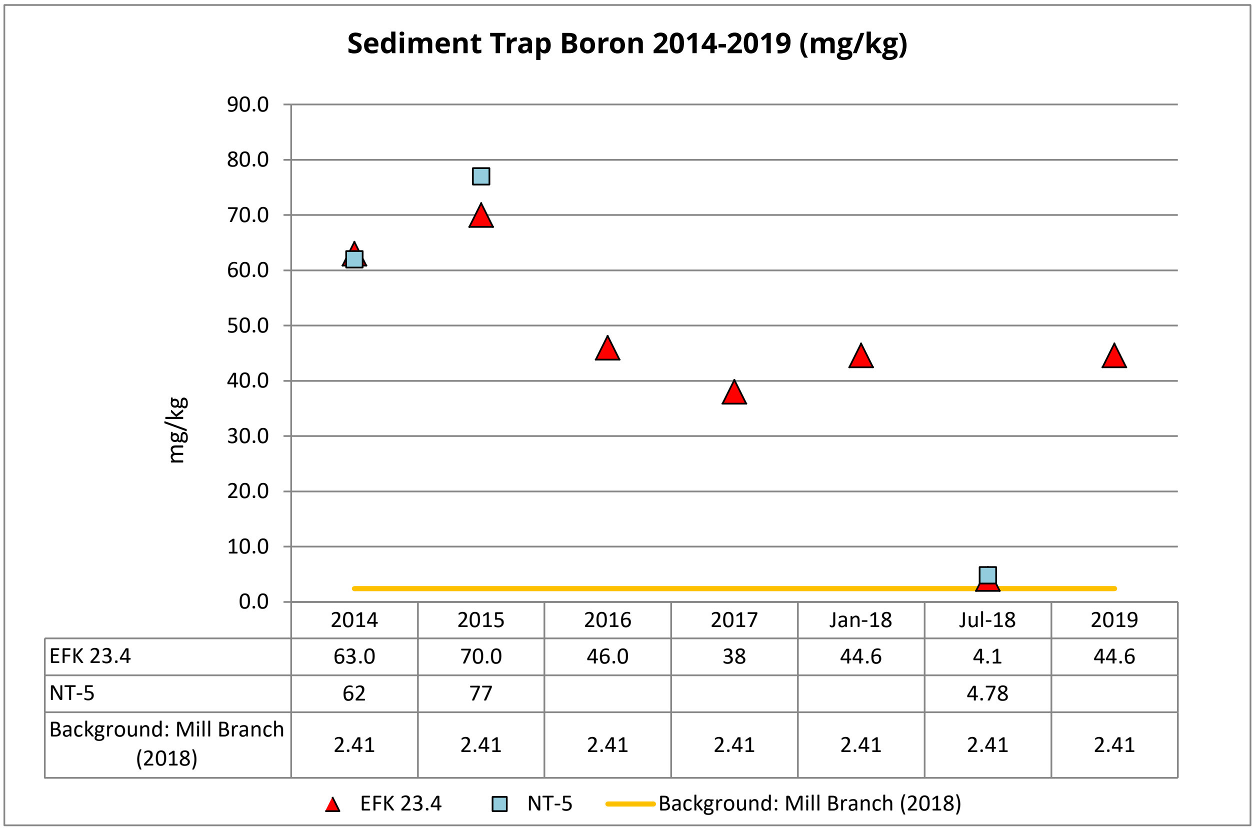
In addition, sample results were compared with data from a background sediment trap sampling station, Mill Branch km 1.6 (MBK 1.6).

The following graphs and associated charts follow the sediment data through five years of sampling. There are some omissions in the charts to be noted:

- Only EFK 23.4 was sampled in January of 2018.
- In 2016 and 2017, the sediment trap at NT-5 had an insufficient yield for metals analysis.
- The background stream's (Mill Branch) data is shown in the graphs as a bar; this bar symbolizes only the data from 2018.
- Blanks in the following charts (figures 6.1.2-6.1.7), mean that the parameter was not analyzed that year.
- Analysis of the 10/7/2020 samples was delayed due to budget issues; as a result, the metals samples were held beyond the holding time and the results were not used.

## Boron

Boron values were much higher than background (Figure 6.1.2). Boron-10 is used as radiation shielding and for radioactivity control. There is not a CBSQG for boron.



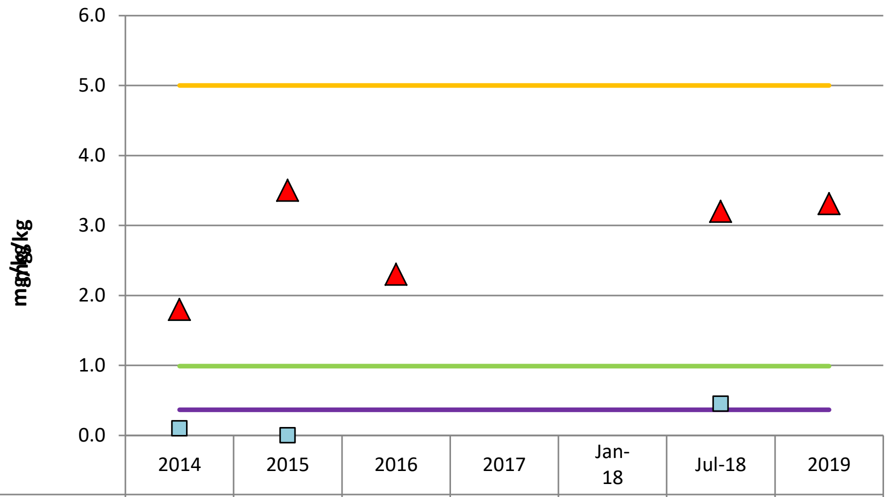
| | 2014 | 2015 | 2016 | 2017 | Jan-18 | Jul-18 | 2019 |
|---|---|---|---|---|---|---|---|
| EFK 23.4 | 63.0 | 70.0 | 46.0 | 38 | 44.6 | 4.1 | 44.6 |
| NT-5 | 62 | 77 | | | | 4.78 | |
| Background: Mill Branch (2018) | 2.41 | 2.41 | 2.41 | 2.41 | 2.41 | 2.41 | 2.41 |

**Figure 6.1.2: Sediment Trap Boron: 2014-2019**

## Cadmium

Cadmium levels at EFK 23.4 are elevated; data were higher than both the TEC and background, but lower than the PEC (Figure 6.1.3). NT-5 cadmium data were near background or undetected.

Sediment Trap Cadmium 2014-2019 (mg/kg)



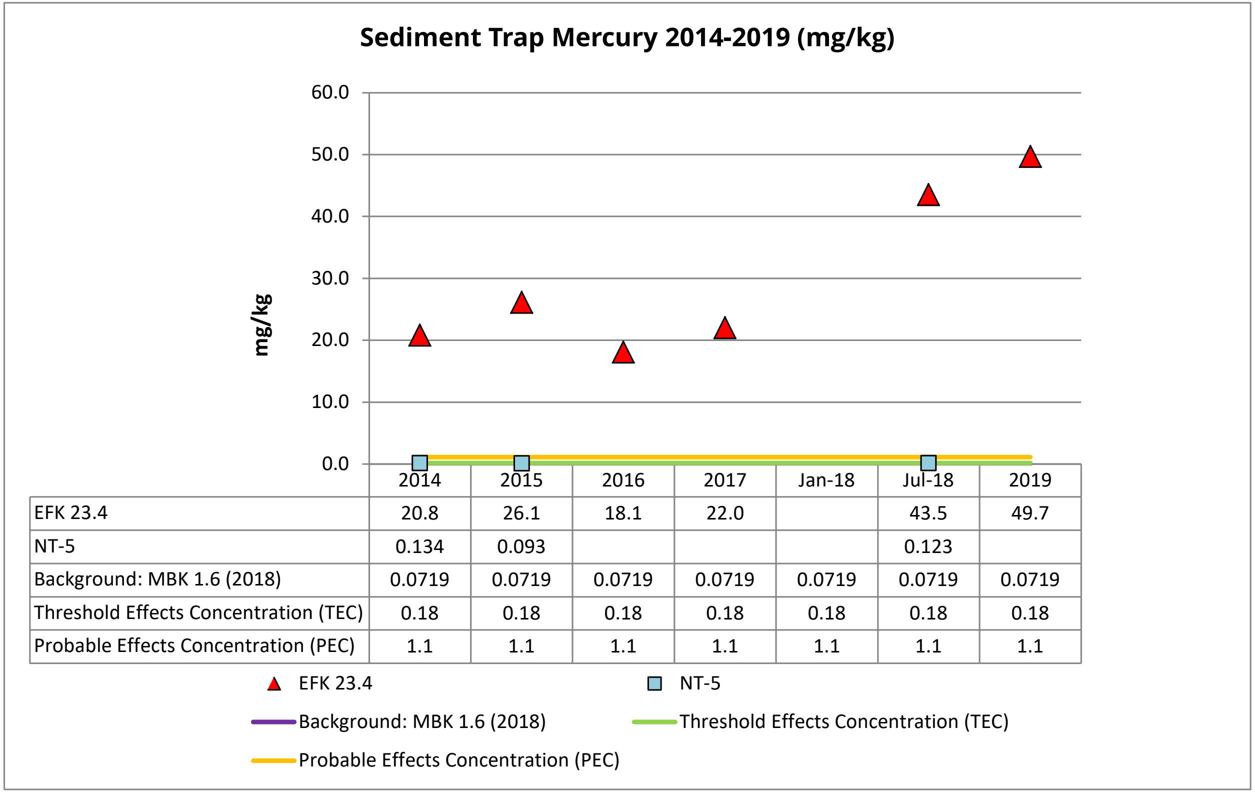
| | 2014 | 2015 | 2016 | 2017 | Jan-18 | Jul-18 | 2019 |
|---|---|---|---|---|---|---|---|
| EFK 23.4 | 1.8 | 3.5 | 2.3 | | | 3.20 | 3.31 |
| NT-5 | 0.1 | 0 | | | | 0.453 | |
| Background - Mill Branch (2018) | 0.365 | 0.365 | 0.365 | 0.365 | 0.365 | 0.365 | 0.365 |
| Threshold Effects Concentration | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| CBSQG Probable Effects Concentration | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

▲ EFK 23.4 ☐ NT-5
Background - Mill Branch (2018) Threshold Effects Concentration
CBSQG Probable Effects Concentration

**Figure 6.1.3: Sediment Trap Cadmium: 2014-2019**

## Mercury

Mercury values for EFK 23.4 were much higher than the PEC (Figure 6.1.4); metals found at levels above the PECs indicate that the metal(s) in question are probably having an adverse effect on benthic macroinvertebrate populations. Mercury values at NT-5 were slightly higher than background but below the TEC.

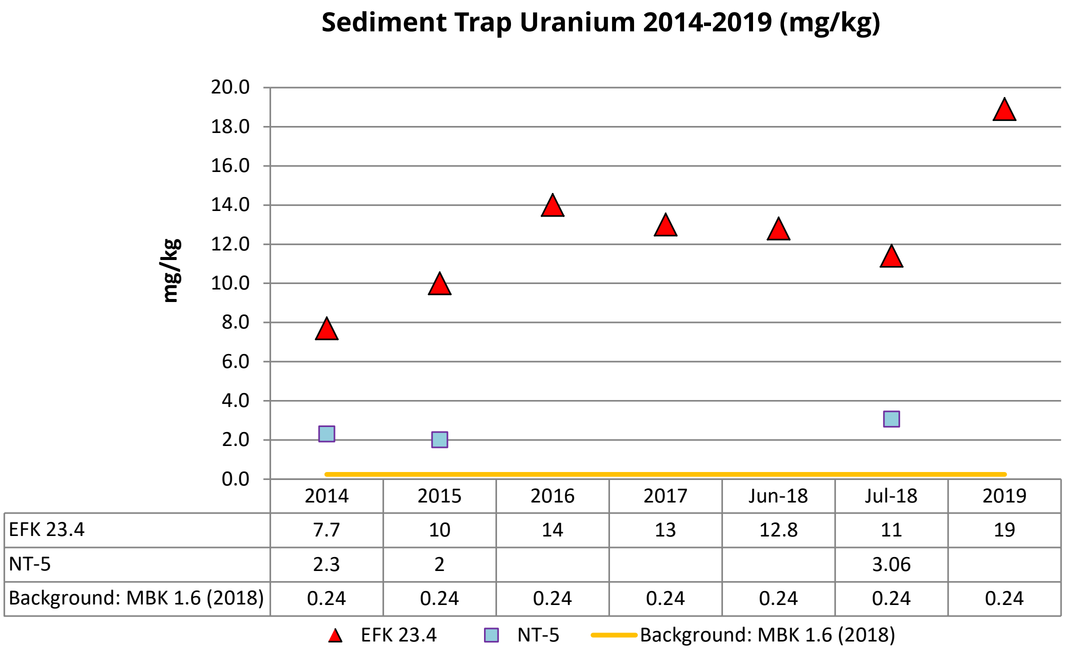


| | 2014 | 2015 | 2016 | 2017 | Jan-18 | Jul-18 | 2019 |
|---|---|---|---|---|---|---|---|
| EFK 23.4 | 20.8 | 26.1 | 18.1 | 22.0 | | 43.5 | 49.7 |
| NT-5 | 0.134 | 0.093 | | | | 0.123 | |
| Background: MBK 1.6 (2018) | 0.0719 | 0.0719 | 0.0719 | 0.0719 | 0.0719 | 0.0719 | 0.0719 |
| Threshold Effects Concentration (TEC) | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 |
| Probable Effects Concentration (PEC) | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |

**Figure 6.1.4: Sediment Trap Mercury: 2014-2019**

## Uranium

Uranium was greater than background at EFK 23.4 and NT-5 from 2014-2018 in the sediment trap samples (Figure 6.1.5). There are no CBSQGs established for uranium.



| | 2014 | 2015 | 2016 | 2017 | Jun-18 | Jul-18 | 2019 |
|---|---|---|---|---|---|---|---|
| EFK 23.4 | 7.7 | 10 | 14 | 13 | 12.8 | 11 | 19 |
| NT-5 | 2.3 | 2 | | | | 3.06 | |
| Background: MBK 1.6 (2018) | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 |

**Figure 6.1.5: Sediment Trap Uranium**

### Metals below the Probable Effects Concentration

Arsenic in sediments at all the sites was lower than the TEC (9.8 mg/kg). Barium at both EFK 23.4 and NT-5 was found to be at a similar concentration as the Mill Branch background station. There is not a CBSQG for barium. Chromium values, for all stations, were below the TEC. Copper data for EFK 23.4 was greater than the TEC and less than the PEC. Values above the TEC indicate that the metal may be adversely affecting stream organisms that inhabit sediments, such as benthic macroinvertebrates. The copper values for NT-5 were similar to background. Lead values for EFK 23.4 were slightly above the TEC for the most part. As such, there is a slight chance that lead could be harming the benthic macroinvertebrate community, particularly in concert with other metals that exceed the TEC. Nickel was greater than background at EFK 23.4 and NT-5 in 2014-2018 (11.1 mg/kg) with the exception of the 2017 datum. The data are clustered around the TEC (23 mg/kg).

### Gross Alpha

Gross alpha activity was greater than background in the sediment trap samples (Figure 6.1.6). There are no CBSQGs established for gross alpha radioactivity.

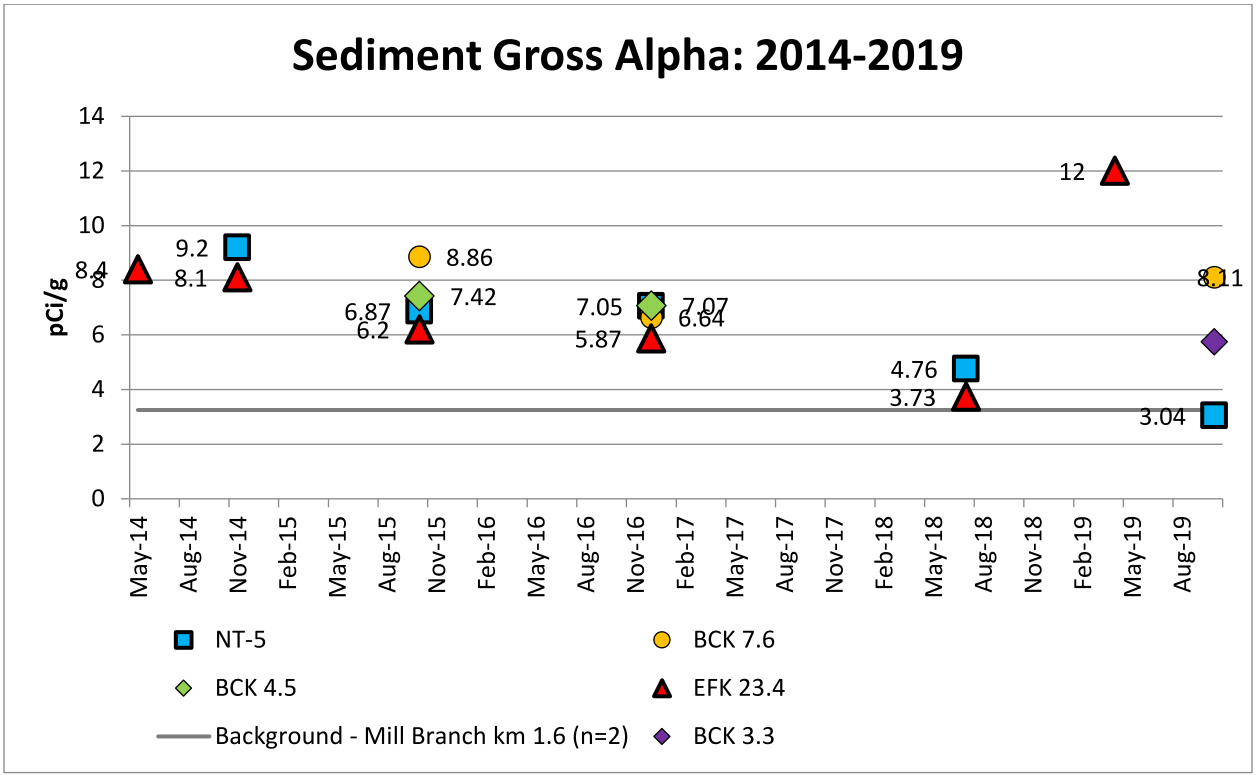


Figure 6.1.6: Sediment Trap Gross Alpha

### Gross Beta

Gross beta activity was greater than background in the sediment trap samples (Figure 6.1.7). There are no CBSQGs established for gross beta radioactivity.

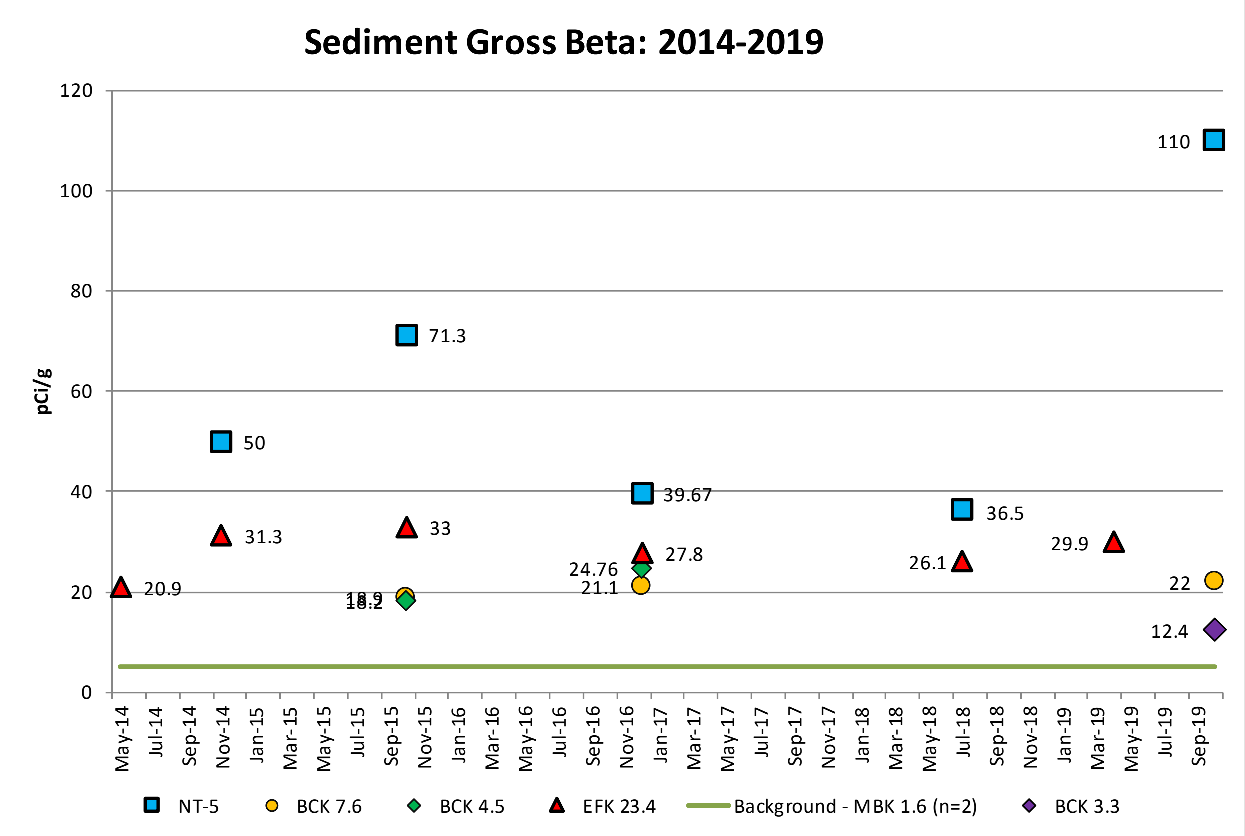


**Figure 6.1.7: Sediment Trap Gross Beta**

### Gamma Radionuclides

Only naturally occurring gamma radionuclides were detected. These radioisotopes, such as Bi-214, K-40, Pb-212 and others had similar levels of gamma radioactivity as did the background station, MBK 1.6.

## 6.1.8 Conclusions

The analysis of sediment collected from the sediment traps indicates metals contamination at EFK 23.4. Cadmium and copper levels were above the TEC at EFK 23.4 and mercury levels exceeded the PEC. Lead and nickel concentrations were above the TEC in 2015 and 2016 at EFK 23.4. When a metal occurs at a concentration above the TEC, a possibility of impairment to benthic macroinvertebrate populations is possible. Above the PEC, it is probable that these populations will be impaired. The concentrations of these metals indicate that there is a probable impairment to the biota of the sediment. At NT-5, results from metals analysis were less than the TEC. Both EFK 23.4 and NT-5 have levels of gross alpha and beta radioactivity that are above background in the trapped sediment samples collected. However, the levels do not pose a threat to human health or the stream life.

### 6.1.9 Recommendations

These sediment traps capture suspended sediments that are being carried by the current of the stream. Analysis of the sediments collected in this manner gives an idea of what has been travelling down the stream in the period that the trap was deployed. Sediment traps provide an intermediary form of information between sediment grab sampling and surface water sampling. It is the purpose of this project to stay abreast of the quality of sediment being transported in the ORR exit pathway streams. The DoR-OR Trapped Sediment Project is needed to provide this information. In the coming years, there will be many decommissioning and demolition (D&D) projects as well as construction projects in the upper East Fork Poplar Creek watershed. The Trapped Sediment Project should be continued and funded as necessary to provide ample information about East Fork Poplar Creek during these years ahead. In addition, the Trapped Sediment Project should continue to provide information about what is in the suspended sediments being released from the EMWMF outfall on NT-5.

### 6.1.10 References

MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. Development and Evaluation of Consensus-based Sediment Quality Guidelines for Freshwater Ecosystems. Archives of Environmental Contamination and Toxicology. 39:20-31. (2000).

Phillips, J. M., Russell, M.A., and Walling, D.E. (2000). Time-integrated sampling of fluvial suspended sediment: a simple methodology for small catchments: Hydrological Processes, v. 14, no. 14, p. 2,589-2,602.

United States Environmental Protection Agency. Field Branches Quality System and Technical Procedures: Field Sampling Procedures – Sediment Sampling Region IV, Athens, GA. (2010)

WDNR 2003. Consensus-based Sediment Quality Guidelines: Recommendations for Use & Application, Interim Guidance. PUBL-WT-732 2003. Wisconsin Department of Natural Resources.

# 7.0 GROUNDWATER MONITORING

## 7.1 GROUNDWATER MONITORING OF BEAR CREEK VALLEY

### 7.1.1 Background

The BCV encompasses many different DOE ORR sites as discussed in the TDEC DoR-OR EMRs (TDEC, 2015; DOE, 2017). The main BCV sites are listed below and shown in Figure 7.1.1.

- Y-12
- EMWMF
- EMDF
- Bear Creek Burial Grounds (BCBG)
- Y-12 WEMA

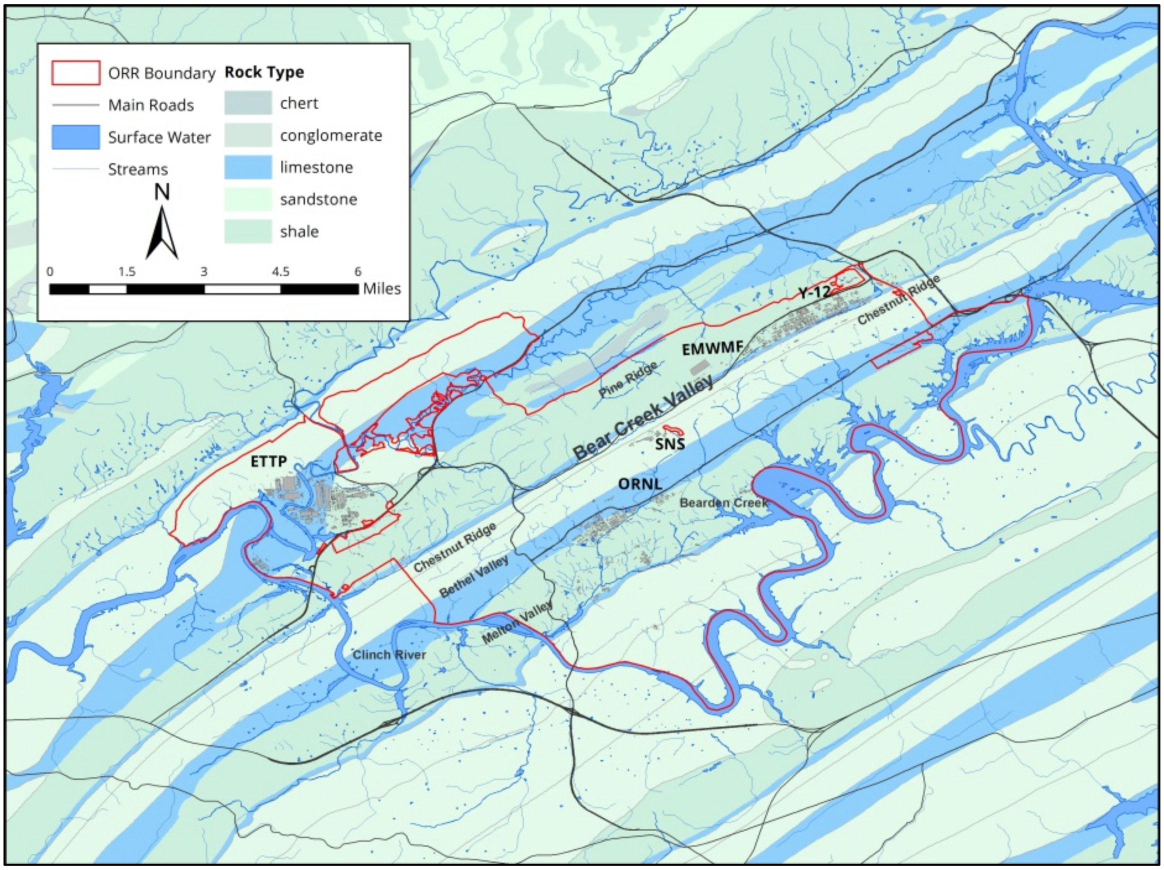


**Figure 7.1.1: The ORR Facilities within BCV and the Major Lithologies (rock types).**

Bear Creek originates within the Y-12 complex and is impacted by storm water runoff, groundwater infiltration, and tributaries that drain historical waste sites such as the Bear Creek Burial Grounds (BCBG) as well as the current EMWMF (DOE, 2018a). Historically, the ORR has been responsible for discharging large amounts of mercury into the environment, primarily from the Y-12 West End Mercury Area (WEMA) (TDEC, 2015; DOE, 2017). The BCBG is also a known sources of volatile organic compounds (VOCs), uranium, and other trace metal contamination (DOE, 2018a).

Previously, TDEC DoR-OR has assessed groundwater through multiple projects (background, offsite, and springs). For FY2020, DOR-OR focused groundwater assessment activities in areas within the BCV watershed. This focus on BCV will provide data for the holistic assessment of BCV described under TDEC DoR-OR's Bear Creek Assessment Project (BCAP) that is described in TDEC's FY2020 Environmental Monitoring Plan. The intent of this Project was to support development of a baseline delineating groundwater quality in BCV. This Project aimed to provide greater understanding of potential impacts to the groundwater within the BCV and to evaluate contaminant concentration distributions spatially as well as temporally in an effort to guide future remediation decisions.

This TDEC DoR-OR Groundwater Monitoring of the Bear Creek Valley Project correlates to current DOE projects in the following ways:

- Exit pathway monitoring is currently conducted onsite by DOE within BCV. This project will provide additional data to support continued assessment of the possibility of ORR legacy contamination migrating off site.
- Current and proposed waste disposal sites (EMWMF and EMDF) discharge groundwater into this watershed system. This groundwater project may provide relevant data to identify potential impacts to the water quality of BCV.
- The sampling areas were based on surface watersheds (Figure 7.1.2), primarily because remedial decisions on the ORR have been made at the watershed scale due to surface water being a major exit pathway for contaminants (DOE, 2018c). DOE bases the current groundwater conceptual site model (CSM), which guides assessment modeling and clean up decisions, on those surface water watersheds (Figure 7.1.2). Focusing sampling in these watersheds will provide data sets that will be used to support future decisions.
- Delineating current offsite impacts and identifying the potential for additional offsite impacts to groundwater downgradient in BCV will help guide TDEC DoR-OR's input for future FFA site-wide groundwater decisions.

- Two of the three top priorities for remediation work as presented in the 2018 RER (DOE, 2018c) are to *"reduce further migration of contaminants offsite"* and to *"address sources of offsite surface water and groundwater contamination"*.
- Within BCV, during FY2020, DOE planned to sample five wells offsite, southwest of the reservation, as part of the Remedial Site Evaluation Phase 2 (DOE, 2018b).
- *"Groundwater quality data obtained during CY 2017 from the exit pathway monitoring wells indicate that groundwater is contaminated above drinking water standards in the Maynardville Limestone" (DOE, 2018a)*. The exceedances include gross-alpha activity, nitrate, barium, cadmium, nickel, and uranium (DOE, 2018a).

There is a surface water divide in BCV that influences whether surface waters will flow southwest or northeast. The northeastern portions of this area have rarely been sampled by TDEC DoR-OR. As stated in the 2017 ASER, *"the surface water in Bear Creek, the springs, and the groundwater in the Maynardville Limestone are hydraulically connected" (DOE, 2018a)*. The interconnected nature of surface water and groundwater identified in Bear Creek valley is a key component to evaluating groundwater flow in this valley. Assumptions in DOE's Groundwater Strategy Conceptual Site Model (CSM) imply that the region's shallow groundwater may also follow that surface water divide structure.

The Tuskegee neighborhood lies within the northeastern portion of the EFPC surface watershed on the north side of Pine Ridge. Pine Ridge bounds BCV to the north. This surface watershed also encompasses portions of BCV and many ORR facilities. The Tuskegee neighborhood is located on the other side of this ridge from the proposed EMDF location. In addition to the previously stated reasons, residents' have requested inclusion in the residential well sampling.

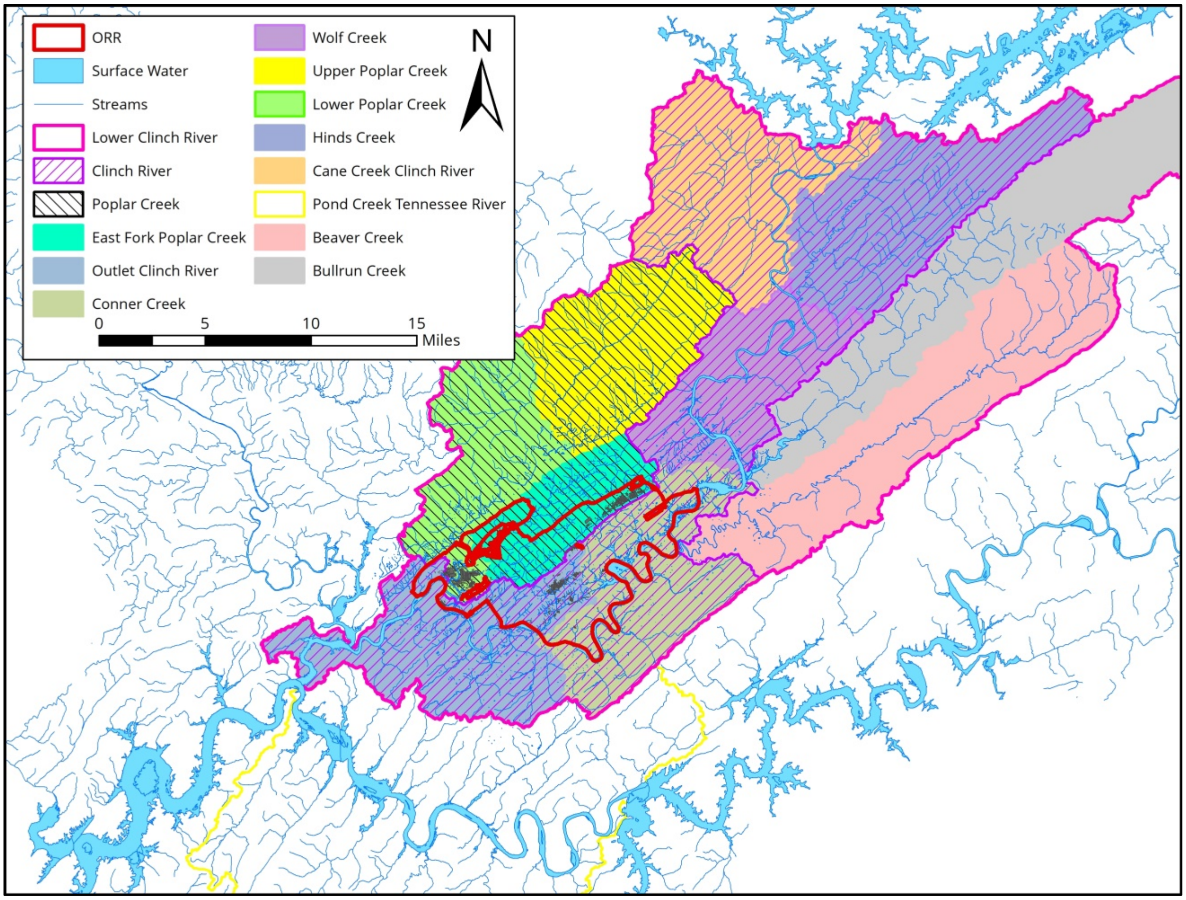


**Figure 7.1.2: Surface Watersheds (TNGIS, no date)**

### 7.1.2 Problem Statements

- Delineation of the nature and extent of groundwater contamination is incomplete in many areas of the ORR (DOE, 2018c). Groundwater in BCV is contaminated due to waste disposal and uranium separation processes. The disposal of acidic liquid wastes at the S-3 site caused a reduction in groundwater pH (DOE, 2018a). This reduction in pH decreases metal precipitation, which causes metals to stay in solution longer and migrate away from the source areas (DOE, 2018c). The most prevalent trace metal in BCV is uranium, and one of its sources is the Boneyard Burnyard site (DOE, 2018a). VOCs are widespread in BCV and may occur at depths up to 300ft (92m) below ground surface (bgs) (DOE, 2018a).

- Contaminant plumes in BCV are defined by DOE as elongated due to contaminants and groundwater preferentially migrating parallel to strike (to the south and southwest) (DOE, 2018a). Groundwater, surface water, and springs are hydraulically related. Exit pathway monitoring wells have indicated that groundwater is contaminated in the Maynardville Limestone (DOE, 2018a). Monitoring, to evaluate the extent of plume migration along strike, should continue to support the goals of protection of human health and the environment.

- The Maynardville Limestone lies within BCV and its karst characteristics enable contaminant movement by conduit flow. Conduits do not always follow strike. There are indications that surface water and shallow groundwater are connected in this area. The residential wells in the Tuskegee area to the north and northeast of BCV within the East Fork Poplar Creek surface watershed and other northeast areas should be monitored to complete the full evaluation of the BCV area.

### 7.1.3 Goals

This Groundwater Monitoring portion of the BCV Project planned to collect groundwater samples to the southwest and northeast of Y-12 within BCV to detect and evaluate potential legacy contaminant migration and establish a current baseline to facilitate the assessment of current groundwater quality in this area. The data from this Project was to be used to assist the remedial decision-making process as defined by the FFA.

The objectives of this Project were:

- To enable TDEC DoR-OR to focus groundwater efforts on one valley at a time. By focusing solely on BCV for FY2020, formal determination regarding additional sampling needs for that specific area was to be attained. Focusing limited resources should help to generate statistically supportable data for FFA remedial decision-making in the BCV.
- To assist with FFA site-wide groundwater decisions for BCV by evaluating additional potential exit-pathways.
- To provide information to support the FY2020 holistic assessment of BCV being conducted by the TDEC DoR-OR.
- To support the potential interpretation of the onsite groundwater data collected by DOE within BCV by comparing data from onsite groundwater and offsite groundwater.
- The overarching goal of this project is to identify any contaminants and delineation of possible sources of contaminants detected in groundwater samples in the southwest BCV, northeast BCV, and the Tuskegee area.

### 7.1.4 Scope

The planned actions of this Project were:

1) Collect groundwater samples from residential groundwater wells or springs at the following 17 locations:
   a. Northeast: five locations
   b. Southwest: eight locations
2) Tuskegee Area: four (A total of seven are in the neighborhood. However, three of the seven were sampled in the previous fiscal year).
3) Evaluate received data for potential COC and water chemistry.
4) Use graphing and mapping technology to determine possible trends between the three sampling areas.

Some of the analytes are naturally occurring, while some are contamination signatures from anthropogenic sources. Some chemicals (e.g., metals and some radionuclides) exist in nature, but their concentrations may be impacted by or increased to levels that pose risks to people through the release of legacy contaminants into the environment.

Parameters including alkalinity, pH, and total hardness were measured to help characterize geochemical conditions or groundwater types within the aquifer.

Groundwater samples were planned to be collected from residential wells and springs.

The three focus study areas are shown in Figure 7.1.3. The sample locations were to be focused within BCV and surface watersheds that encompass BCV, EMWMF, EMDF, and Y-12. This includes areas to the northeast, southwest, and the Tuskegee neighborhood.

Seventeen locations were planned to be sampled and quality assurance/quality control (QA/QC) samples were planned to be collected from approximately 10% of the sample locations for a total analytical set of 19 samples including two duplicates. Some previously sampled locations were resampled.

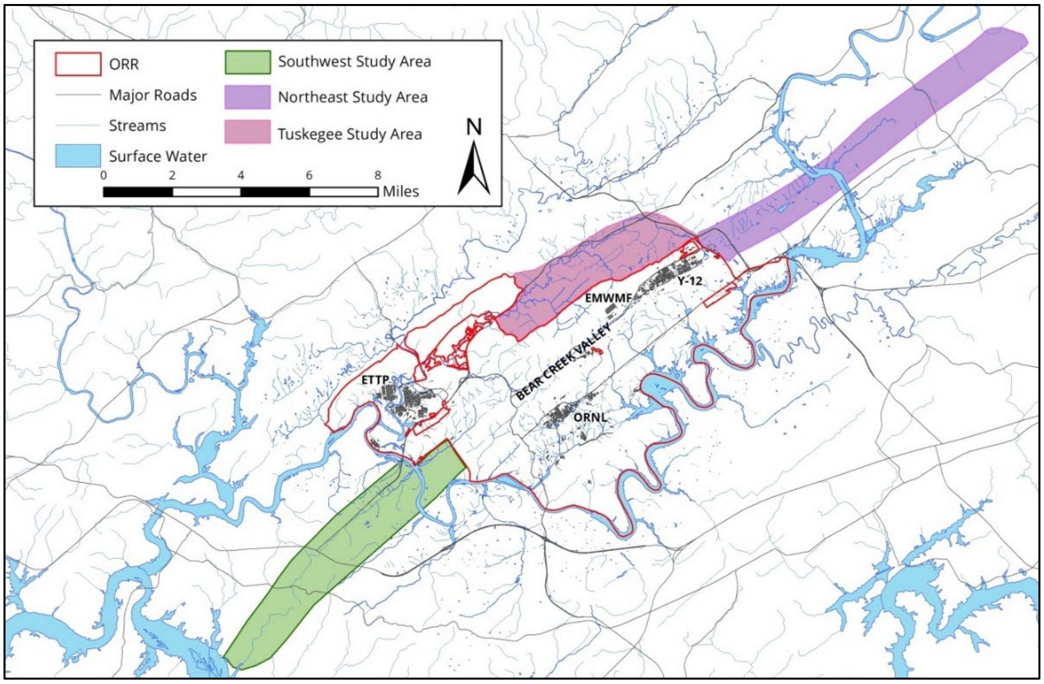


**Figure 7.1.3: Proposed Study Area**

### 7.1.5 Methods, Materials, Metrics

Groundwater samples were planned to be collected from 17 locations; QA/QC samples were also planned to be collected from at least 10% of the 17 locations. The residential well groundwater samples were planned to be collected from an outside tap located as close to the well as possible, and ideally, before water passes through filtration and water softener systems. Wells that were not in use and have no viable dedicated pump system were to be sampled by peristaltic or bladder-pump. Springs were planned to be sampled using a dipper or peristaltic pump in accordance with internal TDEC DoR-OR procedures.

The wells sampled by TDEC DoR-OR were not co-sampled with DOE contractors.

The field parameters that were measured included: temperature (°C), electrical conductivity (µS/cm), pH (SU), oxidation reduction potential millivolts (mV), dissolved oxygen (mg/L), and turbidity (NTU). Wells were purged until, at a minimum, the volume of water stored in the pressure tank or other water storage container had been removed and parameters become stable. Field parameter stabilization is defined as four consecutive readings presented in Table 7.1.1.

## Table 7.1.1: Water Quality Indicator Parameters

| Water Quality Indicator Parameters | | |
|---|---|---|
| **Measurement (units)** | **Normal Range** | **Acceptable Variability[1]** |
| Temperature (°C) | 10 to 18 | ± 10% |
| pH (SU) | 4.6 to 8.5 | ± 0.1 |
| Specific Conductivity (µS/cm) | 10 to 8,000 | ± 5% |
| Turbidity (NTU) | variable | ± 10% |
| ORP[Eh](mV) | variable | ± 10 mv |

**[1] Acceptable variability over four consecutive readings.**

**°C- Degrees Celsius**

**µS/cm- MicroSiemens per centimeter**

**mV- Millivolt**

**NTU- Nephelometric Turbidity Unit**

**SU- Standard Units**

**ORP- Oxidation Reduction Potential**

**Eh- Reduction Potential**

Samples were sent to the Tennessee Department of Health – Nashville Environmental Lab (TDH-NEL) within specified holding times for VOCs, inorganics, and radiochemical analyses. Table 7.1.2 lists the proposed analyte list. Although *"the primary groundwater contaminants in the Bear Creek regime are nitrate, trace metals, VOCs, and radionuclides,"* the extensiveness of the list is due to deposited waste in EMWMF and other waste burial sites within the valley (DOE, 2017).

**Table 7.1.2: Proposed Analyte List**

| **VOCs** | | |
|---|---|---|
| EPA 8260 B list for low level detection[1] | | |
| **METALS** | | |
| aluminum | copper | selenium |
| antimony | iron | silver |
| arsenic | lithium | sodium |
| barium | lead | strontium |
| beryllium | magnesium | thallium |
| boron | manganese | uranium |
| cadmium | mercury | vanadium |
| calcium | nickel | zinc |
| chromium | potassium | total hardness, as calcium |
| **INORGANICS** | | |
| calcium carbonate | total dissolved solids | nitrate and nitrite |
| chloride | sulfate | ammonia |
| fluoride | | |
| **RADIONUCLIDES** | | |
| gross alpha | tritium | radium-228 |
| gross beta | gamma | isotopic uranium |
| strontium-89 | technetium-99 | transuranic radionuclides |
| strontium-90 | radium-226 | |

[1] EPA-8260 B- volatile organic compound analyses list: https://www.epa.gov/sites/production/files/2015-12/documents/8260b.pdf

[2] gamma list includes: Ra-226, Pb-210, Pb-212, Pb-214, Tl-206, Tl-208, Bi-212, Bi-214, K-40

The data were compared to the NPDWR (EPA, 2009) and NSDWR (EPA, no date). When neither of these were available for a contaminant, the data were compared to other EPA standards including Regional Screening Levels (RSLs) (EPA, 2017), Health Advisories (HA); or Preliminary Remediation Goals (PRG) (EPA, no date)). These standards align with Tennessee public water utility standards.

A summary package of the sample results was prepared and provided to the well owners. Residents, whose groundwater contaminants exceed drinking water criteria or interested health information, were referred to TDH for a health consultation.

The offsite data was planned to be compared to onsite groundwater data collected by DOE within the BCV. Onsite data that was planned to be used spans 2009 through 2018 and was evaluated to help determine if contaminants have migrated offsite. The data was also planned to be compared to historical TDEC DoR-OR groundwater data.

### 7.1.6 Deviations from the Plan

Groundwater samples were planned to be collected from residential wells and springs. The samples were also planned to be collected from five locations in the northeast area, eight locations in the southeast area, and four from Tuskegee area (Figure 7.1.3 Proposed Study Area). Due to TDEC budget constraints only four project samples were collected. The samples chosen were the Tuskegee area to finish sampling in the neighborhood. Three of the seven planned wells in the neighborhood were sampled in FY2019, refer to Figure 7.1.4. The four samples were planned to be taken during March-April 2020; however, COVID-19 restraints precluded the collection of the samples. Well owners were contacted to schedule sampling as limited TDEC field sampling resumed but there were no responses from the well owners. The northeast and southwest BCV locations are planned to be sampled in FY2021.

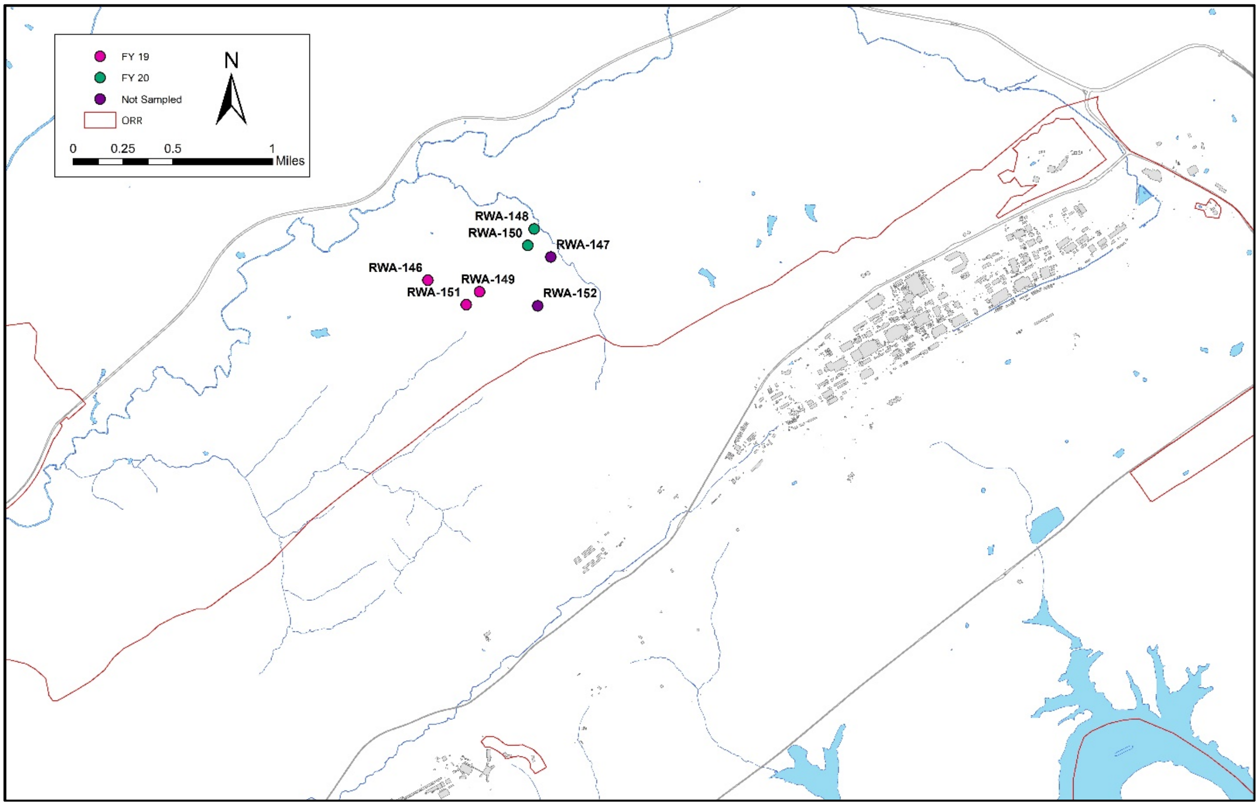


**Figure 7.1.4: Sampling in 2019 and 2020 Fiscal Years**

### 7.1.7 Results and Analysis

Radionuclides are naturally present in groundwater due to interactions with the atmosphere, soil, or bedrock. One of the many challenges of this project is determining if the radionuclide analytical results are indicative of man-made radionuclides, natural radionuclides, or a mix of both.

Only two samples were taken during FY2020, so the Tuskegee sample results from FY2019 are included with these results in an attempt to give a more comprehensive understanding of the Tuskegee Area. There are seven wells in the Tuskegee area, three were sampled in FY2019, two in FY2020, and two wells remain unsampled. The 2019FY and 2020FY samples were compared to the most recent TDEC DoR-OR historic groundwater data.

**Regulatory Comparison Values**

The results of the analyses from the private wells sampled were compared to EPA guidance standards. These standards are not legally enforceable on private wells. The EPA has established the NPDWR to maintain the quality of potable water in public water supplies. These criteria include Maximum Contaminant Levels (MCLs) and Secondary Maximum Contaminant Levels (SMCLs).

- MCLs are standards used to protect people by limiting levels of harmful contaminants in public drinking water supplies. MCLs are legally enforceable rules for public water utilities.
- SMCLs are associated with public acceptance of water. These constituents include characteristics such as taste, odor, and color, as well as the staining of teeth, clothing, or fixtures. SMCLs are only guidelines for public water utilities.

When EPA MCLs and SMCLs are not available, other EPA criteria for comparison values are used. These EPA guidelines include Health Advisories (HA), Regional Screening Levels (RSL), and preliminary remediation goals (PRG). These levels are not legally enforceable for public water utilities, but they can be useful when putting laboratory results in context for comparison.

- HAs identify the concentration levels of a constituent of concern in drinking water at which or below which adverse health effects are not anticipated to occur over a lifetime of exposure.

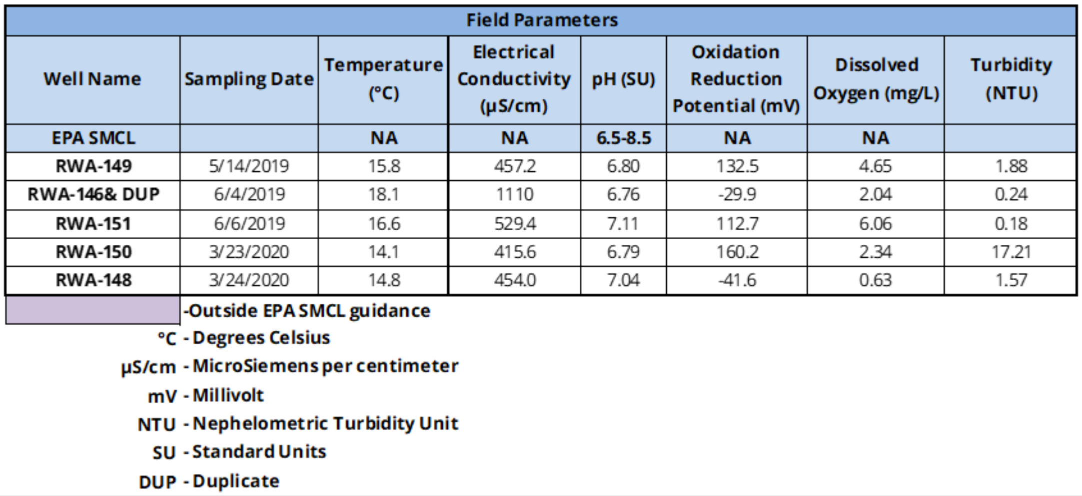
- RSLs are a screening tool that the EPA sets for CERCLA sites. They are calculated by combining exposure assumptions with chemical-specific toxicity in humans. If an RSL is met or exceeded, then further investigation or cleanup may be necessary because of a concern about adverse health effects.

- PRGs are calculated during the risk-assessment stage of a CERCLA regulated project to identify levels of a constituent which a cleanup project aims to reach. PRGs are concentration levels that correspond to a specific lifetime excess cancer risk level, (i.e. $10^{-4}$ or $10^{-6}$). PRGs may be modified throughout a cleanup project as more site-specific information becomes available. PRGs are concentration levels that correspond to a specific excess lifetime cancer risk level of $10^{-6}$. If a radionuclide exceeds a target risk (TR) of $10^{-6}$, then the risk of a groundwater consumer contracting cancer is one in one million (1 in 1,000,000) above the normal chances of developing cancer. For more information on EPA’s drinking water standards, visit https://www.epa.gov/dwstandardsregulations or https://www.epa.gov/risk.

## Field Parameters

Temperature, electrical conductivity, pH, oxidation-reduction potential (ORP), dissolved oxygen, and turbidity were measured during the initial purging of the wells. Table 7.1.3 shows the final stable readings taken immediately before collecting samples at each sampling event. The only field parameter with a comparison criterion is pH (normal ground water pH= 6.5 to 8.5). All the wells are within the EPA SMCL criteria for pH concentrations.

**Table 7.1.3: Field Parameters**



| Field Parameters | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Well Name** | **Sampling Date** | **Temperature (°C)** | **Electrical Conductivity (µS/cm)** | **pH (SU)** | **Oxidation Reduction Potential (mV)** | **Dissolved Oxygen (mg/L)** | **Turbidity (NTU)** |
| **EPA SMCL** | | **NA** | **NA** | **6.5-8.5** | **NA** | **NA** | |
| **RWA-149** | 5/14/2019 | 15.8 | 457.2 | 6.80 | 132.5 | 4.65 | 1.88 |
| **RWA-146& DUP** | 6/4/2019 | 18.1 | 1110 | 6.76 | -29.9 | 2.04 | 0.24 |
| **RWA-151** | 6/6/2019 | 16.6 | 529.4 | 7.11 | 112.7 | 6.06 | 0.18 |
| **RWA-150** | 3/23/2020 | 14.1 | 415.6 | 6.79 | 160.2 | 2.34 | 17.21 |
| **RWA-148** | 3/24/2020 | 14.8 | 454.0 | 7.04 | -41.6 | 0.63 | 1.57 |

▨ **-Outside EPA SMCL guidance**
**°C - Degrees Celsius**
**µS/cm - MicroSiemens per centimeter**
**mV - Millivolt**
**NTU - Nephelometric Turbidity Unit**
**SU - Standard Units**
**DUP - Duplicate**

### Volatile Organics

All the volatile organic analytical results were “U”, or undetected, for samples in both FY2019-FY2020 and in the most recent historical samples for these sites.

### Metals

There were less exceedances in the most recent data from the wells (Table 7.1.4). One well, RWA-151 had zero exceedances in both samples. RWA-149 went from having no exceedances in the most recent historical sample to having one aluminum SMCL exceedance. RWA-146 also increased in exceedances from the most recent historical sample to the one collected on 6/4/2019. Iron SMCL exceedance in RWA-146 went up from the historical sample to the sample and duplicate collected on 6/4/2019. Sodium HA also increased slightly from the historical sample to the most recent sample and duplicate. RWA-146 and DUP (6/4/2019) had a new RSL exceedance of lithium. There were iron SMCL and sodium HA exceedances in both samples from 2020, RWA-150 and RWA-148. Iron increased and sodium decreased in both wells.

## Table 7.1.4: Metals

| Metals Results | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | FY 2019 - FY 2020 | | | | | | Most Recent Historical Data | | | | | | | |
| Analyte | Units | EPA national primary drinking water standards MCL | EPA drinking water standards SMCL (March 2018) | EPA RSLs PRG (tapwater) (Nov 2017) | EPA Health Advisory (lifetime) from the "2018 edition of drinking water standards and health advisory tables" | RWA-149 | RWA-146 | RWA-146 DUP | RWA-151 | RWA-150 | RWA-148 | RWA-149 | RWA-146 | RWA-151 | RWA-150 | RWA-148 | RWA-147 | RWA-152 | RWA-152 DUP |
| Date | | | | | | 5/14/2019 | 6/4/2019 | 6/4/2019 | 6/6/2019 | 3/23/2020 | 3/24/2020 | 3/15/2018 | 11/6/2017 | 11/7/2017 | 9/27/2016 | 9/22/2016 | 3/1/2018 | 10/5/2016 | 10/5/2016 |
| aluminum | µg/L | | 50-200 | | | 58.4 | U | U | U | 26.8 | U | 11.0 | U | 4.73J | U | U | 25.0 | 37.0 | U |
| antimony | µg/L | 6 | | | 6 | U | U | | U | U | U | U | U | U | U | U | U | U | U |
| arsenic | µg/L | 10 | | 0.052 | | U | U | U | U | 8.63 | 2.89J | U | U | U | 0.95J | 3.7J | U | U | U |
| barium | µg/L | 2,000 | | 3,800 | | 28.5 | 49.1 | 49.2 | 18.7 | 147 | 20.3 | 31.4 | 50.3 | 22.8 | 88 | 19 | 27.8 | 130 | 130 |
| beryllium | µg/L | 4 | | 4 | | U | U | U | U | U | U | U | U | U | U | U | U | U | U |
| boron | µg/L | | | 4,000 | 6000 | 108 | 313 | 310 | 55.1 | 130 | 188 | 55.5 | 285 | 71.7 | 310 | 290 | 98.8 | 37 | 35 |
| cadmium | µg/L | 5 | | 9.2 | 5 | U | U | U | U | U | U | U | U | U | U | U | U | U | U |
| calcium | mg/L | | | | | 54.7 | 102.0 | 103 | 60.3 | 36.8 | 38.8 | 69.9 | 105 | 63.8 | 21 | 31 | 46.1 | 50 | 50 |
| chromium | µg/L | 100 | | | | U | U | U | U | U | U | U | U | U | 1.9J | 1.2J | U | U | U |
| copper | µg/L | 1,300 | 1000 | | | 2.98 | 144 | 4.52 | 13.4 | 8.86 | 1.85 | 3.82 | 0.612J | 64.6 | 2.4 | 3 | 2.00 | 20 | 18 |
| iron | µg/L | | 300 | 14000 | | 138 | 1,030 | 1,110 | 18.8 | 3,200 | 396 | 57.7 | 768 | 47.4 | 49 | 350 | 8,090 | 310 | 310 |
| lead | µg/L | 15 | | 15 | | 0.467J | 0.598J | U | 0.396J | 0.574J | 0.145J | 0.956J | U | 2.32 | U | 0.28J | U | U | U |
| lithium | µg/L | | | 40 | | 3.65 | 43.8 | 42.4 | 12.0 | 28.5 | 16.2 | 13.4 | 39.6 | 17.4 | 18 | 23 | 31.0 | 24 | 23 |
| magnesium | mg/L | | | | | 29.9 | 92.2 | 90.4 | 34.0 | 20.5 | 15.0 | 32.1 | 94.8 | 35.1 | 12 | 12 | 17.1 | 27 | 27 |
| manganese | µg/L | | 50 | non diet 430 | 300 | 10.3 | 26.6 | 25.2 | 6.14 | 102 | 26.9 | 5.53 | 16.7 | 18.5 | 5.5 | 19 | 307 | 230 | 220 |
| mercury | µg/L | 2 | | 0.63 | 2 | U | U | U | U | U | U | U | U | U | U | U | U | U | U |
| nickel | µg/L | | | | 100 | 1.72 | 1.91 | 2.1 | 1.96 | 1.25 | 0.655J | 2.48 | 2.65 | 3.37 | 1 | 1.2 | 25.2 | 3.3 | 2.8 |
| potassium | mg/L | | | | | 1.11 | 5.89 | 5.91 | 1.19 | 4.38 | 5.67 | 1.44 | 5.53 | 1.75 | 3.5 | 5.6 | 3.71 | 3.3 | 3.3 |
| selenium | µg/L | 50 | | 100 | 50 | 3.25J | U | U | 3.31J | U | U | 3.82 | U | 3.07J | U | U | U | U | U |
| silver | µg/L | | 100 | 94 | 100 | U | U | U | U | U | U | U | U | U | U | U | U | U | U |
| sodium | mg/L | | | | 20 | 3 | 33.5 | 33.7 | 5.57 | 26.9 | 39.4 | 5.61 | 29.6 | 8.15 | 64 | 94 | 10.5 | 13 | 13 |
| strontium | µg/L | | | stable 12,000 | 4,000 | 127 | 2,050 | 1,830 | 327 | 334 | 1,420 | 264 | 1,800 | 576 | 320 | - | 357 | 180 | 160 |
| thallium | µg/L | 2 | | | | U | U | U | 0.775J | U | U | U | U | U | U | U | U | U | U |
| uranium | µg/L | 30 | | | | 0.391J | 0.431J | 0.399j | 0.317J | U | U | 0.413J | U | 0.374J | U | U | U | U | U |
| vanadium | µg/L | | | 86 | | U | U | U | U | U | U | U | U | U | U | U | U | 11 | 10 |
| zinc | µg/L | | 5,000 | 6,000 | 2,000 | 8.80 | 3.02J | U | 4.09J | 17.7 | 3.07J | 10.6 | 3.04J | 42.8 | 4.0J | 9.3 | 31 | 10 | 8.8 |
| total hardness | mg/L | | | | | 260 | 636 | 629 | 291 | 176 | 159 | 307 | 653 | 304 | 99 | 120 | 186 | 240 | 240 |

🟧 - EPA MCL Exceedance

🟧 - EPA SMCL Exceedance

🟫 - EPA RSL Exceedance

🟪 - EPA HA Exceedance

🟦 - Comparison Values used

⬜ -Data not yet Received

🟥 -No Previous DoR OR Data

DUP -Duplicate

J - Estimated Value

U - Undetected

NR -Not Reported

µg/L - micrograms per liter

mg/L -milligrams per liter

### Inorganics

There was only one well both in the FY2019-FY2020 and most recent historical samples that had exceedances for any inorganics, RWA-146 (Table 7.1.5). From 2017 to 2019, sulfate decreased, and total dissolved solids increased in the well. The other samples are all under comparison criteria.

## Table 7.1.5: Inorganics

| Inorganic Results (mg/L) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | FY 2019 - FY 2020 | | | | | | Most Recent Historical Data | | | | | | | |
| Analyte | EPA national primary drinking water standards MCL | EPA drinking water standards SMCL (March 2018) | EPA RSLs PRG (tapwater) (Nov 2017) | EPA Health Advisory (lifetime) from the "2018 edition of drinking water standards and health advisory tables" | RWA-149 | RWA-146 | RWA-146 DUP | RWA-151 | RWA-150 | RWA-148 | RWA-149 | RWA-146 | RWA-151 | RWA-150 | RWA-148 | RWA-147 | RWA-152 | RWA-152 DUP |
| Date | | | | | 5/14/2019 | 6/4/2019 | 6/4/2019 | 6/6/2019 | 3/23/2020 | 3/24/2020 | 3/15/2018 | 11/6/2017 | 11/7/2017 | 9/27/2016 | 9/22/2016 | 3/1/2018 | 10/5/2016 | 10/5/2016 |
| ammonia | | | | | U | 0.224 | 0.244 | 0.419 | U | 0.479 | NR | 0.245 | 1.16 | 0.15 | 0.61 | - | 0.17 | 0.19 |
| chloride | | 250 | | | 2.20J | 3.16 | 3.34 | 2.23J | 1.99J | 5.96 | 2.30J | 2.99 | 1.88J | 0.28 | 17 | 1.82 | 15 | 15 |
| fluoride | 4 | 2 | | | 0.141 | 0.120 | 0.120 | NR | 0.318 | 0.216 | 0.201 | 0.135 | 0.160 | 0.440 | 0.32 | 0.446 | 0.12 | 0.12 |
| nitrate and nitrite | 10 | | | 10 | 0.331 | U | U | 0.0956J | 0.400 | 0.0273J | 0.719 | U | 0.0763J | 0.37 | U | U | U | U |
| sulfate | | 250 | | | 18.6 | 252 | 273 | 36.2 | 20.8 | 46.8 | 46.6 | 281 | 47.5 | 29 | 93 | 82.5 | 16 | 16 |
| total dissolved solids | | 500 | | | 259 | 741 | 731 | 266 | 219 | 246 | 312 | 501 | 318 | 260 | 230 | 274 | 230 | 230 |
| total alkalinity | | | | | 228 | 357 | 366 | 246 | 194 | 180 | 244 | 399 | 279 | 210 | 390 | 128 | U | 300 |

| | | | |
|---|---|---|---|
| 🟧 | - EPA MCL Exceedance | DUP | -Duplicate |
| 🟨 | - EPA SMCL Exceedance | J | - Estimated Value |
| 🟫 | - EPA RSL Exceedance | U | - Undetected |
| 🟪 | - EPA HA Exceedance | mg/L | -milligrams per liter |
| 🟦 | - Comparison Values used | NR | -Not Reported |
| 🟥 | -No Previous DoR OR Data | | |

### Radiochemical Analytes

Only four samples from FY2019-FY2020 and the most recent historical samples had comparison criteria exceedances, Table 7.1.6. RWA-146 had an EPA MCL exceedance of radium-226 in the most recent historical sample, however it went down in the sample from 2019. There were a few EPA PRG exceedances. RWA-149 exceeded the EPA PRG for curium-245/246 in the most recent historical sample and decreased to below detection level in the most recent sample. Two wells, RWA-148 and RWA-150, went from no comparison criteria exceedances in the most recent historical sample to exceeding the EPA PRG for both uranium-233/234 and uranium-238. RWA-150 also exceeded the EPA PRG for uranium-235/236.

# Table 7.1.6.a: Radiochemical Analytes – Part 1

| | | | Radiochemical Results (pCi/L) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Well Name | Date | bismuth-214 | lead-214 | Gross Alpha | Gross Beta | radium-226 | radium-228 | strontium-89 | strontium-90 | technetium-99 | tritium |
| | EPA National Primary Drinking Water Standards 2018 MCLs | NA | | | 15 | 50 | 1 | 1 | | | | |
| | EPA PRG tapwater TR=1E-6 Nov 2014 | NA | 270 | 150 | | | | | | | | |
| | NBS Handbook 69 (correlation of pCi/L to 4mrem/year (TR=1E-4)) | NA | | | | | | | 20 | 8 | 900 | 20,000 |
| FY 2019 - FY 2020 | RWA-149 | 5/14/2019 | 74 | 72 | 0.59 BDL | 2.36 BDL | 0.24 BDL | -0.55 BDL | -1.27 BDL | 0.218 BDL | 0.31 BDL | 39 BDL |
| | RWA-146 | 6/4/2019 | 174 | 152 | 4.53 | 6.1 | 0.78 | 0.42 BDL | 0.96 | 0.07 | 0.06 BDL | -19 BDL |
| | RWA-146 DUP | 6/4/2019 | 171 | 150 | 3.96 | 7.73 | 0.98 BDL | -0.08 BDL | -3.2 BDL | 1.2 | -0.38 BDL | -16 BDL |
| | RWA-151 | 6/6/2019 | 30 | NDA | 1.27 BDL | 1 BDL | 0.38 BDL | -0.56 BDL | 0.63 | -0.2 BDL | -0.15 BDL | -15 BDL |
| | RWA-150 | 3/23/2020 | 42.9 | 36.7 | 1.93 | 6.3 | 0.16 | -0.2BDL | 1.90 | 0.18 BDL | 0.36 BDL | -48 BDL |
| | RWA-148 | 3/24/2020 | 49 | 28.2 | 0.79 BDL | 4.5 | 0.12 BDL | -0.58 BDL | 4.80 | -0.61 BDL | 0.44 BDL | 29 BDL |
| Most Recent Historical Data | RWA-149 | 3/15/2018 | 67 | 56.1 | 2.41 | 1.4 BDL | 0.2 BDL | 0.78 | -0.5 BDL | 0.48 BDL | 0.22 BDL | 3 BDL |
| | RWA-146 | 11/6/2017 | 47 | 44.9 | 3.78 | 7.2 | 1.06 | 0.35 BDL | -0.75 BDL | 0.21 BDL | -0.26 BDL | -46 BDL |
| | RWA-151 | 11/7/2017 | NR | 13 | 0.8 BDL | 0.6 BDL | 0.95 | -0.08 BDL | -0.18 BDL | -0.19 BDL | -0.2 BDL | 54 BDL |
| | RWA-150 | 9/27/2016 | 19.6 | 19.2 | -0.19 BDL | 2.8 BDL | 0.24 BDL | -0.10 BDL | -0.17 BDL | 0.52 | 0.62 BDL | 35 BDL |
| | RWA-148 | 9/22/2016 | 25 | 17.7 | 0.59 BDL | 5.4 | 0.23 BDL | 0.28 BDL | 0.27 BDL | -0.10 BDL | -0.13 BDL | 99 |
| | RWA-147 | 3/1/2018 | 122 | 107 | 1.61 BDL | 1.1 BDL | -0.14 BDL | -0.07 BDL | -3.21 BDL | 0.85 BDL | -0.01 BDL | 20 BDL |
| | RWA-152 | 10/5/2016 | 21.2 | 14.2 | -0.03BDL | 16.2 | -0.59 BDL | 0.30 | 0.24 BDL | -0.21 BDL | 0.22 BDL | -6 BDL |
| | RWA-152 DUP | 10/5/2016 | 18.5 | 22.4 | -0.11 BDL | 16.1 | -0.51 BDL | 0.29 | 0.38 BDL | -0.22 BDL | 0.77 | 26 BDL |

🟧 **- EPA MCL Exceedance**
🟧 **- EPA SMCL Exceedance**
🟫 **- EPA PRG Exceedance**
🟪 **- EPA HA Exceedance**

**DUP -Duplicate**
**TR -Target Risk**
**pCi/L - picoCuries per liter**
**BDL -Below Detection Limit**
**NDA - Not Detected Analyte**
**NR -Not Reported**

# Table 7.1.6.b: Radiochemical Analytes – Part 2

| | | | Radiochemical Results (pCi/L) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Well Name** | **Date** | **americium-241** | **curium-242** | **curium-243/244** | **curium-245/246** | **neptunium-237** | **plutonium-238** | **plutonium-239/240** | **uranium-233/234** | **uranium-235/236** | **uranium-238** |
| | **EPA National Primary Drinking Water Standards 2018 MCLs** | **NA** | | | | | | | | | | |
| | **EPA PRG tapwater TR=1E-6 Nov 2014** | **NA** | 0.5 | 1.4 | Cm-243=0.55; Cm-244=0.62 | Cm-245=0.50; Cm-244=0.51 | 0.84 | 0.4 | Pu-239=0.39; Pu-240=0.39 | U-233=0.73; U-234=0.74 | U-235=0.75; U-236=0.78 | 0.82 |
| | **NBS Handbook 69 (correlation of pCi/L to 4mrem/year (TR=1E-4))** | **NA** | | | | | | | | | | |
| **FY 2019 - FY 2020** | **RWA-149** | **5/14/2019** | -0.001 BDL | 0 BDL | 0.025 BDL | -0.001 BDL | 0.024 BDL | 0.058 BDL | 0.062 | 0.433 | 0.07 BDL | 0.136 |
| | **RWA-146** | **6/4/2019** | 0.016 BDL | 0.003 BDL | -0.014 BDL | 0.02 BDL | -0.026 BDL | 0.06 BDL | 0.054 | 0.384 | 0.044 BDL | 0.097 |
| | **RWA-146 DUP** | **6/4/2019** | 0 BDL | 0.005 BDL | 0.023 BDL | -0.014 BDL | 0.015 BDL | 0.03 BDL | 0.032 BDL | 0.241 | 0.079 | 0.206 |
| | **RWA-151** | **6/6/2019** | 0.015 BDL | -0.005 BDL | 0.003 BDL | 0.049 BDL | 0.018 | 0.057 BDL | 0.029 BDL | 0.53 | 0.04 BDL | 0.028 BDL |
| | **RWA-150** | **3/23/2020** | 0.38 BDL | 0.06 BDL | -0.02 BDL | 0.22 BDL | 0 BDL | -0.06 BDL | 0.05 BDL | 2.11 | 0.76 | 1.27 |
| | **RWA-148** | **3/24/2020** | 0.21 BDL | 0.02 BDL | 0.13 BDL | 0.32 BDL | -0 BDL | 0.02 BDL | -0.06 BDL | 1.02 | 0.62 | 0.91 |
| **Most Recent Historical Data** | **RWA-149** | **3/15/2018** | 0.003 BDL | -0.001 BDL | 0.022 BDL | 0.633 | 0.008 BDL | 0.046 BDL | 0.046 BDL | 0.589 | 0.03 BDL | 0.176 |
| | **RWA-146** | **11/6/2017** | -0.013 BDL | 0.016 BDL | 0.013 BDL | -0.01 BDL | 0.019 BDL | 0.062 BDL | 0.025 BDL | 0.292 | 0.063 | 0.178 |
| | **RWA-151** | **11/7/2017** | 0.023 BDL | -0.009 BDL | 0.035 BDL | 0.033 BDL | 0.015 BDL | 0.09 | 0.054 | 0.418 | 0.027 BDL | 0.184 |
| | **RWA-150** | **9/27/2016** | -0.005 BDL | -0.020 BDL | 0.000 BDL | 0.015 BDL | 0.04 BDL | 0.138 | NR | 0.037 BDL | 0.018 BDL | 0.006 BDL |
| | **RWA-148** | **9/22/2016** | 0.019 BDL | 0.012 | 0.000 BDL | 0.010 BDL | 0.027 BDL | 0.063 BDL | NR | 0.179 | 0.075 | 0.077 |
| | **RWA-147** | **3/1/2018** | -0.006 BDL | 0.008 BDL | -0.038 BDL | 0.008 BDL | 0 BDL | 0.019 BDL | 0.044 | 0.072 | 0.018 BDL | 0.047 |
| | **RWA-152** | **10/5/2016** | 0.017 BDL | 0.011 BDL | -0.069 BDL | 0.127 BDL | 0.015 BDL | 0.243 | NR | 0.137 | 0.027 | 0.059 |
| | **RWA-152 DUP** | **10/5/2016** | -0.010 BDL | -0.027 BDL | -0.042 BDL | 0.010 BDL | -0.034 BDL | 0.005 BDL | NR | 0.095 | 0.010 BDL | 0.112 |

🟧 **- EPA MCL Exceedance**
🟨 **- EPA SMCL Exceedance**
🟫 **- EPA PRG Exceedance**
🟪 **- EPA HA Exceedance**

**DUP -Duplicate**
**TR -Target Risk**
**pCi/L - picoCuries per liter**
**BDL -Below Detection Limit**
**NDA - Not Detected Analyte**
**NR -Not Reported**

### 7.1.8 Conclusions

The results from this limited data set represent a snapshot in time and are not resultant from a continuous monitoring effort. Groundwater quality in the fractured rocks and bedrock aquifers can change rapidly. Hydrologic characteristics can fluctuate between geographically proximal locations, and therefore it is difficult to make predictions on potential contaminant pathways and sources of contamination with data from one sampling event. This report documents mostly low concentrations, low activities, and sporadic detections of contaminants that may be a result of human activity. This limited data set has a small number of detections above health-based criteria. Sporadic detections of transuranic isotopes occur in residential well groundwater. No determination regarding potential sources of the identified constituents has been made at this time.

The contamination of groundwater beneath several areas of the ORR and the potential for contaminant migration beyond the ORR boundary make it imperative to continue the monitoring of offsite residential wells that may be a primary or sole source of drinking water for some local residents in Anderson, Loudon, and Roane counties.

### 7.1.9 Recommendations

Recommendation for future TDEC DoR-OR groundwater projects include:

Focus limited resources to sampling offsite the ORR one valley at a time; compare the results to onsite data results. The first focus is intended to be Bear Creek Valley to make up for the budget cuts during FY2020.

Take an in-depth look at the TDEC DoR-OR offsite historical groundwater data in conjunction with DOE offsite data to help guide future groundwater decisions.

Conduct a data search for each valley and analyze onsite data focusing on the main COCs from each main area (Y-12, ORNL, ETTP), to evaluate impacts to offsite receptors.

### 7.1.10 References

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## 7.2 HISTORICAL GROUNDWATER TRENDS

### 7.2.1 Background

The primary intent of the TDEC DoR-OR groundwater projects has been to protect human health and the environment by monitoring for possible DOE legacy contamination that may have migrated from the ORR into the surrounding areas.

Groundwater samples have been collected and analyzed by TDEC DoR-OR since the late 1990s. In the beginning, only springs and offsite groundwater wells, located south and southwest of ORR, were sampled. Background groundwater samples from residential wells and springs, north and northeast, were added to the groundwater program in 2016 to establish a baseline for groundwater on the ORR and its surrounding areas. In 2009 and 2010, the list of analytes increased to include common groundwater cations, anions, metals, and individual radiochemical and transuranic analytes (in addition to gross alpha and gross beta).

While data has been collected by TDEC DoR-OR for many years, a comprehensive TDEC DoR-OR data evaluation of trends over time had not been completed.

This Historical Groundwater Trend Project will evaluate and summarize previous TDEC DoR-OR groundwater project data, encompassing approximately a twenty-year time span. This data may be used to assess data gaps in current monitoring programs and should help guide future TDEC DoR-OR groundwater sampling efforts and offsite groundwater remedial decisions.

Although this project focused on TDEC DoR-OR data, this project correlates to the DOE groundwater projects across the ORR, including:

- Melton Valley / Bethel Valley Exit Pathway Remedial Investigation Work Plan
- Offsite Groundwater Assessment Remedial Site Evaluation projects
- Groundwater Strategy for the DOE ORR

### 7.2.2 Problem Statements

Offsite groundwater samples have been collected and analyzed by TDEC DoR-OR since the late 1990s. There has been little to no trend analyses performed on historical data which makes it challenging to analyze the spatial and temporal data and draw conclusions for future remedial work. TDEC DoR-OR's offsite groundwater data includes offsite residential wells, background residential wells, and springs surrounding the ORR.

These data sets are currently housed separately but need to be combined and evaluated holistically. The lack of data from a trend analysis or baseline restricts TDEC DoR-OR's data evaluation and project planning. A solid understanding of current site conditions and historical impacts is needed to support complete and informed FFA decision-making related to groundwater. This project will also enhance TDEC DoR-OR's monitoring and oversight of the DOE ORR remedial processes.

### 7.2.3 Goals

The Historical Groundwater Project was intended to organize and analyze historical TDEC DoR-OR data from offsite wells, background wells, and local springs. The project's goal was to illustrate possible trends throughout time and relate them spatially.

The main objectives follow:

- Compare TDEC DoR-OR historical laboratory data from offsite wells, background wells, and spring locations
- Create a baseline of the wells sampled, analytes sampled, and years sampled
- Use graphing and mapping technology to determine possible trends
- Make recommendations on future sampling locations and sample analytes

### 7.2.4 Scope

TDEC DoR-OR began groundwater sample collection in the late 1990s. The number of analytes that were evaluated and the counting time requirements used for radiochemical analytes increased during the 2009-2010 timeframe, which greatly enhanced the data set.

This project started with current data and worked backwards through time to analyze the TDEC DoR-OR laboratory data. This project encompasses a large amount of data and is categorized in five-year increments, to correlate with DOE's five-year Remedial Effectiveness Review cycle as seen in the *2017 Remediation Effectiveness Report* (RER) requirements.

- Data set 1: 2016-2021
- Data set 2: 2010-2015
- Data set 3: 2004-2009
- Data set 4: 2003-1996

### 7.2.5 Methods, Materials, Metrics

Where data remains in hard copy format, the existing analytical data was gathered, organized, and digitized. Statistics, tables, graphs, maps etc. were planned to be generated using various statistical methods, graphing, and mapping technology. This technology included software such as MS Excel and ArcGIS. The analyses were conducted using basic geochemical assessment tools such as ternary diagrams, piper plots, etc. The COCs were graphed and mapped to show any possible temporal and spatial trends and potential fingerprint patterns for constituent combinations in various wells.

Data sets were managed carefully to preserve laboratory data information and to standardize the reporting formats. The data were separated among the various groundwater projects including offsite, background, White Wing Road, and springs.

### 7.2.6 Deviations from the Plan

The plan for Phase 1 included analyzing data from 2016-2021, however the data used ended in 2020. The 2020 data is a very limited data set with only including two wells. The plan was to analyze the data using GIS and Excel, however the GIS licenses for various extensions such as the spatial analyst tools were not always available, hindering this initial effort.

### 7.2.7 Results and Analysis

#### Analytes

Some of the data set analyses and comparisons were incomplete due to the fact that the background and springs groundwater project data spanned a very short time period (background 2016-2018; springs 2016)—refer to Table 7.2.1. The springs project’s limited analyte list did not compare well with the other groundwater projects broad analyte list. Additionally, the springs field parameters were not in the digital database, rather they were recorded in the project field books. Because the DoR-OR office was closed due to COVID-19 restrictions, access to records and field books was greatly limited. Further compilation of this data is expected to continue in further projects.

The analyte tables from the respective projects are shown in Tables 7.2.2, 7.2.3, and 7.2.4.

**Table 7.2.1: Wells and Springs showing when they were sampled.**

| STATION | PROJECT | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|
| CRBR057 | O |  | ■ |  |  |  |
| CRBR067/074 | O |  | ■ |  |  |  |
| CRBR-076 | O |  |  | ■ |  |  |
| Delightful Spring | B |  | ■ |  |  |  |
| Lovely Spring | B | ■ | ■ |  |  |  |
| RWA-029 | O | ■ | ■ | ■ |  |  |
| RWA-035 | O |  |  | ■ |  |  |
| RWA-047 | O | ■ | ■ |  |  |  |
| RWA-060 | O | ■ |  |  |  |  |
| RWA-071 | O | ■ |  |  |  |  |
| RWA-079 | O |  | ■ |  |  |  |
| RWA-097 | O | ■ |  |  |  |  |
| RWA-100 | O | ■ |  |  |  |  |
| RWA-106 | O | ■ |  |  |  |  |
| RWA-116 | O |  | ■ |  |  |  |
| RWA-117 | O |  | ■ |  |  |  |
| RWA-118 | O |  | ■ | ■ |  |  |
| RWA-127 | O |  |  |  | ■ |  |
| RWA-128 | O | ■ | ■ | ■ |  |  |
| RWA-129 | O |  |  | ■ |  |  |
| RWA-132 | O |  |  | ■ |  |  |
| RWA-139 | O | ■ |  |  |  |  |
| RWA-142 | O | ■ |  | ■ |  |  |
| RWA-145 | B | ■ |  | ■ |  |  |
| RWA-146 | O | ■ | ■ |  | ■ |  |
| RWA-147 | O | ■ |  | ■ |  |  |
| RWA-148 | O | ■ |  |  |  | ■ |
| RWA-149 | O | ■ |  | ■ | ■ |  |
| RWA-150 | O | ■ |  |  |  | ■ |
| RWA-151 | O | ■ | ■ |  | ■ |  |
| RWA-152 | O | ■ |  |  |  |  |
| RWA-153 | O |  |  |  |  |  |
| RWA-154 | B |  |  |  |  |  |
| RWA-155 | B | ■ |  | ■ |  |  |
| RWA-156 | B | ■ |  |  |  |  |
| RWA-157 | B | ■ |  | ■ |  |  |
| RWA-158 | B | ■ | ■ |  |  |  |
| RWA-159 | O | ■ |  |  |  |  |
| RWA-160 | O |  | ■ | ■ |  |  |
| RWA-161 | O |  | ■ |  |  |  |
| RWA-162 | O |  | ■ |  |  |  |
| RWA-163 | B |  |  | ■ |  |  |
| RWA-164 (DOE CRBR-071) | O |  |  | ■ |  |  |
| Syn-164 | O |  |  |  | ■ |  |
| WW06 | W | ■ |  |  |  |  |
| WW07 | W | ■ |  |  |  |  |
| WW09 | W | ■ |  |  |  |  |
| WW10 | W | ■ |  |  |  |  |
| WW11 | W | ■ |  |  |  |  |
| WW12 | W | ■ |  |  |  |  |
| SPG-055 | S |  | ■ |  |  |  |
| SPG-081 | S |  | ■ |  |  |  |
| SPG-046 | S |  | ■ |  |  |  |
| SPG-064 | S |  | ■ |  |  |  |
| SPG-063 | S |  | ■ |  |  |  |

**B** -Background
**O** -Offsite
**W** -White Wing Road
**S** -Springs

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## Table 7.2.2: Groundwater Analyte List for Offsite, Background, and White Wing Road projects.

| Groundwater Analyte List for Offsite, Background, and White Wing Road Projects | | |
|---|---|---|
| **VOCs** | | |
| EPA 8260 B list for low level detection[1] | | |
| **METALS** | | |
| aluminum | copper | selenium |
| antimony | iron | silver |
| arsenic | lithium | sodium |
| barium | lead | strontium |
| beryllium | magnesium | thallium |
| boron | manganese | uranium |
| cadmium | mercury | vanadium |
| calcium | nickel | zinc |
| chromium | potassium | total hardness, as calcium carbonate |
| **INORGANICS** | | |
| calcium carbonate alkalinity | total dissolved solids | nitrate and nitrite |
| chloride | sulfate | ammonia |
| fluoride | | |
| **RADIONUCLIDES** | | |
| gross alpha | tritium | radium-228 |
| gross beta | gamma radionuclides[2] | isotopic uranium |
| strontium-89 | technetium-99 | transuranic radionuclides |
| strontium-90 | radium-226 | |

[1] EPA-8260 B- volatile organic compound analyses list: https://www.epa.gov/sites/production/files/2015-12/documents/8260b.pdf

[2] gamma list includes: Ra-226, Pb-210, Pb-212, Pb-214, Tl-206, Tl-208, Bi-212, Bi-214, K-40

## Table 7.2.3: Spring Analyte List

| Groundwater Analyte List for Springs | |
|---|---|
| gross alpha | tritium |
| gross beta | strontium-89 |
| lead-214 | strontium-90 |
| bismuth-214 | technetium-99 |

### Table 7.2.4: Field Parameters for all projects except springs

| Water Quality Indicator Parameters | | |
|---|---|---|
| **Measurement (units)** | **Normal Range** | **Acceptable Variability[1]** |
| Temperature (°C) | 10 to 18 | ± 10% |
| pH (SU) | 4.6 to 8.5 | ± 0.1 |
| Specific Conductivity (µS/cm) | 10 to 8,000 | ± 5% |
| Turbidity (NTU) | variable | ± 10% |
| ORP[Eh](mV) | variable | ± 10 mv |

**[1] Acceptable variability over four consecutive readings.**

**°C- Degrees Celsius**

**µS/cm- MicroSiemens per centimeter**

**mV- Millivolt**

**NTU- Nephelometric Turbidity Unit**

**SU- Standard Units**

**ORP- Oxidation Reduction Potential**

**Eh- Reduction Potential**

**Regulatory Comparison Values**

The results of the analyses from the private wells sampled were compared to EPA standards. It is important to note that these standards are not enforceable on private wells, they are used for comparison only. The EPA has established the National Primary Drinking Water Regulations (NPDWR) to maintain good quality water in public water supplies. These criteria include Maximum Contaminant Levels (MCLs) and Secondary Maximum Contaminant Levels (SMCLs).

- MCLs are standards used to protect people by limiting levels of harmful contaminants in public drinking water supplies. They are legally enforceable rules for public water utilities.

- SMCLs are associated with public acceptance of water. These constituents include characteristics such as taste, odor, and color, as well as the staining of teeth, clothing, or fixtures. SMCLs are only guidelines for public water utilities.

When EPA MCLs and SMCLs are not available for a particular analyte, other EPA criteria for comparison values are used. These EPA guidelines include Health Advisories (HA), Regional Screening Level (RSL), and Preliminary Remediation Goals (PRG). These levels are not enforceable for public water utilities, but they can be useful when putting laboratory results in context for comparison.

- HAs identify the concentration levels of a constituent of concern in drinking water at which or below which adverse health effects are not anticipated to occur over a lifetime of exposure. HA's are non-regulatory.
- RSLs are a screening tool that the EPA sets for CERCLA sites. They are calculated by combining exposure assumptions with chemical-specific toxicity in humans. If an RSL is met or exceeded, then further investigation or cleanup may be necessary because of a concern about adverse health effects.
- PRGs are calculated during the risk-assessment stage of a CERCLA regulated project to identify levels of a constituent which a cleanup project aims to reach. PRGs are concentration levels that correspond to a specific excess lifetime cancer risk level, (i.e. $1 \times 10^{-4}$ or $1 \times 10^{-6}$). PRGs may be modified throughout a cleanup project as more site-specific information becomes available. PRGs are concentration levels that correspond to a specific excess lifetime cancer risk level of $10^{-6}$. If a radionuclide exceeds a target risk (TR) of $1 \times 10^{-6}$, then the risk of a consumer contracting cancer is one in one million (1 in 1,000,000) above the normal risk of developing cancer. For more information on EPA's drinking water standards, visit https://www.epa.gov/dwstandardsregulations. or https://www.epa.gov/risk.

**All Analytes: Data Tables**

**Field Parameters**

Temperature, electrical conductivity, pH, oxidation-reduction potential (ORP), dissolved oxygen, and turbidity were measured during the initial purging of wells from past studies. Table 7.2.5 shows the final stable readings taken immediately before collecting samples at each sampling event. The springs groundwater project does not have field parameters reported in this report. There were three wells with pH above the EPA SMCL criteria and one well that was below the criteria twice. The locations of these wells are shown in Figure 7.2.1.

In addition to field parameters, well depths were provided by the well owners. These well depths are shown in Figure 7.2.2.

**Volatile Organics**

There were no detections or exceedances for volatile organic analytes for the 2016-2020 samples.

### Metals

There were a few wells with comparison criteria exceedances. Nine samples from seven wells exceeded the sodium HA criteria. There were 20 samples, with aluminum SMCL exceedances including three samples with their duplicate and twelve locations. There were three samples from the same location, RWA-047, that exceeded the lead MCL. Eight samples, four locations, exceeded the manganese SMCL. There was only one sample, RWA-047 2/16/2017, that exceeded the zinc SMCL. Nine samples, seven locations, exceeded the iron SMCL. Five samples, four locations, exceeded the lithium RSL PRG. Refer to Table 7.2.6 for a representation of the exceedances only. For a full data set inclusive of all parameters sampled please contact TDEC DOR-OR and complete a public information request. Data will be available upon request.

### Inorganics

There was only one well, RWA-146, that had inorganic exceedances. RWA-146 exceeded the sulfate and total dissolved solids EPA SMCL every time it was sampled. Refer to Table 7.2.7 for a representation of the exceedances only. For a full data set inclusive of all parameters please contact TDEC DOR-OR and complete a public information request. Data will be available upon request.

### Radiochemical Analytes

There were a few samples with detections above the comparison criteria for radiochemical analytes. Most of the wells were below detection limits for many of the analytes. Five samples from four wells exceeded the bismuth-214 PRG from 2016 to 2017. Thirteen samples from nine locations, exceeded the lead-214 PRG with the most recent date being RWA-146 and it’s duplicate on 6/14/2019. Seven samples from four locations had radium-226 MCL exceedances. There were only two samples and locations that exceeded the radium-228 MCL. There were fourteen samples from eight locations with uranium-233/234 PRG exceedances. There were nine samples from four locations, that exceeded the uranium-238 PRG. Refer to Table 7.2.8. for a representation of the exceedances only. For a full data set inclusive of all parameters sampled please contact TDEC DOR-OR and complete a public information request. Data will be available upon request

# Table 7.2.5: Field Parameters

| Field Parameters for Offsite, Background, and White Wing Road Stations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Well Name** | **Location/Project** | **Sampling Date** | **Temperature (°C)** | **Electrical Conductivity (µS/cm)** | **pH (SU)** | **Oxidation Reduction Potential (mV)** | **Dissolved Oxygen (mg/L)** | **Turbidity (NTU)** |
| **EPA SMCL** | | | **NA** | **NA** | **6.5-8.5** | **NA** | **NA** | |
| **CRBR057** | **OFFSITE** | 6/5/2017 | 16.1 | 271.4 | 7.30 | 143.0 | 7.03 | 0.02 |
| **CRBR067/074** | **OFFSITE** | 7/6/2017 | 18.2 | 707.0 | 9.38 | 114.0 | 9.14 | 0.23 |
| **CRBR-076** | **OFFSITE** | 11/5/2018 | 15.8 | 366.6 | 7.77 | 79.5 | 2.01 | 1.26 |
| **Delightful Spring** | **BACKGROUND** | 12/6/2017 | 13.5 | 412.8 | 7.62 | 254.6 | 8.24 | 0.39 |
| **Lovely Spring** | **BACKGROUND** | 12/6/2017 | 11.1 | 353.6 | 7.80 | 254.6 | 9.85 | 0.68 |
| **Lovely Spring** | **BACKGROUND** | 8/3/2016 | 17.5 | 381.9 | 7.55 | 74.4 | 9.90 | 0.37 |
| **RWA-029** | **OFFSITE** | 3/12/2018 | 13.3 | 391.6 | 7.16 | 285.1 | 7.94 | 0.16 |
| **RWA-029** | **OFFSITE** | 11/8/2017 | 14.3 | 438.3 | 7.04 | 61.7 | 7.34 | 0.2; 0.02 |
| **RWA-029 and DUP** | **OFFSITE** | 12/19/2016 | 14.5 | 430.1 | 7.04 | 359.9 | 8.42 | 0.17 |
| **RWA-035** | **OFFSITE** | 2/20/2018 | 13.7 | 215.4 | 7.09 | 171.9 | 7.89 | 0.70 |
| **RWA-047** | **OFFSITE** | 6/28/2017 | 17.6 | 353.2 | 6.97 | 138.0 | 2.42 | 249.00 |
| **RWA-047** | **OFFSITE** | 12/6/2016 | 15.8 | 350.2 | 6.92 | 163.9 | 3.73 | 1016; 5.35 |
| **RWA-060** | **OFFSITE** | 12/8/2016 | 16.0 | 345.6 | 7.53 | 159.2 | 1.37 | 2.08 |
| **RWA-071** | **OFFSITE** | 8/15/2016 | 16.0 | 333.0 | 7.58 | 176.9 | 6.54 | 0.03 |
| **RWA-079** | **OFFSITE** | 6/15/2017 | 16.2 | 617.0 | 9.45 | 131.1 | 0.72 | 1.82 |
| **RWA-097** | **OFFSITE** | 8/29/2016 | 18.3 | 786.0 | 8.68 | -273.7 | 0.16 | 0.06 |
| **RWA-100** | **OFFSITE** | 11/21/2016 | 14.3 | 247.3 | 7.43 | 247.1 | 7.32 | 0.01 |
| **RWA-106** | **OFFSITE** | 8/23/2016 | 18.9 | 305.0 | 7.46 | 111.5 | 6.50 | 2.64 |
| **RWA-116** | **OFFSITE** | 6/26/2017 | 15.0 | 502.4 | 7.33 | 156.1 | 2.83 | 0.77 |
| **RWA-117** | **OFFSITE** | 6/19/2017 | 16.2 | 746.0 | 8.92 | -47.0 | 0.85 | 0.68 |
| **RWA-118** | **OFFSITE** | 10/3/2018 | 15.1 | 419.9 | 7.26 | 90.6 | 1.57 | 1.29 |
| **RWA-118** | **OFFSITE** | 11/30/2017 | 14.6 | 425.7 | 7.21 | 284.1 | 1.37 | 9.78 |
| **RWA-127** | **OFFSITE** | 2/27/2019 | 15.4 | 331.6 | 7.38 | 134.3 | 5.61 | 0.65 |
| **RWA-128** | **OFFSITE** | 10/10/2018 | 16.2 | 369.5 | 7.43 | 86.5 | 3.11 | 0.19 |
| **RWA-128** | **OFFSITE** | 11/9/2017 | 15.5 | 367.5 | 7.45 | 58.1 | 4.28 | 0.00 |
| **RWA-128** | **OFFSITE** | 12/14/2016 | 15.6 | 384.8 | 7.38 | 303.2 | 5.76 | 0.22 |
| **RWA-129** | **OFFSITE** | 3/7/2018 | 15.6 | 375.1 | 7.44 | 70.0 | 0.53 | 0.52 |
| **RWA-132 and DUP** | **OFFSITE** | 2/22/2018 | 14.4 | 424.0 | 6.91 | 156.9 | 4.61 | 30.26 |
| **RWA-139** | **OFFSITE** | 11/16/2016 | 15.4 | 397.4 | 7.43 | 283.5 | 2.67 | 0.01 |
| **RWA-142** | **OFFSITE** | 3/6/2018 | 15.4 | 304.3 | 7.27 | 133.0 | 4.67 | 3.57 |
| **RWA-142** | **OFFSITE** | 11/17/2016 | 15.7 | 444.8 | 7.07 | 214.7 | 3.53 | 1.62 |
| **RWA-145** | **BACKGROUND** | 4/2/2018 | 15.9 | 387.3 | 7.13 | -50.9 | 0.23 | 44.77 |
| **RWA-145** | **BACKGROUND** | 9/7/2016 | 18.0 | 398.9 | 7.01 | 235.9 | 0.43 | 1.98 |
| **RWA-146 and DUP** | **OFFSITE** | 6/4/2019 | 18.1 | 1110 | 6.76 | -29.9 | 2.04 | 0.24 |
| **RWA-146** | **OFFSITE** | 11/6/2017 | 15.5 | 808 | 7.13 | -69.1 | 0.58 | 1.64 |
| **RWA-146** | **OFFSITE** | 9/19/2016 | 18.1 | 1140 | 6.97 | -51.8 | 0.21 | 0.85 |
| **RWA-147** | **OFFSITE** | 3/1/2018 | 14.6 | 396.1 | 6.25 | 26.6 | 0.74 | 2.16 |
| **RWA-147** | **OFFSITE** | 9/20/2016 | 15.8 | 392.4 | 6.28 | 23.5 | 1.25 | 11.73 |
| **RWA-148** | **OFFSITE** | 9/22/2016 | 14.8 | 625.0 | 7.26 | -66.1 | 1.40 | 0.18 |
| **RWA-148** | **OFFSITE** | 3/24/2020 | 14.8 | 454.0 | 7.04 | -41.6 | 0.63 | 1.57 |
| **RWA-149** | **OFFSITE** | 5/14/2019 | 15.8 | 457.2 | 6.80 | 132.5 | 4.65 | 1.88 |
| **RWA-149** | **OFFSITE** | 3/15/2018 | 13.7 | 531.0 | 7.06 | 435.2 | 1.11 | 2.64 |
| **RWA-149** | **OFFSITE** | 9/26/2016 | 21.6 | 538.0 | 7.64 | 349.9 | 3.16 | 4.05 |
| **RWA-150** | **OFFSITE** | 9/27/2016 | 17.6 | 468.5 | 7.69 | 308.4 | 1.76 | 0.47 |
| **RWA-150** | **OFFSITE** | 3/23/2020 | 14.1 | 415.6 | 6.79 | 160.2 | 2.34 | 17.21 |
| **RWA-151** | **OFFSITE** | 6/6/2019 | 16.6 | 529.4 | 7.11 | 112.7 | 6.06 | 0.18 |
| **RWA-151** | **OFFSITE** | 11/7/2017 | 15.9 | 510.2 | 7.16 | 18.3 | 6.28 | 0.26 |
| **RWA-151** | **OFFSITE** | 9/28/2016 | 16.2 | 786.0 | 7.10 | -31.4 | 3.93 | 0.85 |
| **RWA-152 and DUP** | **OFFSITE** | 10/5/2016 | 17.3 | 505.8 | 6.80 | 16.3 | 0.84 | 2.14 |
| **RWA-153** | **OFFSITE** | 10/26/2016 | 15.6 | 315.5 | 7.30 | 253.3 | 5.09 | 0.32 |
| **RWA-154** | **BACKGROUND** | 11/4/2016 | 16.1 | 675.0 | 6.68 | 288.7 | 4.80 | 4.99 |
| **RWA-155** | **BACKGROUND** | 3/19/2018 | 13.9 | 553.9 | 6.87 | 199.3 | 2.07 | 4.41 |
| **RWA-155** | **BACKGROUND** | 11/7/2016 | 16.0 | 552.9 | 6.97 | 268.7 | 1.33 | 3.47 |
| **RWA-156** | **BACKGROUND** | 11/8/2016 | 15.5 | 596.2 | 7.2 | -82.6 | 1.0 | 0.24 |
| **RWA-157** | **BACKGROUND** | 3/21/2018 | 15.6 | 309.2 | 8.06 | 172.0 | 2.5 | 0.90 |
| **RWA-157** | **BACKGROUND** | 11/9/2016 | 16.1 | 306.2 | 7.70 | 100.5 | 1.71 | 0.37 |
| **RWA-158 and DUP** | **BACKGROUND** | 12/4/2017 | 15.4 | 396.7 | 7.40 | 176.4 | 2.04 | 0.85 |
| **RWA-158 and DUP** | **BACKGROUND** | 11/10/2016 | 15.3 | 393.5 | 7.46 | -6.9 | 2.13 | 0.51 |
| **RWA-159** | **OFFSITE** | 11/20/2017 | 15.3 | 521.2 | 7.51 | 31.7 | 1.00 | 0.65 |
| **RWA-159** | **OFFSITE** | 11/14/2016 | 15.8 | 544.3 | 7.38 | -11.2 | 1.35 | 0.23 |
| **RWA-160** | **OFFSITE** | 10/18/2018 | 16.9 | 542.4 | 7.24 | 91.9 | 4.38 | 1.16 |
| **RWA-160 and DUP** | **OFFSITE** | 7/18/2017 | 16.5 | 452.0 | 7.55 | 32.2 | 4.02 | 6.00 |
| **RWA-160** | **OFFSITE** | 6/6/2017 | 15.6 | 424.1 | 7.41 | 497.1 | 6.03 | 6.65 |
| **RWA-161** | **OFFSITE** | 6/14/2017 | 15.3 | 191.6 | 7.55 | 154.1 | 5.67 | 4.03 |
| **RWA-162** | **OFFSITE** | 11/16/2017 | 14.8 | 394.3 | 7.30 | 259.1 | 6.76 | 0.74 |
| **RWA-162** | **OFFSITE** | 6/27/2017 | 15.0 | 400.4 | 7.47 | 167.6 | 6.11 | 2.32 |
| **RWA-163** | **BACKGROUND** | 2/28/2018 | 15.3 | 235.2 | 6.92 | 142.6 | 7.32 | 1.64 |
| **RWA-164 (DOE CRBR-071)** | **OFFSITE** | 3/14/2018 | 16.4 | 386.4 | 8.30 | 15.0 | 0.74 | 0.86 |
| **Syn-164** | **OFFSITE** | 3/11/2019 | 14.6 | 186.2 | 7.50 | 150.9 | 8.80 | 0.22 |
| **WW06 and DUP** | **WHITE WING ROAD** | 1/4/2016 | 13.9 | 205.7 | 7.30 | 178.5 | 6.89 | 6.42 |
| **WW07** | **WHITE WING ROAD** | 1/12/2016 | 13.6 | 266.7 | 7.16 | 188.1 | 3.75 | 7.18 |
| **WW09** | **WHITE WING ROAD** | 1/13/2016 | 12.8 | 530.0 | 7.55 | 223.8 | 2.90 | 2.62 |
| **WW10** | **WHITE WING ROAD** | 1/12/2016 | 15.2 | 325.5 | 7.35 | 185.0 | 6.80 | 0.11 |
| **WW11** | **WHITE WING ROAD** | 1/4/2016 | 13.9 | 281.1 | 7.55 | 214.9 | 6.63 | 0.0 |
| **WW12 and DUP** | **WHITE WING ROAD** | 1/5/2016 | 14.4 | 422.4 | 7.40 | 169.8 | 4.75 | 2.19 |

**▨ -Outside EPA SMCL guidance**

**°C - Degrees Celsius**

**µS/cm - MicroSiemens per centimeter**

**mV - Millivolt**

**NTU - Nephelometric Turbidity Unit**

**SU - Standard Units**

**DUP - Duplicate**

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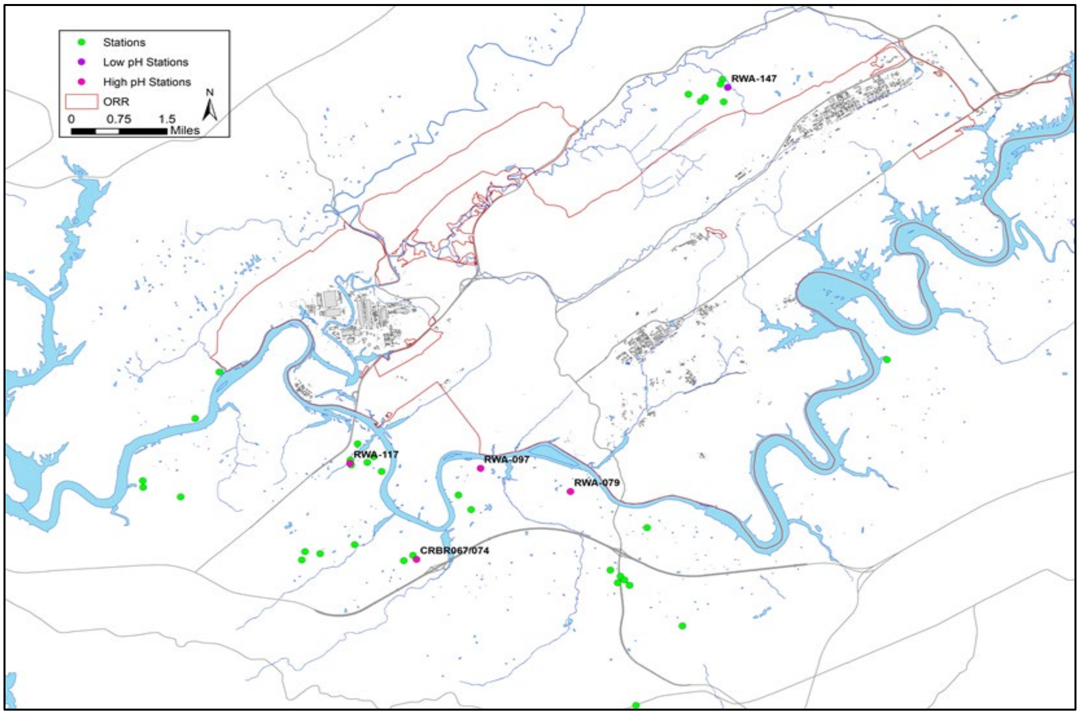


**Figure 7.2.1: Map showing the high and low pH stations.**

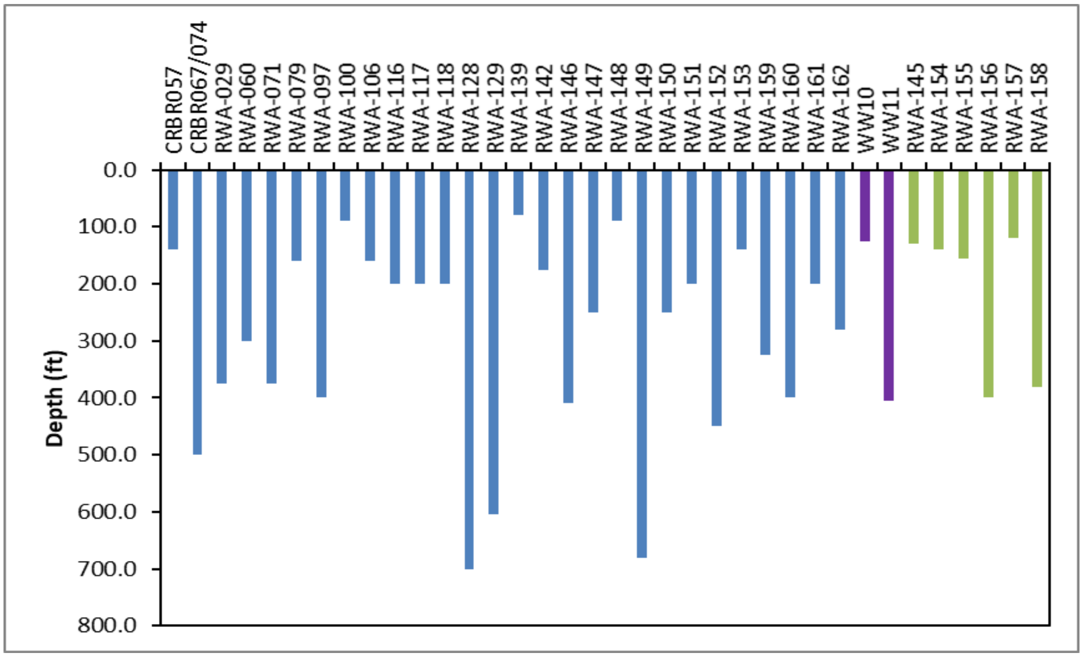


**Figure 7.2.2: Graph showing the known well depths.**

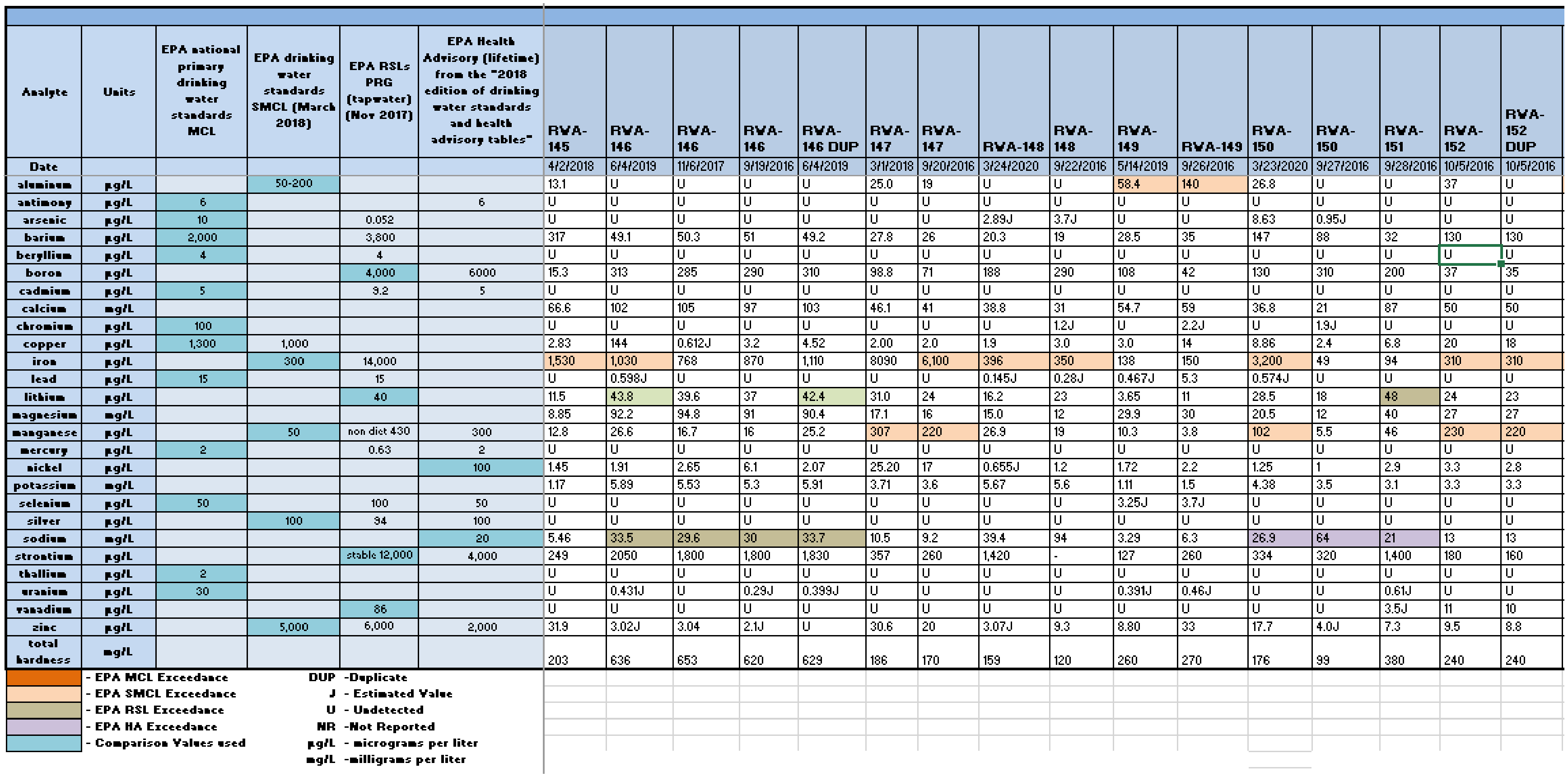
## Table 7.2.6.a: Metals Exceedances - Data Part 1

| Analyte | Units | EPA national primary drinking water standards MCL | EPA drinking water standards SMCL (March 2018) | EPA RSLs PRG (tapwater) (Nov 2017) | EPA Health Advisory (lifetime) from the "2018 edition of drinking water standards and health advisory tables" | CRBR067 /074 | CRBR-076 | RVA-029 | RVA-047 | RVA-047 | RVA-047 | RVA-079 | RVA-097 | RVA-117 | RVA-118 | RVA-118 | RVA-132 | RVA-132 DUP | RVA-142 | RVA-142 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | | | | | | 7/6/2017 | 11/5/2018 | 11/8/2017 | 6/28/2017 | 2/16/2017 | 12/6/2016 | 6/15/2017 | 8/29/2016 | 6/19/2017 | 10/3/2018 | 11/30/2017 | 2/22/2018 | 2/22/2018 | 3/6/2018 | 11/17/2016 |
| aluminum | µg/L | | 50-200 | | | U | U | 4.12 | 1200 | 17000 | 810 | 8.0J | U | 6.6J | 55.0 | 126 | 380 | 383 | 68.3 | 52 |
| antimony | µg/L | 6 | | | 6 | U | U | U | U | 0.63J | U | U | U | U | U | U | U | U | U | U |
| arsenic | µg/L | 10 | | 0.052 | | U | U | U | U | U | U | 1.0J | U | U | U | U | U | U | U | U |
| barium | µg/L | 2,000 | | 3,800 | | 38 | 154 | U | 360 | 270 | 300 | 8.3 | 3.3J | 60 | 102 | 101 | 80.8 | 81.2 | 118 | 310 |
| beryllium | µg/L | 4 | | 4 | | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U |
| boron | µg/L | | | 4,000 | 6000 | 870 | 276 | U | 14 | 16 | 12 | 320 | 340 | 550 | 21.3 | 11.9 | 3.94 | 4.74 | 58.1 | 150 |
| cadmium | µg/L | 5 | | 9.2 | 5 | U | U | U | 0.41J | 1.4 | 0.33J | U | U | U | U | U | U | U | U | U |
| calcium | mg/L | | | | | 0.82 | 19.2 | U | 58 | 65 | 61 | 0.41 | 1.8 | 2.2 | 54.2 | 51.7 | 53.2 | 51.6 | 51.1 | 51 |
| chromium | µg/L | 100 | | | | U | U | 1.12 | 13 | U | 10 | U | U | U | U | U | 0.838 | 0.81 | 0.844J | U |
| copper | µg/L | 1,300 | 1,000 | | | 1.5 | 0.940J | 2.58 | 32 | 68 | 150 | 13 | 2.6 | 3.1 | 2.43 | 1.72 | 9.68 | 9.34 | 7.63 | 4 |
| iron | µg/L | | 300 | 14,000 | | 810 | 16.3 | U | 8500 | 80000 | 6200 | 150 | U | 47 | 58.5 | 155 | 202.00 | 207.00 | 95.40 | 28 |
| lead | µg/L | 15 | | 15 | | U | U | U | 41 | 98 | 24 | 3.2 | U | 0.38J | 0.268J | 0.692J | 4.45 | 4.48 | 0.344J | U |
| lithium | µg/L | | | 40 | | 72 | 34.9 | U | 7.8 | 9.0 | 7.9 | 34 | 52 | 63 | 3.54 | 3.5 | 1.4 | 1.56 | 5.2 | 10 |
| magnesium | mg/L | | | | | 0.18 | 14.1 | U | 7.3 | 8 | 6.1 | 0.12 | 1.3 | 1.5 | 23.8 | 22.1 | 30.5 | 29.6 | 19.4 | 26 |
| manganese | µg/L | | 50 | non diet 430 | 300 | 8.2 | 3.43 | U | 630 | 95 | 580 | 1.3 | 0.51J | 0.68J | 2.92 | 20.2 | 161 | 165 | 4.4 | 1.4 |
| mercury | µg/L | 2 | | 0.63 | 2 | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U |
| nickel | µg/L | | | | 100 | U | U | U | 5.1 | 38 | 4.5 | U | U | U | 0.595J | 2.12 | 3.21 | 3.14 | 0.988J | 1.7 |
| potassium | mg/L | | | | | 0.94 | 2.33 | 0.179 | 6.9 | 3.8 | 1.5 | 0.69 | 1.6 | 1.8 | 1.12 | 1.1 | 1.25 | 1.22 | 2.11 | 3.7 |
| selenium | µg/L | 50 | | 100 | 50 | U | U | U | U | U | U | U | 1.6J | U | U | U | U | U | U | U |
| silver | µg/L | | 100 | 94 | 100 | U | U | U | U | 0.13J | U | U | U | U | U | U | U | U | U | U |
| sodium | mg/L | | | | 20 | 160 | 45.1 | 106 | 5.2 | 5.2 | 4.8 | 130 | 190 | 170 | 4.09 | 4.13 | 1.68 | 1.64 | 6.67 | 18 |
| strontium | µg/L | | | stable 12,000 | 4,000 | 23 | 583 | U | 280 | 220 | 250 | 16 | 130 | 150 | 194 | 185 | 137 | 141 | 293 | 530 |
| thallium | µg/L | 2 | | | | U | U | U | U | 0.85J | U | U | U | U | U | U | U | U | U | U |
| uranium | µg/L | 30 | | | | U | U | U | U | U | U | U | U | U | 0.416J | 0.420J | 0.513 | 0.51 | 0.409J | 0.66J |
| vanadium | µg/L | | | 86 | | U | U | U | U | U | 3.1J | U | 3.1J | U | U | U | U | U | U | U |
| zinc | µg/L | | 5,000 | 6,000 | 2,000 | U | 7.23 | 2.59 | 830 | 6700 | 370 | 130 | 2.6J | U | 31.8 | 16 | 40.1 | 38.2 | 4.91J | 7.2 |
| total hardness | mg/L | | | | | 2.8 | 106 | U | 180 | 190 | 180 | 1.5 | 10 | 11 | 233 | 220 | 259 | 251 | 207 | 230 |

🟧 - EPA MCL Exceedance
🟨 - EPA SMCL Exceedance
🟫 - EPA RSL Exceedance
🟪 - EPA HA Exceedance
🟦 - Comparison Values used

DUP -Duplicate
J - Estimated Value
U - Undetected
NR -Not Reported
µg/L - micrograms per liter
mg/L -milligrams per liter

# Table 7.2.6b: Metals Exceedances - Data Part 2



| Analyte | Units | EPA national primary drinking water standards MCL | EPA drinking water standards SMCL (March 2018) | EPA RSLs PRG (tapwater) (Nov 2017) | EPA Health Advisory (lifetime) from the "2018 edition of drinking water standards and health advisory tables" | RVA-145 | RVA-146 | RVA-146 | RVA-146 | RVA-146 DUP | RVA-147 | RVA-147 | RVA-148 | RVA-148 | RVA-149 | RVA-149 | RVA-150 | RVA-150 | RVA-151 | RVA-152 | RVA-152 DUP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | | | | | | 4/2/2018 | 6/4/2019 | 11/6/2017 | 9/19/2016 | 6/4/2019 | 3/1/2018 | 9/20/2016 | 3/24/2020 | 9/22/2016 | 5/14/2019 | 9/26/2016 | 3/23/2020 | 9/27/2016 | 9/28/2016 | 10/5/2016 | 10/5/2016 |
| aluminum | µg/L | | 50-200 | | | 13.1 | U | U | U | U | 25.0 | 19 | U | U | 58.4 | 140 | 26.8 | U | U | 37 | U |
| antimony | µg/L | 6 | | | 6 | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U |
| arsenic | µg/L | 10 | | 0.052 | | U | U | U | U | U | U | U | 2.89J | 3.7J | U | U | 8.63 | 0.95J | U | U | U |
| barium | µg/L | 2,000 | | 3,800 | | 317 | 49.1 | 50.3 | 51 | 49.2 | 27.8 | 26 | 20.3 | 19 | 28.5 | 35 | 147 | 88 | 32 | 130 | 130 |
| beryllium | µg/L | 4 | | 4 | | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U |
| boron | µg/L | | | 4,000 | 6000 | 15.3 | 313 | 285 | 290 | 310 | 98.8 | 71 | 188 | 290 | 108 | 42 | 130 | 310 | 200 | 37 | 35 |
| cadmium | µg/L | 5 | | 9.2 | 5 | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U |
| calcium | mg/L | | | | | 66.6 | 102 | 105 | 97 | 103 | 46.1 | 41 | 38.8 | 31 | 54.7 | 59 | 36.8 | 21 | 87 | 50 | 50 |
| chromium | µg/L | 100 | | | | U | U | U | U | U | U | U | U | 1.2J | U | 2.2J | U | 1.9J | U | U | U |
| copper | µg/L | 1,300 | 1,000 | | | 2.83 | 144 | 0.612J | 3.2 | 4.52 | 2.00 | 2.0 | 1.9 | 3.0 | 3.0 | 14 | 8.86 | 2.4 | 6.8 | 20 | 18 |
| iron | µg/L | | 300 | 14,000 | | 1,530 | 1,030 | 768 | 870 | 1,110 | 8090 | 6,100 | 396 | 350 | 138 | 150 | 3,200 | 49 | 94 | 310 | 310 |
| lead | µg/L | 15 | | 15 | | U | 0.598J | U | U | U | U | U | 0.145J | 0.28J | 0.467J | 5.3 | 0.574J | U | U | U | U |
| lithium | µg/L | | | 40 | | 11.5 | 43.8 | 39.6 | 37 | 42.4 | 31.0 | 24 | 16.2 | 23 | 3.65 | 11 | 28.5 | 18 | 48 | 24 | 23 |
| magnesium | mg/L | | | | | 8.85 | 92.2 | 94.8 | 91 | 90.4 | 17.1 | 16 | 15.0 | 12 | 29.9 | 30 | 20.5 | 12 | 40 | 27 | 27 |
| manganese | µg/L | | 50 | non diet 430 | 300 | 12.8 | 26.6 | 16.7 | 16 | 25.2 | 307 | 220 | 26.9 | 19 | 10.3 | 3.8 | 102 | 5.5 | 46 | 230 | 220 |
| mercury | µg/L | 2 | | 0.63 | 2 | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U |
| nickel | µg/L | | | | 100 | 1.45 | 1.91 | 2.65 | 6.1 | 2.07 | 25.20 | 17 | 0.655J | 1.2 | 1.72 | 2.2 | 1.25 | 1 | 2.9 | 3.3 | 2.8 |
| potassium | mg/L | | | | | 1.17 | 5.89 | 5.53 | 5.3 | 5.91 | 3.71 | 3.6 | 5.67 | 5.6 | 1.11 | 1.5 | 4.38 | 3.5 | 3.1 | 3.3 | 3.3 |
| selenium | µg/L | 50 | | 100 | 50 | U | U | U | U | U | U | U | U | U | 3.25J | 3.7J | U | U | U | U | U |
| silver | µg/L | | 100 | 94 | 100 | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U |
| sodium | mg/L | | | | 20 | 5.46 | 33.5 | 29.6 | 30 | 33.7 | 10.5 | 9.2 | 39.4 | 94 | 3.29 | 6.3 | 26.9 | 64 | 21 | 13 | 13 |
| strontium | µg/L | | | stable 12,000 | 4,000 | 249 | 2050 | 1,800 | 1,800 | 1,830 | 357 | 260 | 1,420 | - | 127 | 260 | 334 | 320 | 1,400 | 180 | 160 |
| thallium | µg/L | 2 | | | | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U | U |
| uranium | µg/L | 30 | | | | U | 0.431J | U | 0.29J | 0.399J | U | U | U | U | 0.391J | 0.46J | U | U | 0.61J | U | U |
| vanadium | µg/L | | | 86 | | U | U | U | U | U | U | U | U | U | U | U | U | U | 3.5J | 11 | 10 |
| zinc | µg/L | | 5,000 | 6,000 | 2,000 | 31.9 | 3.02J | 3.04 | 2.1J | U | 30.6 | 20 | 3.07J | 9.3 | 8.80 | 33 | 17.7 | 4.0J | 7.3 | 9.5 | 8.8 |
| total hardness | mg/L | | | | | 203 | 636 | 653 | 620 | 629 | 186 | 170 | 159 | 120 | 260 | 270 | 176 | 99 | 380 | 240 | 240 |

🟧 - EPA MCL Exceedance
🟨 - EPA SMCL Exceedance
🟫 - EPA RSL Exceedance
🟪 - EPA HA Exceedance
🟦 - Comparison Values used

DUP -Duplicate
J - Estimated Value
U - Undetected
NR -Not Reported
µg/L - micrograms per liter
mg/L -milligrams per liter

# Table 7.2.6c: Metals Exceedances - Data Part 3

| Analyte | Units | EPA national primary drinking water standards MCL | EPA drinking water standards SMCL (March 2018) | EPA RSLs PRG (tapwater) (Nov 2017) | EPA Health Advisory (lifetime) from the "2018 edition of drinking water standards and health advisory tables" | RVA-154 | RVA-155 | RVA-156 | RVA-157 | RVA-159 | RVA-159 | RVA-161 | RVA-164 (DOE CRBR-071) | VV06 | VV06 DUP | VV07 | VV12 | VV12 DUP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | | | | | | 11/4/2016 | 11/7/2016 | 11/8/2016 | 3/21/2018 | 11/20/2017 | 11/14/2016 | 6/14/2017 | 3/14/2018 | 1/4/2016 | 1/4/2016 | 1/12/2016 | 1/5/2016 | 1/5/2016 |
| aluminum | µg/L | | 50-200 | | | 260 | 70 | 120 | U | U | 8.5J | 1,300 | U | 640 | 560 | 92 | 95 | 86 |
| antimony | µg/L | 6 | | | 6 | U | U | U | U | U | 0.60J | U | U | U | U | U | U | U |
| arsenic | µg/L | 10 | | 0.052 | | U | U | U | U | U | U | U | U | 0.74J | 0.64J | U | U | U |
| barium | µg/L | 2,000 | | 3,800 | | 47 | 28 | 110 | 12.0 | 166 | 120 | 36 | 143 | 7.5 | 7.5 | 19 | 11 | 11 |
| beryllium | µg/L | 4 | | 4 | | U | U | U | U | U | U | U | U | U | U | U | U | U |
| boron | µg/L | | | 4,000 | 6000 | 18 | 27 | 100 | 63.0 | 226 | 250 | 5.9J | 371 | 2.3J | NR | 3.8J | 2.4J | 2.7J |
| cadmium | µg/L | 5 | | 9.2 | 5 | U | U | U | U | U | U | U | U | U | U | U | U | U |
| calcium | mg/L | | | | | 120 | 91 | 66 | 35.8 | 36.0 | 39 | 33 | 10.8 | 21 | 21 | 35 | 45 | 46 |
| chromium | µg/L | 100 | | | | U | U | U | U | U | U | 1.8J | U | U | U | 1.1J | U | U |
| copper | µg/L | 1,300 | 1,000 | | | 7.8 | 1.1 | 0.94J | 1.17 | 2.01 | 1.7 | 3.3 | 1.72 | 0.86J | 0.78J | U | 2.8 | 2.8 |
| iron | µg/L | | 300 | 14,000 | | 420 | 80 | 66 | 11.1 | 49.3 | 130 | 780 | 9.30 | 740 | 660 | 130 | 72 | 65 |
| lead | µg/L | 15 | | 15 | | 1.1 | U | U | U | U | U | 1.2 | U | 2.5 | 2.5 | U | U | U |
| lithium | µg/L | | | 40 | | 2.1 | 2.8 | 21 | 11.3 | 42.2 | 39 | 2.4 | 45.2 | U | U | U | 0.54J | 0.55J |
| magnesium | mg/L | | | | | 11 | 16 | 26 | 8.02 | 27.6 | 32 | 17 | 9.60 | 13 | 13 | 8.2 | 26 | 27 |
| manganese | µg/L | | 50 | non diet 430 | 300 | 12 | 27 | 8.4 | U | 7.13 | 10 | 31 | 3.63 | 22 | 24 | 3.7 | 2.3 | 2.6 |
| mercury | µg/L | 2 | | 0.63 | 2 | U | U | U | U | U | U | U | U | U | U | U | U | U |
| nickel | µg/L | | | | 100 | 5.4 | 2.8 | 2.3 | 0.881J | U | 2.3 | U | 0.501 | 1.4 | 1.4 | 1.6 | 2.5 | 2.7 |
| potassium | mg/L | | | | | 5.8 | 1.2 | 3.7 | 1.58 | 2.89 | 3.2 | 0.68 | 1.78 | 0.80 | 0.80 | 0.86 | 1.2 | 1.2 |
| selenium | µg/L | 50 | | 100 | 50 | U | U | U | U | U | U | U | U | U | U | U | 1.2J | 1.2J |
| silver | µg/L | | 100 | 94 | 100 | U | U | U | U | U | U | U | U | U | U | U | U | U |
| sodium | mg/L | | | | 20 | 5.9 | 4.6 | 24 | 21.80 | 35.2 | 37 | 0.54 | 67.7 | 0.50 | 0.51 | 0.86 | 1.1 | 1.1 |
| strontium | µg/L | | | stable 12,000 | 4,000 | 250 | 190 | 1,200 | 128 | 4,130 | 4,200 | 45 | 222 | 14 | 13 | 48 | 22 | 23 |
| thallium | µg/L | 2 | | | | U | U | U | U | 0.676 | U | U | U | U | U | U | U | U |
| uranium | µg/L | 30 | | | | 0.31J | U | U | 0.383J | U | U | U | U | U | U | U | 0.99J | 1.0 |
| vanadium | µg/L | | | 86 | | U | U | U | U | U | U | U | U | 4.3J | 3.3J | U | U | U |
| zinc | µg/L | | 5,000 | 6,000 | 2,000 | 55 | 2.4J | 9.4 | 227 | 3.9 | 4.4J | 6.1 | 2.57 | 11 | 5.5 | 5.7 | 6.5 | 6.2 |
| total hardness | mg/L | | | | | 350 | 290 | 270 | 122 | 204 | 230 | 150 | 66.5 | 110 | 110 | 120 | 220 | 220 |

| | | | |
|---|---|---|---|
| 🟧 | - EPA MCL Exceedance | DUP | -Duplicate |
| 🟨 | - EPA SMCL Exceedance | J | - Estimated Value |
| 🟫 | - EPA RSL Exceedance | U | - Undetected |
| 🟪 | - EPA HA Exceedance | NR | -Not Reported |
| 🟦 | - Comparison Values used | µg/L | - micrograms per liter |
| | | mg/L | -milligrams per liter |

## Table 7.2.6d: Metals Exceedances - Data Part 4

| Analyte | Units | EPA national primary drinking water standards MCL | EPA drinking water standards SMCL (March 2018) | EPA RSLs PRG (tapwater) (Nov 2017) | EPA Health Advisory (lifetime) from the "2018 edition of drinking water standards and health advisory tables" | CRBR057 | CRBR067/074 | CRBR-076 | Delightful Spring | Lovely Spring | Lovely Spring | RWA-029 | RWA-029 | RWA-029 | RWA-029 DUP | RWA-035 | RWA-047 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | | | | | | 6/5/2017 | 7/6/2017 | 11/5/2018 | 12/6/2017 | 12/6/2017 | 8/3/2016 | 3/12/2018 | 11/8/2017 | 12/19/2016 | 12/19/2016 | 2/20/2018 | 6/28/2017 |
| cadmium | µg/L | 5 | | 9.2 | 5 | U | U | U | U | U | U | U | U | U | U | U | 0.41J |
| calcium | mg/L | | | | | 58 | 0.82 | 19.2 | 45.0 | 35.6 | 41 | 39.2 | U | 46 | 46 | 48.9 | 58 |
| chromium | µg/L | 100 | | | | U | U | U | U | U | U | U | 1.12 | U | U | U | 13 |
| copper | µg/L | 1,300 | 1,000 | | | 4.5 | 1.5 | 0.940J | U | U | U | 3.21 | 2.58 | 2.8 | 1.5 | 3.13 | 32 |
| iron | µg/L | | 300 | 14,000 | | U | 810 | 16.3 | U | 9.30J | 14 | 5.50J | U | 5.5J | 9.4J | U | 8500 |
| lead | µg/L | 15 | | 15 | | U | U | U | U | U | U | U | U | 0.40J | 0.39J | U | 41 |
| lithium | µg/L | | | 40 | | 3.1 | 72 | 34.9 | 0.955J | U | U | 0.524J | U | U | 0.34J | 0.552 | 7.8 |
| magnesium | mg/L | | | | | 3.7 | 0.18 | 14.1 | 26.8 | 23.0 | 25 | 26.3 | U | 28 | 28 | 26.8 | 7.3 |
| manganese | µg/L | | 50 | non diet 430 | 300 | U | 8.2 | 3.43 | U | 2.04 | 18 | U | U | 0.42J | U | U | 630 |
| mercury | µg/L | 2 | | 0.63 | 2 | U | U | U | U | U | U | U | U | U | U | U | U |
| nickel | µg/L | | | | 100 | 1.3 | U | U | 1.44 | 1.40 | 1.3 | 1.08 | U | 1.4 | 1.2 | 1.38 | 5.1 |
| potassium | mg/L | | | | | 0.21 | 0.94 | 2.33 | 0.584 | 0.660 | 0.97 | 0.667 | 0.179 | 0.8 | 0.78 | 1.03 | 6.9 |
| selenium | µg/L | 50 | | 100 | 50 | U | U | U | U | U | U | U | U | U | U | U | U |
| silver | µg/L | | 100 | 94 | 100 | U | U | U | U | U | U | U | U | U | U | U | U |
| sodium | mg/L | | | | 20 | 0.76 | 160 | 45.1 | 0.712 | 1.47 | 2.4 | 1.57 | 106 | 1.5 | 1.4 | 1.25 | 5.2 |
| strontium | µg/L | | | stable 12,000 | 4,000 | 65 | 23 | 583 | 73.1 | 19.9 | 24 | 14.5 | U | U | 26 | 29.8 | 280 |
| thallium | µg/L | 2 | | | | U | U | U | U | U | U | U | U | U | U | U | U |
| uranium | µg/L | 30 | | | | U | U | U | 1.05 | U | 0.29J | U | U | U | U | U | U |
| vanadium | µg/L | | | 86 | | U | U | U | U | U | 10 | U | U | U | U | U | U |
| zinc | µg/L | | 5,000 | 6,000 | 2,000 | 24 | U | 7.23 | U | U | U | 7.56 | 2.59 | 5.7 | 5.9 | 2.0 | 830 |
| total hardness | mg/L | | | | | 160 | 2.8 | 106 | 223 | 184 | 200 | 206 | U | 230 | 230 | 233 | 180 |

| | | | |
|---|---|---|---|
| 🟧 | - EPA MCL Exceedance | DUP | -Duplicate |
| 🟨 | - EPA SMCL Exceedance | J | - Estimated Value |
| 🟫 | - EPA RSL Exceedance | U | - Undetected |
| 🟪 | - EPA HA Exceedance | NR | -Not Reported |
| 🟦 | - Comparison Values used | µg/L | - micrograms per liter |
| | | mg/L | -milligrams per liter |

## Table 7.2.7: Inorganics Exceedances Only Data

| Analyte | EPA national primary drinking water standards MCL | EPA drinking water standards SMCL (March 2018) | EPA Health Advisory (lifetime) from the "2018 edition of drinking water standards and health advisory tables" | RWA-146 | RWA-146 | RWA-146 | RWA-146 DUP |
|---|---|---|---|---|---|---|---|
| Date | | | | 6/4/2019 | 11/6/2017 | 9/19/2016 | 6/4/2019 |
| ammonia | | | | 0.224 | 0.245 | 0.2 | 0.224 |
| chloride | | 250 | | 3.16 | 2.99 | 3.1 | 3.34 |
| fluoride | 4 | 2 | | 0.120 | 0.135 | 0.13 | 0.120 |
| nitrate and nitrite | 10 | | 10 | U | U | U | U |
| sulfate | | 250 | | 252 | 281 | 270 | 273 |
| total dissolved solids | | 500 | | 741 | 501 | 810 | 731 |
| total alkalinity | | | | 357 | 399 | 380 | 366 |

| | | |
|---|---|---|
| 🟧 | - EPA MCL Exceedance | -Duplicate |
| 🟨 | - EPA SMCL Exceedance | - Estimated Value |
| 🟫 | - EPA RSL Exceedance | - Undetected |
| 🟪 | - EPA HA Exceedance | -milligrams per liter |
| 🟦 | - Comparison Values used | -Not Reported |

## Table 7.2.8: Radiochemical Analytes Exceedances Only Data

| Well Name | Date | bismuth-214 | lead-214 | radium-226 | radium-228 | curium-245/246 | uranium-233/234 | uranium-238 |
|---|---|---|---|---|---|---|---|---|
| EPA National Primary Drinking Water Standards 2018 MCLs | NA | | | 1 | 1 | | | |
| EPA PRG tapwater TR=1E-6 Nov 2014 | NA | 270 | 150 | | | Cm-245=0.50; Cm-244=0.51 | U-233=0.73; U-234=0.74 | 0.82 |
| RWA-029 | 12/19/2016 | 245 | 223 | -0.51 BDL | 0.09 BDL | -0.018 BDL | 0.137 | 0.064 |
| RWA-029 DUP | 12/19/2016 | 283 | 242 | -0.21 BDL | 0.21 BDL | 0.012 BDL | 0.098 | 0.057 |
| RWA-060 | 12/8/2016 | 56 | 59 | 0.46 | 0.18 BDL | -0.017 BDL | 1.00 | 0.475 |
| RWA-127 | 2/27/2019 | 210 | 167 | -0.09 BDL | -0.03 BDL | 0.014 BDL | 0.83 | 0.54 |
| RWA-128 | 10/10/2018 | 56 | 44.4 | 2.08 | 0.2 BDL | 0.016 BDL | 2.66 | 1.21 |
| RWA-128 | 11/9/2017 | 49 | NDA | 9.3 | 5.8 | 0.059 BDL | 2.17 | 1.17 |
| RWA-128 | 12/14/2016 | 23.6 | 30.4 | 0.75 | 0.19 BDL | 0.009 BDL | 1.51 | 1.12 |
| RWA-129 | 3/7/2018 | 88 | 67 | 1.96 | 0.55 | 0.009 BDL | 2.82 | 0.779 |
| RWA-132 | 2/22/2018 | NDA | NDA | 0.1 BDL | 0.43 | 0.007 BDL | 0.481 | 0.267 |
| RWA-132 DUP | 2/22/2018 | 44 | 27.4 | 0.73 | 1.18 | 0.032 BDL | 0.387 | 0.17 |
| RWA-139 | 11/16/2016 | NDA | NDA | 0.67 | 0.16 BDL | 0.015 BDL | 1.62 | 1.22 |
| RWA-146 | 6/4/2019 | 174 | 152 | 0.78 | 0.42 | 0.02 BDL | 0.384 | 0.097 |
| RWA-146 | 11/6/2017 | 47 | 44.9 | 1.06 | 0.35 BDL | -0.01 BDL | 0.292 | 0.178 |
| RWA-146 | 9/19/2016 | 212 | 213 | 0.98 | 0.40 BDL | -0.002 BDL | 0.364 | 0.159 |
| RWA-146 DUP | 6/4/2019 | 171 | 150 | 0.98 | -0.08 BDL | -0.014BDL | 0.241 | 0.206 |
| RWA-149 | 3/15/2018 | 67 | 56.1 | 0.2 BDL | 0.78 | 0.633 | 0.589 | 0.176 |
| RWA-150 | 3/23/2020 | 42.9 | 36.7 | 0.16 | -0.2BDL | 0.22 BDL | 2.11 | 1.27 |
| RWA-160 | 10/18/2018 | 10.9 | NDA | 1.44 | -0.22 BDL | 0.007 BDL | 2.57 | 3.2 |
| RWA-160 | 7/18/2017 | NDA | NDA | 0.91 | 0.44 | 0.048 BDL | 1.4 | 1.61 |
| RWA-160 | 6/6/2017 | 22.7 | 27.3 | 1.27 | 0.060 BDL | 0.020 BDL | 0.917 | 1.23 |
| RWA-160 DUP | 7/18/2017 | NDA | NDA | 1.27 | 0.23 BDL | -0.015 BDL | 1.43 | 1.7 |
| RWA-162 | 6/27/2017 | 300 | 280 | 0.570 | 0.060 BDL | 0.053 BDL | 0.562 | 0.342 |
| SYN-164 | 3/11/2019 | 224 | 212 | -0.31 BDL | 0.43 BDL | 0.062 BDL | 0.238 | 0.1 |
| WW06 DUP | 1/4/2016 | 147 | 163 | 0.21 BDL | -0.29 BDL | 0.038 BDL | 0.056 | 0.049 |
| WW07 | 1/12/2016 | 323 | 296 | -0.33 BDL | -0.08 BDL | 0.067 | 0.067 | 0.049 |
| WW09 | 1/13/2016 | 179 | 163 | 0.16 BDL | -0.05 BDL | 0.055 BDL | 0.414 | 0.246 |
| WW12 | 1/5/2016 | 536 | 537 | 0.24 | -0.02 BDL | 0.062 BDL | 0.826 | 0.321 |
| WW12 DUP | 1/5/2016 | 578 | 565 | -0.30 BDL | 0.12 | 0.058 BDL | 0.798 | 0.283 |

🟧 - EPA MCL Exceedance
🟨 - EPA SMCL Exceedance
🟫 - EPA PRG Exceedance
🟪 - EPA HA Exceedance

**DUP** -Duplicate
**TR** -Target Risk
**pCi/L** - picoCuries per liter
**BDL** -Below Detection Limit
**NDA** - Not Detected Analyte
**NR** -Not Reported

### Comparison Criteria Exceedances Graphs

The following graphs were made of any analyte that had comparison criteria exceedances for any of the four groundwater projects, in order to see how the exceedance values compared to the other sample results (Figures 7.2.3 – 7.2.15). Undetects (U values) were left off the graphs, and when a sample was "J-coded" or estimated, the J was removed and just the number was used. Refer to the full analyte tables for the exact values. Only thirteen analytes had any samples that exceeded the comparison criteria.

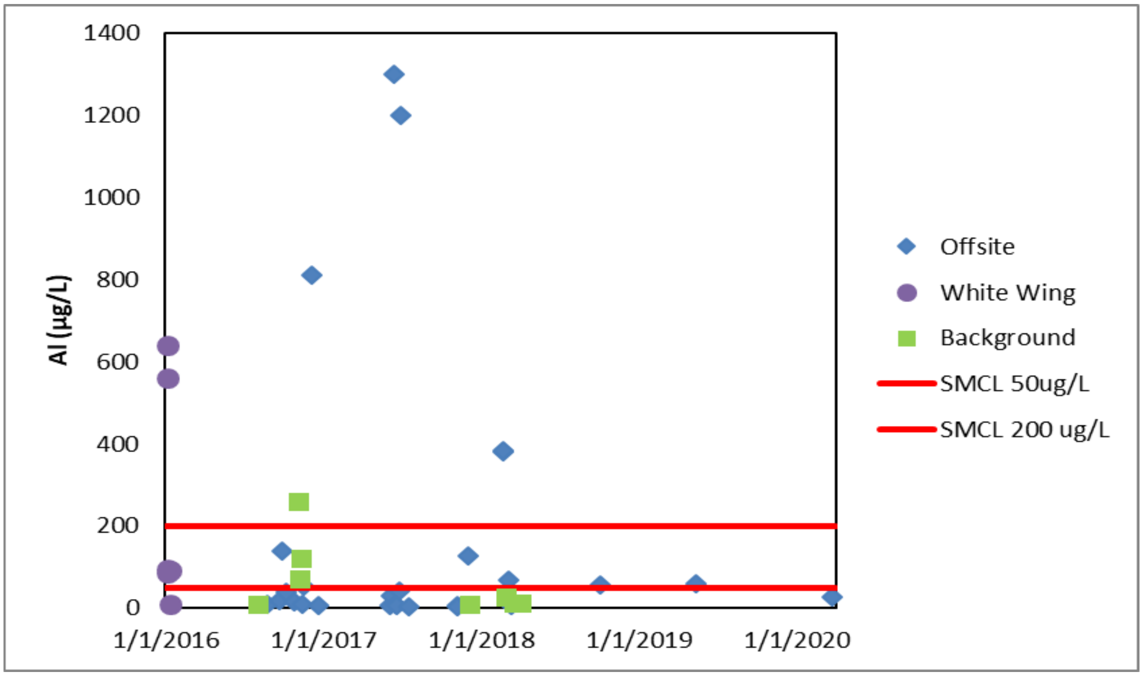


**Figure 7.2.3: Aluminum (Al) measured in micrograms/liter (µg/L) with the SMCL range shown as the red lines.**

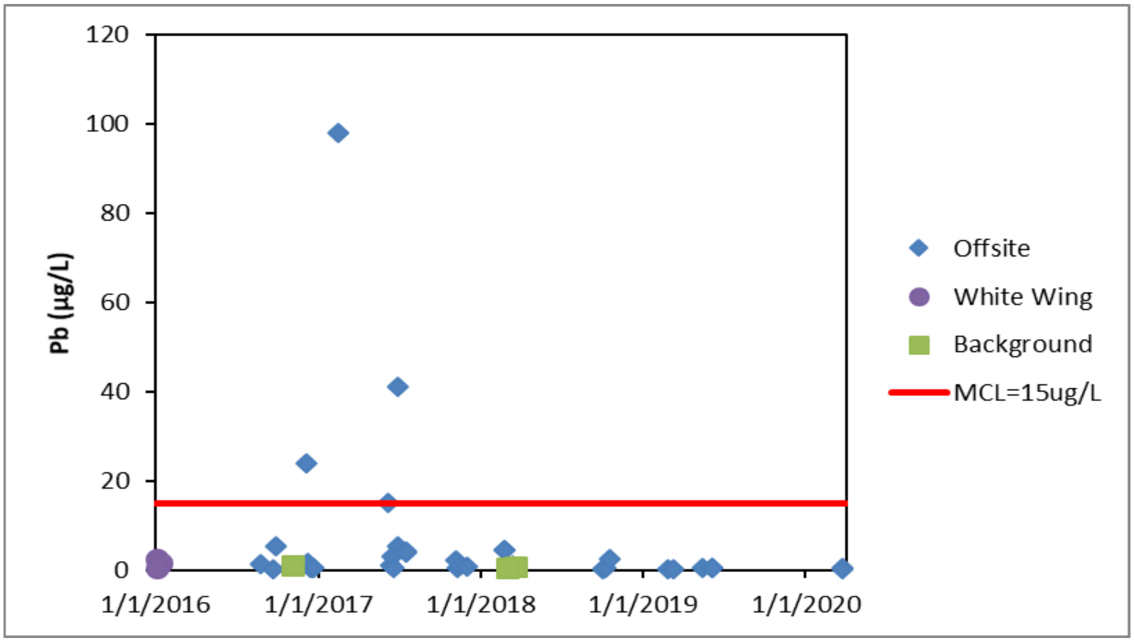


**Figure 7.2.4: Lead (Pb) measured in micrograms/liter (µg/L) with the MCL shown. The three exceedances are largely above the other samples.**

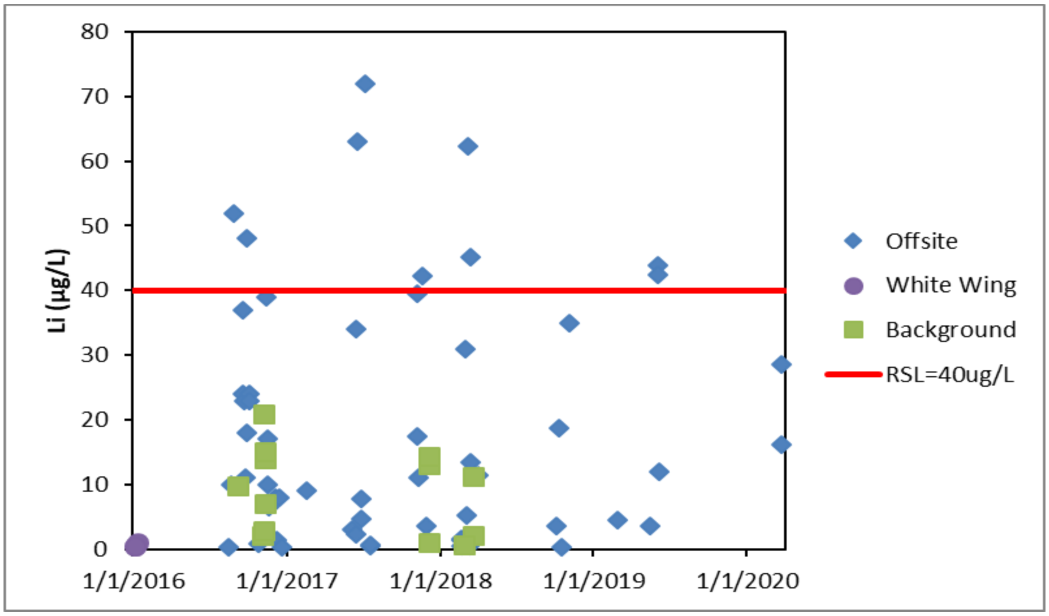


**Figure 7.2.5: Lithium (Li) measured in (µg/L) with the RSL shown. The only exceedances were from the offsite project.**

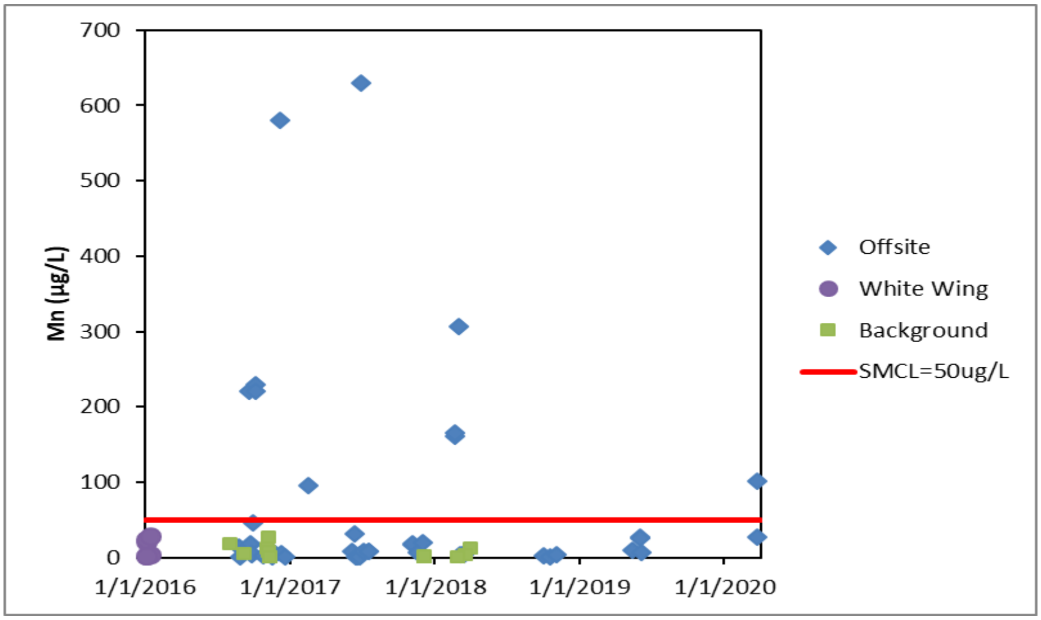


**Figure 7.2.6: Manganese (Mn) measured in micrograms (µg/L) with the SMCL shown. The only exceedances were from the offsite project.**

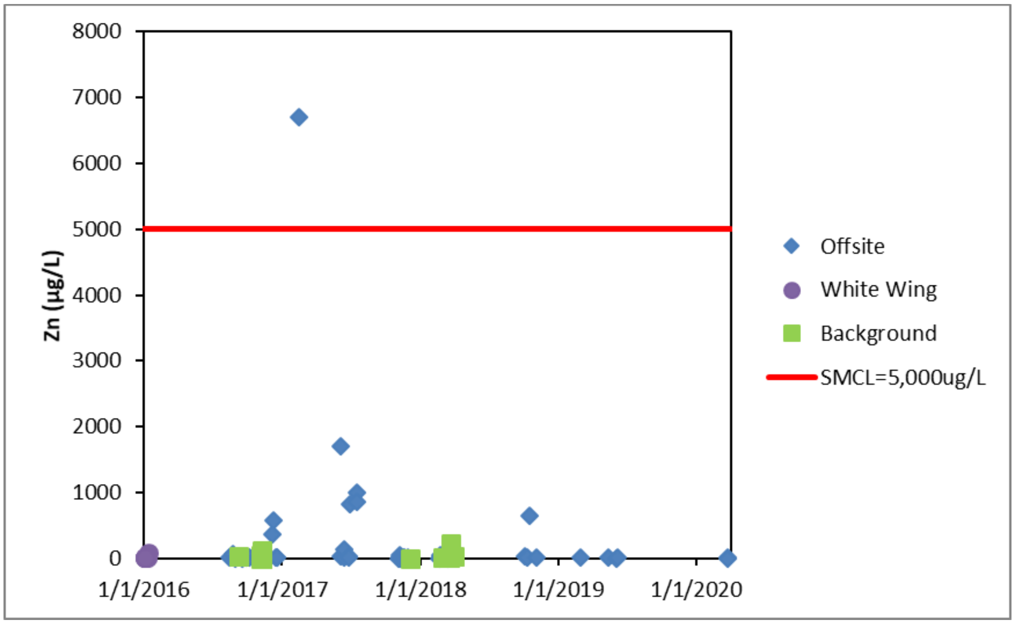


**Figure 7.2.7: Zinc (Zn) measured in micrograms (µg/L) with the SMCL on it. There was one offsite sample (RWA-047 on 2/16/2017) greatly above the other samples and the SMCL.**

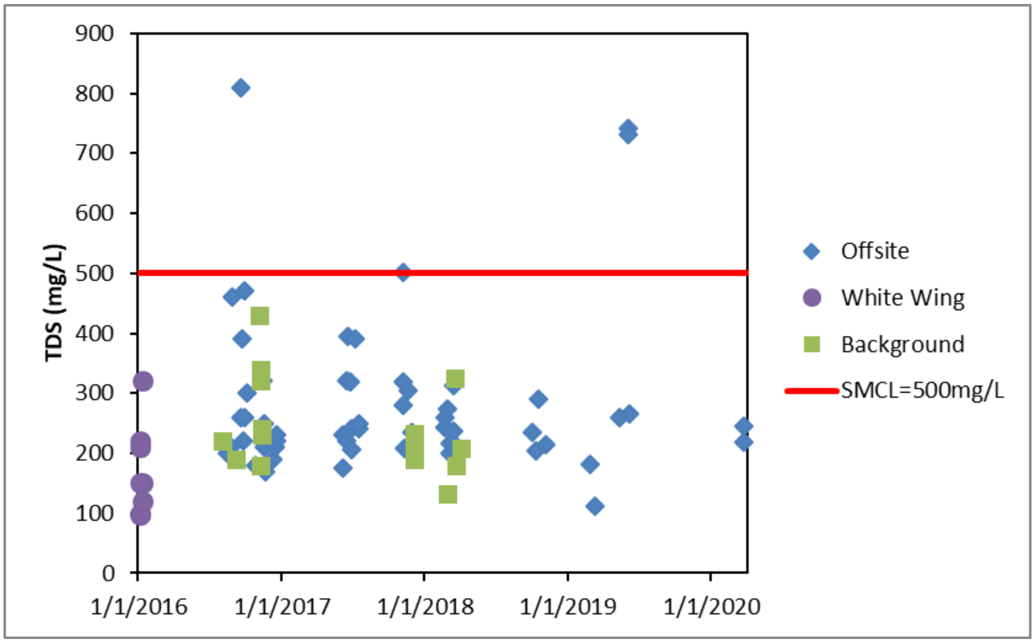


**Figure 7.2.8: Total dissolved solids (TDS) measured in milligrams/liter (mg/L).**

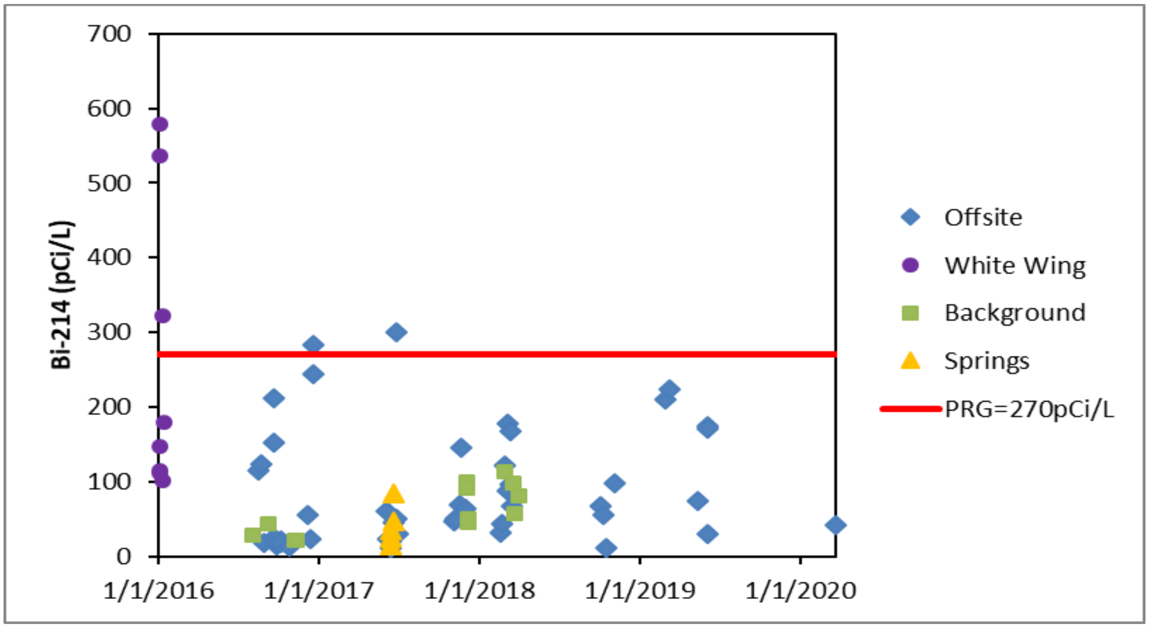


Figure 7.2.9: Bismuth-214 (Bi-214) measured in picoCuries per liter (pCi/L) showing the PRG. Most of the samples that exceeded the PRG are from the White Wing Road project.

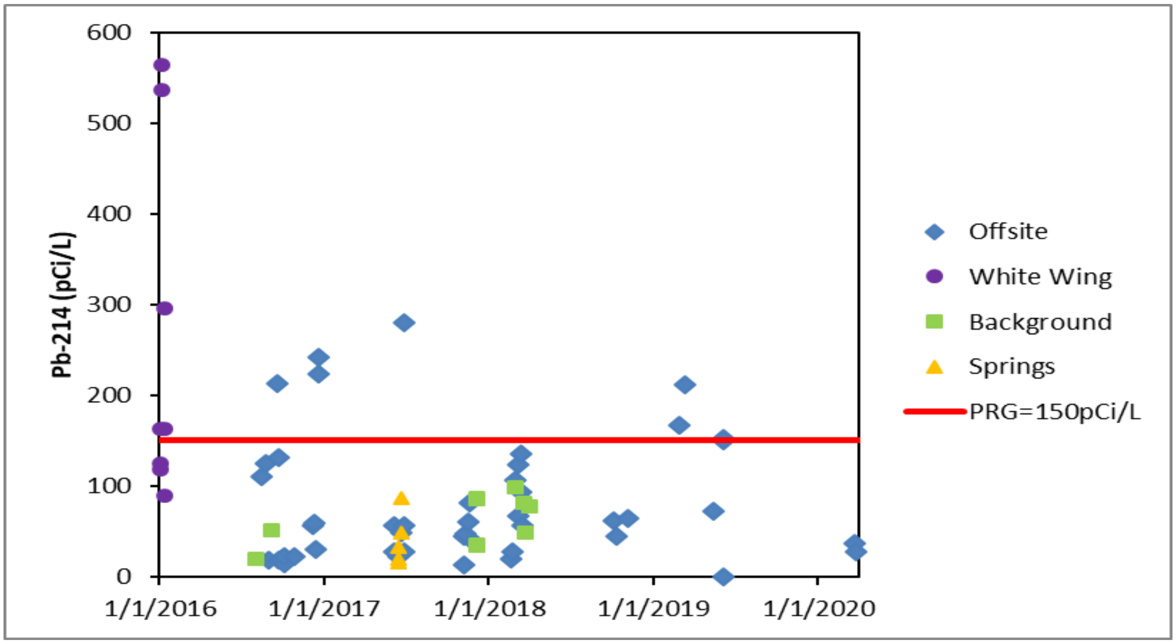


Figure 7.2.10: Lead-214 (Pb-214) measured in picoCuries per liter (pCi/L) showing the PRG. The majority of the wells above the PRG are offsite, however almost all White Wing Road samples are above it as well.

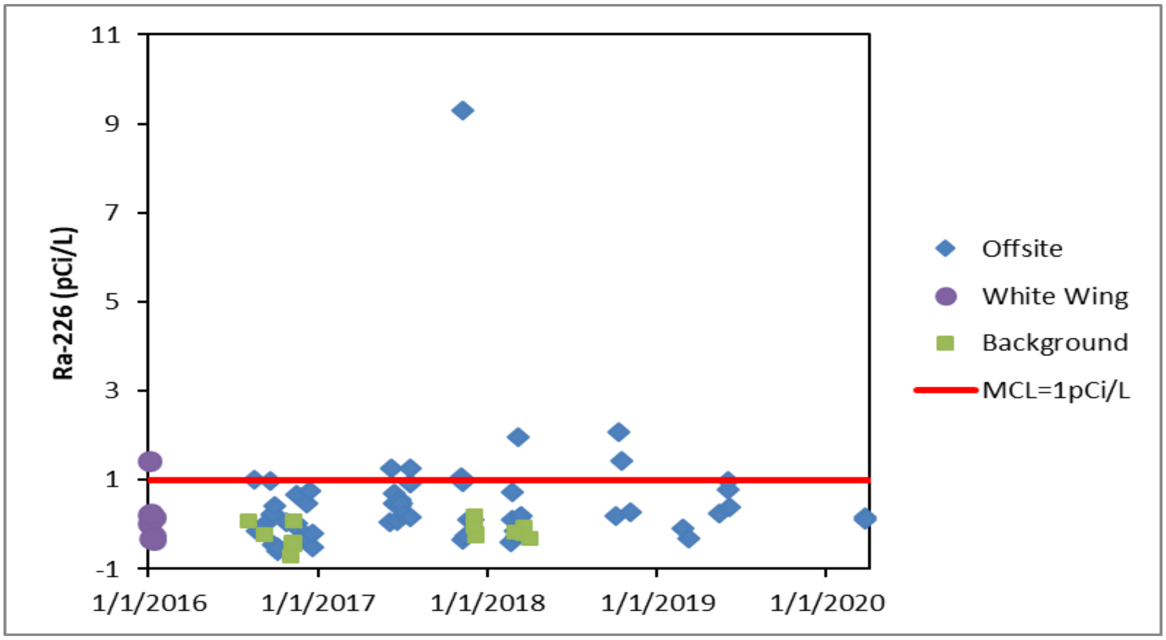


**Figure 7.2.11: Radium-226 measured in picoCuries per liter (pCi/L) showing the MCL. Most of the exceedances were close to the MCL, but one offsite well was very high (RWA-128 on 11/9/17).**

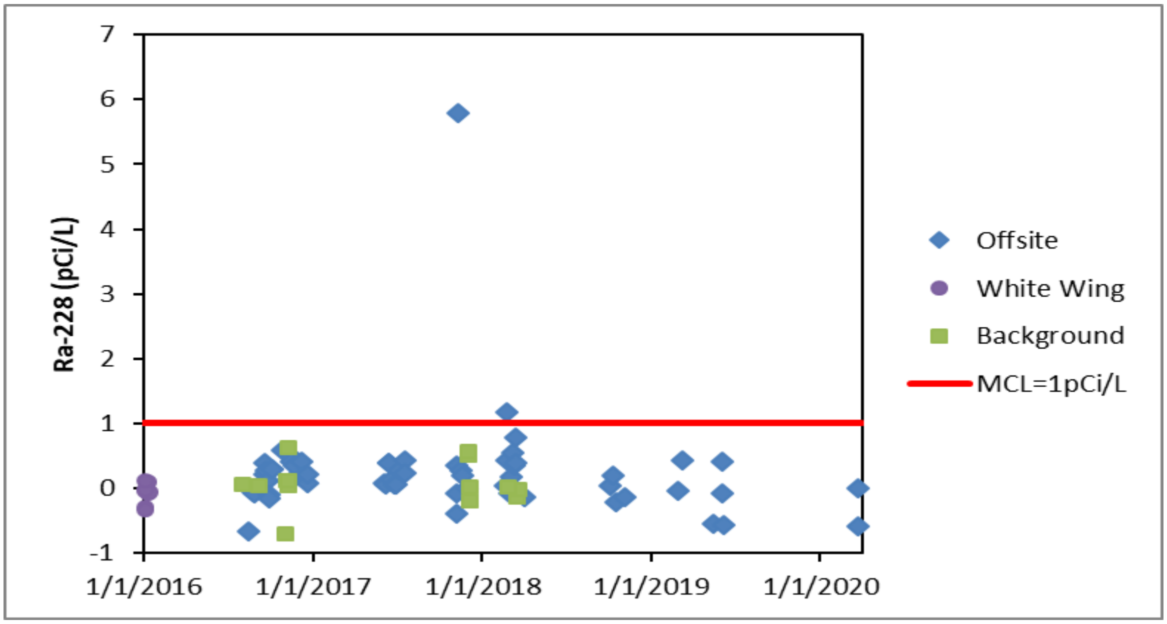


**Figure 7.2.12: Radium-228 measured in picoCuries per liter (pCi/L) showing the MCL. There were only 2 offsite exceedances, one of which was a lot higher than the MCL (RWA-128 on 11/9/17).**

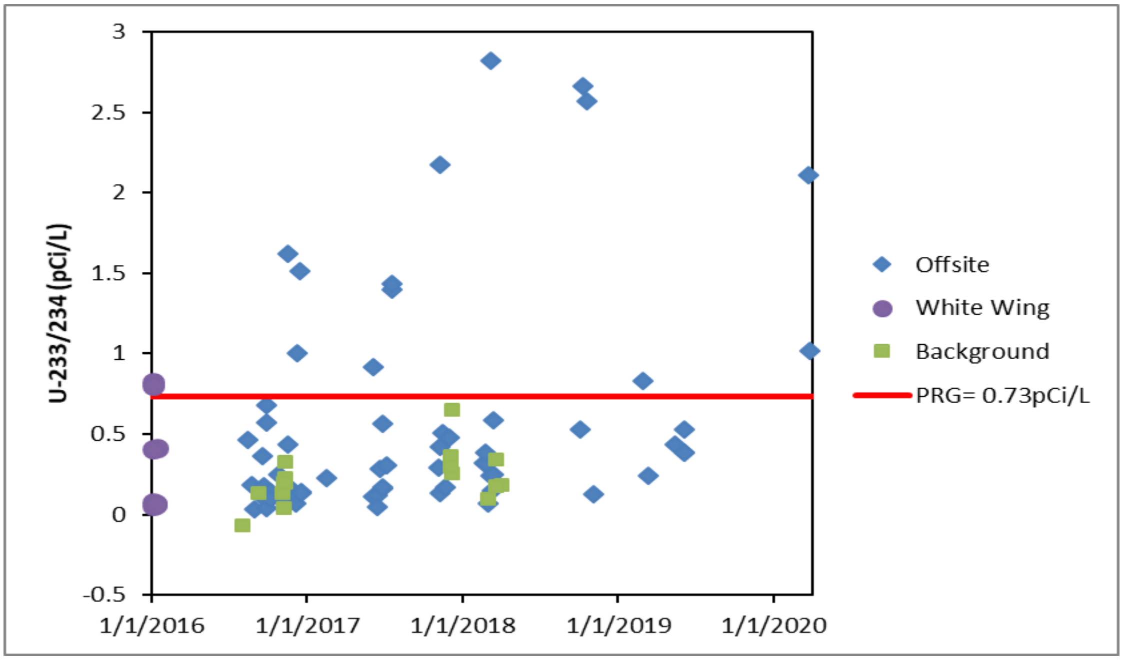


**Figure 7.2.13: Uranium-233/234 (U-233/234) measured in picoCuries per liter (pCi/L) showing the PRG. The exceedances were mainly offsite samples and a few White Wing Road.**

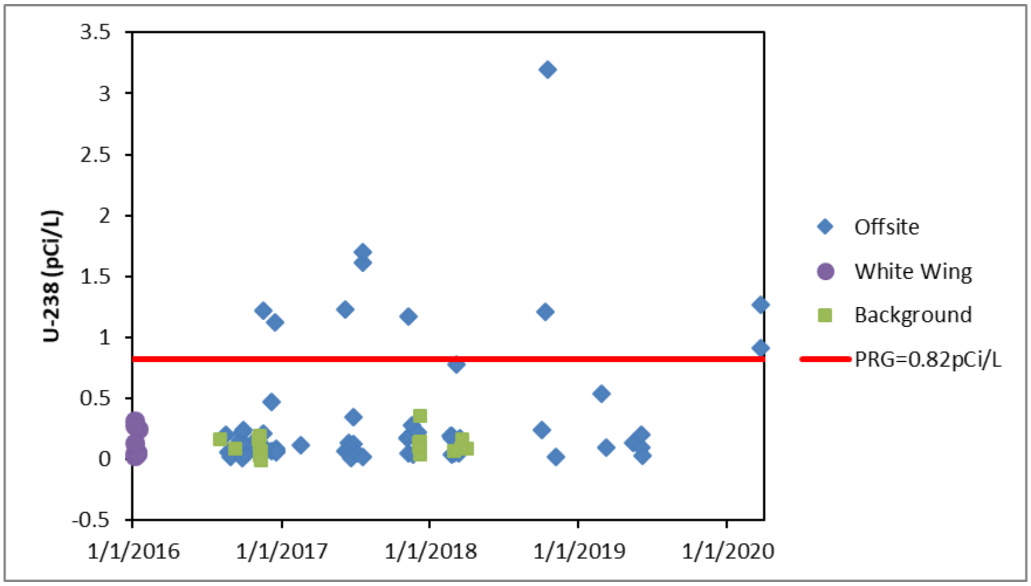


**Figure 7.2.14: Uranium-238 (U-238) measured in picoCuries per liter (pCi/L) showing the PRG. The exceedances were only offsite samples.**

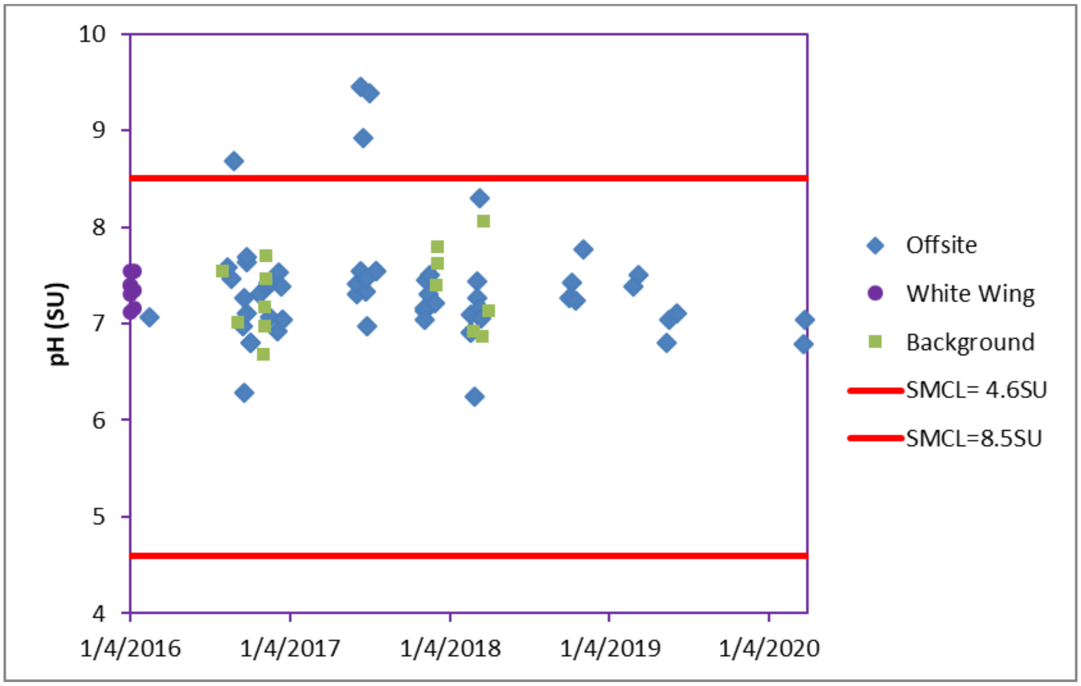


**Figure 7.2.15: Graph showing pH measured in Standard Units (SU) and the acceptable SMCL range.**

### Groundwater Signature

Groundwaters in a specific area have a signature that is based off common groundwater anion and cations which is why it is important that they are included as analytes in groundwater studies. Anions are negatively charged ions while cations are positively charged ions. The most abundant anions are bicarbonate ($HCO_3^-$), chloride ($Cl^-$), and sulfate ($SO_4^{2-}$). The most abundant cations in groundwater are calcium ($Ca^+$), magnesium ($Mg^+$), sodium ($Na^+$), and potassium ($K^+$).

The first way to identify groundwater is to look at two commonly bonded ions, sodium and chloride. These were plotted in Figure 7.2.16 to see the relationship between them. The red line in the graph is a 1:1 ratio where, if they were bonding together, the sample points would fall along or be very close to this line. However, this is not the case with this data. The points trend above the line towards more sodium rich. Sodium still needs something to bond to in order to be stable and likely would then bond with $HCO_3^-$. This means that the groundwater in the area is defined as a sodium-bicarbonate.

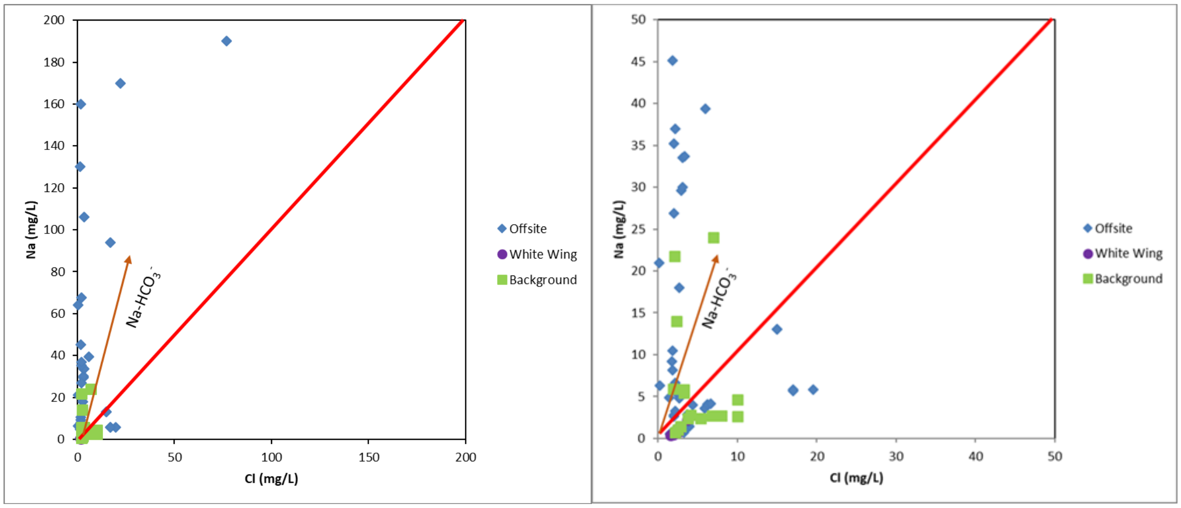


**Figure 7.2.16: Graphs showing the relationship between sodium and chloride.**

Alkalinity is reported as bicarbonate. The sodium and alkalinity relationship in these groundwater samples are shown in Figure 7.2.17 below. The plots here show that these constituents (alkalinity and bicarbonate) do correlate for a natural system with that R value. This analysis further shows that the groundwater evaluated here is a sodium-bicarbonate type groundwater.

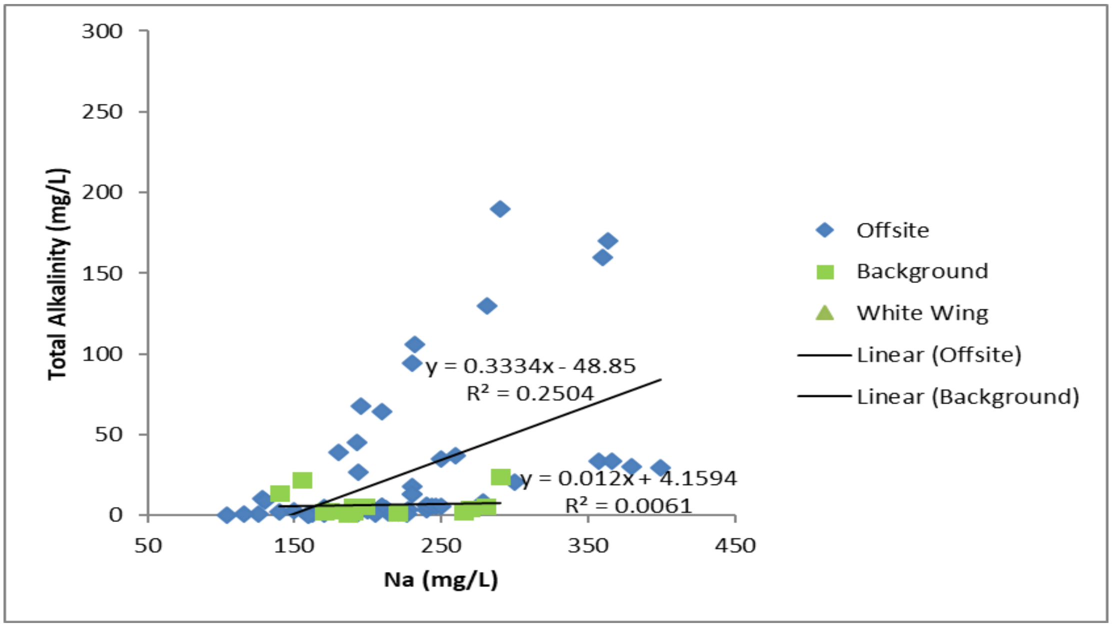


**Figure 7.2.17: Graph showing the relationship between alkalinity and sodium.**

Figure 7.2.18 shows a piper plot incorporating all the major anions and cations data from these groundwater samples. This data shows that the groundwater is between a magnesium bicarbonate to sodium bicarbonate groundwater. This designation determination was further explored by plotting magnesium and alkalinity in Figure 7.2.19. The linear equations show that there is correlation between magnesium and alkalinity. The correlation among the three projects is the strongest with the White Wing Project samples.

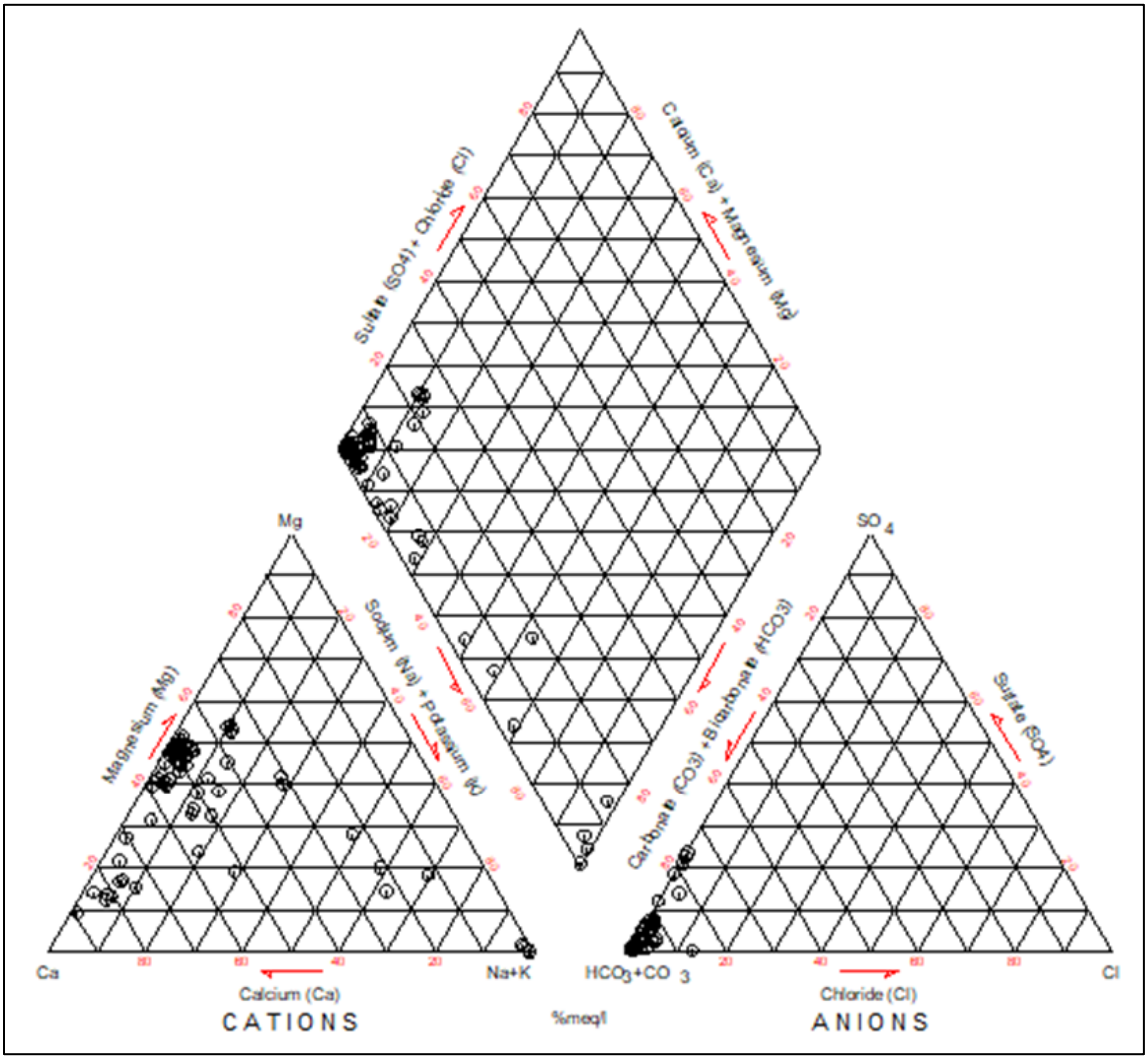


**Figure 7.2.18: Piper plot showing all of the data points and common groundwater cations and anions.**

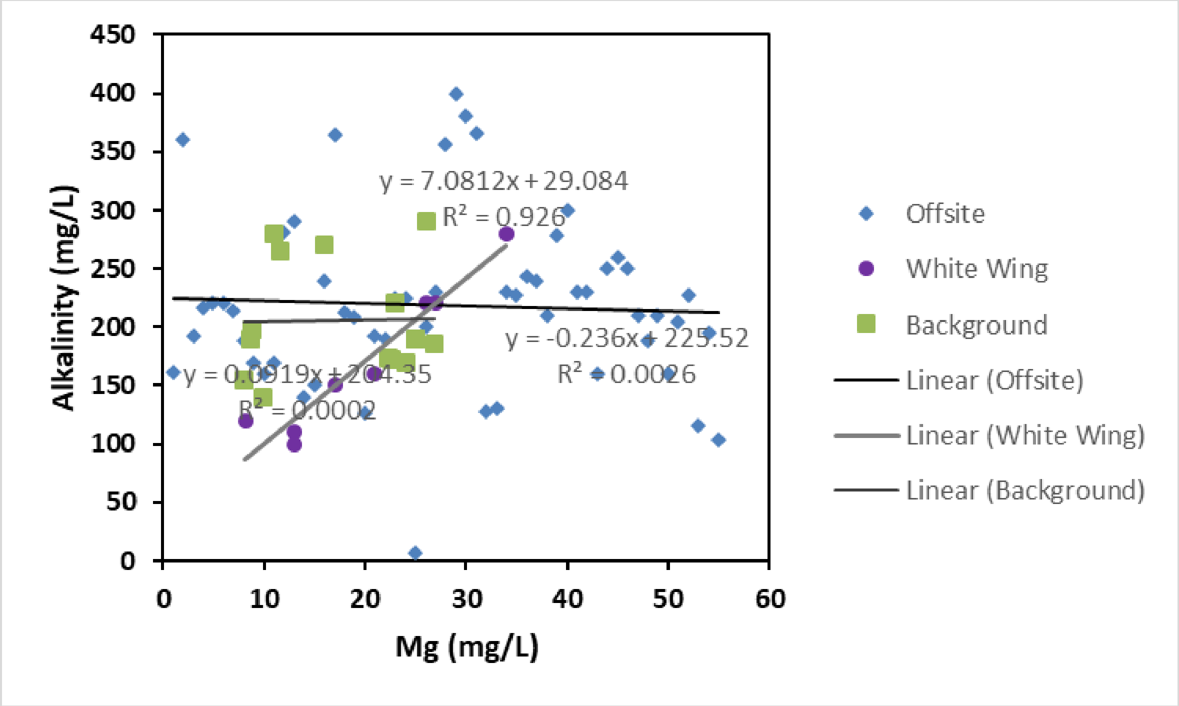


Figure 7.2.19: Graph showing the relationship and correlation between alkalinity (mg/L) and magnesium (Mg) (mg/L).

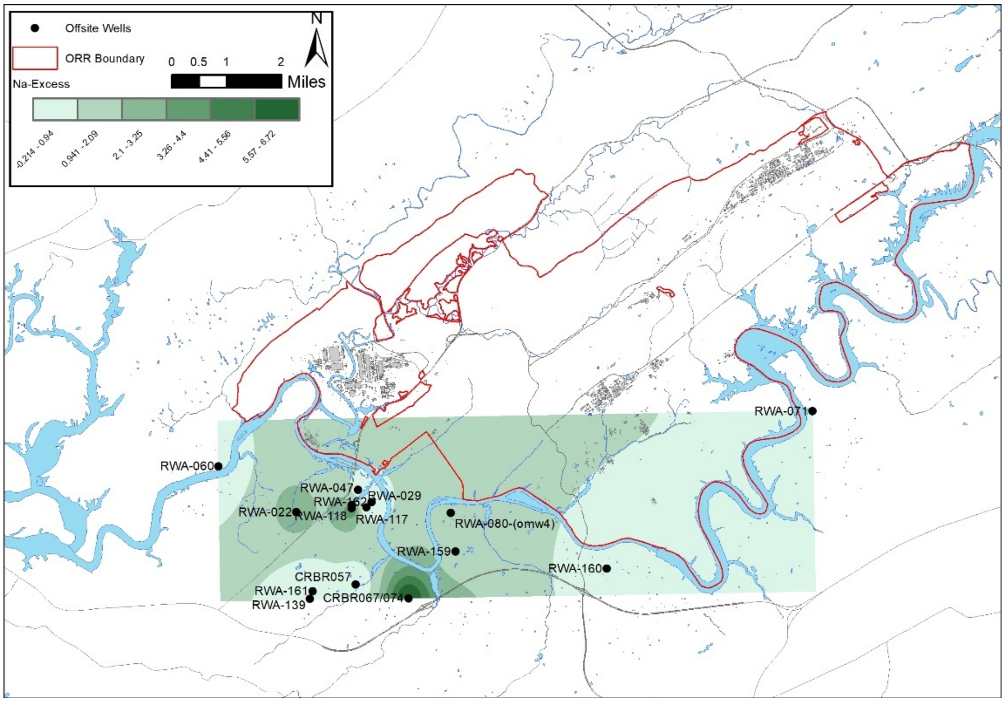


Figure 7.2.20: Map showing sodium excess in milliequivalents.

A final way that was utilized in this assessment to show if the sodium is high in the groundwater in this area is to look at sodium-excess. (Figure 7.2.20) This is determined by using the sodium in mg/L and chloride in mg/L and taking the charge and weight into account converting them into milliequivalents. Next the chloride is subtracted from the sodium, providing a value for sodium-excess. This was mapped in Figure 7.2.20, using only the 2018 data. This mapping shows that there are some areas with a lot of excess sodium in the groundwater samples at this site. Interpretation should be reviewed further but this characteristic may be relevant to historical oak ridge operations and associated groundwater flow in the subsurface, as sodium hydroxide a component of some of the wastes disposed on the ORR during prior disposal actions at the site.

### 7.2.8 Conclusions

The results from this investigation show that there is not enough data from each individual well or spring on which to run meaningful statistics. Although this data set spans five years, 2016-2020, the data set still only represents a snapshot in time and not continuous monitoring. Also, the data sets for each year over this time frame also became smaller and smaller making determinations from this data set it more limited.

The contamination of groundwater beneath several areas of the ORR and the potential pathways for contaminant migration beyond the ORR boundary make it imperative to continue the monitoring and evaluating plume dynamics, historical data sets and offsite residential wells that may be a primary or sole source of drinking water for local residents in Anderson, Loudon, and Roane counties. Planning future actions as well as making determinations with the sampling data from current activities will be well suited to include historical data while assessing the new.

### 7.2.9 Recommendations

Recommendation for future TDEC DoR-OR groundwater projects include:

- Focus limited resources to sampling offsite the ORR one valley at a time; compare the results to onsite data results.
- Take an in-depth look at the TDEC DoR-OR offsite historical groundwater data in conjunction with DOE offsite data to help guide future groundwater decisions. Widen the phased data sets to more than just five years to get a better picture and ability to run statistics with more data points per location. Incorporate on site DOE data to the data analysis.

- Conduct a data search for each valley and analyze onsite data focusing on the main COCs from each main area (Y-12, ORNL, ETTP), to evaluate impacts to offsite receptors.

### 7.2.10 References

U.S. Environmental Protection Agency (EPA). (2017, November). Regional Screening Levels (RSLs)-Generic Tables (November 2017). Retrieved 2018 from https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-november-2017

U.S. Environmental Protection Agency (EPA). (2012). 2012 Edition of the Drinking Water Standards and Health Advisories. EPA 822-S-12-001 Retrieved 2018 from https://www.epa.gov/sites/production/files/2015-09/documents/dwstandards2012.pdf

# 8.0 RADNET MONITORING

## 8.1 RADNET AIR MONITORING

### 8.1.1 Background

In the past, air emissions from Department of Energy (DOE) activities on the Oak Ridge Reservation (ORR) were believed to have been a potential cause of illnesses affecting area residents. While these emissions have substantially decreased over the years, concerns have remained that air pollutants from current activities (e.g., production of radioisotopes and demolition of radioactive contaminated facilities) could pose a threat to public health, the surrounding environment, or both. Consequently, the Tennessee Department of Conservation (TDEC) Division of Remediation Oak Ridge Office (DoR-OR) has implemented several air monitoring programs to assess the impact of ORR air emissions on the surrounding environment and the effectiveness of DOE controls and monitoring systems. This project provides additional monitoring along with independent third-party analysis.

The RadNet Air Monitoring Project on the ORR began in August of 1996 and provides radiochemical analysis of air particulate samples collected twice weekly from five air monitoring stations located near potential sources of radiological air emissions on the ORR. RadNet samples are collected by DoR-OR and analysis is performed at the EPA National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama.

### 8.1.2 Problem Statements

The three sites on the ORR ,Oak Ridge National Lab (ORNL), the Y-12 National Security Complex (Y-12), and East Tennessee Technology Park (ETTP), can potentially release radioactive contaminants into the air from current operations, as well as from the deterioration of contaminated buildings at each site, and the decontamination and decommissioning (D&D) of these facilities.

### 8.1.3 Goals

Protect the human health and the environment by assuring the public that the State of Tennessee independently evaluates gross beta activity in air on the ORR with the continuous monitoring of five RadNet Air monitoring stations, with over 500 total samples analyzed yearly.

- Determine that levels of gross beta radioactivity are not above regulatory levels for a beta emitter with stringent criteria, and, preferably, that they are below screening levels requiring additional analysis.

- Compare gross beta levels from the RadNet Air monitors on the ORR to gross beta levels observed at the RadNet station in Knoxville, used as a background location.
- Complement the TDEC Fugitive Radiological Air Emissions Project by providing gross beta analysis (and other analysis if screening levels are exceeded), by providing additional air monitors for greater area coverage of the ORR, and by providing more frequent analysis

### 8.1.4 Scope

The RadNet Air Monitoring Project uses five high-volume air samplers to monitor air for radiological contamination. Two of the five air samplers are located at Y-12; one is located near each end of the plant. One sampler is located at ETTP, off Blair Road. Two samplers are located at ORNL; one is in Bethel Valley and one is located in Melton Valley. An additional air sampler is located and run by the TDEC field office in Knoxville and is only used for background comparison.

The five RadNet Air samplers on the ORR were sampled on Mondays and Thursdays except when skipped due to a holiday. Each of the samples were analyzed by EPA's NAREL for gross beta, which can mean the analysis of over 500 samples from the ORR each year. Gamma analysis is performed on any samples with gross beta levels greater than 1 pCi/m$^3$ and on an annual composite of the year's samples at each station. Once every four years, the EPA laboratory performs uranium and plutonium isotopic analysis on an annual composite of the filters from each station.

### 8.1.5 Methods, Materials, Metrics

The locations of the five RadNet Air samplers are provided in Figure 8.1.1 and described in the scope of this project. EPA's analytical parameters and frequencies are listed in Table 8.1.1.

The RadNet Air samplers run continuously, collecting suspended particulates on synthetic fiber filters (10 centimeters in diameter) as air is drawn through the units by a pump at approximately 35 cubic feet per minute. TDEC collects the filters from each sampler, twice weekly, following EPA protocol (U.S. EPA, 1988; U.S. EPA, 2006). After collection, the filters are shipped to EPA's NAREL for analysis. Each year about 500 samples from the ORR are analyzed through this project. While gross beta analysis is used as a screening tool, with further analysis triggered when levels are over 1.0 pCi/ m$^3$, much lower levels can be seen with average minimum detectable concentrations of about 0.000358 pCi/ m$^3$ (for the ORR locations from 2010 through 2019).

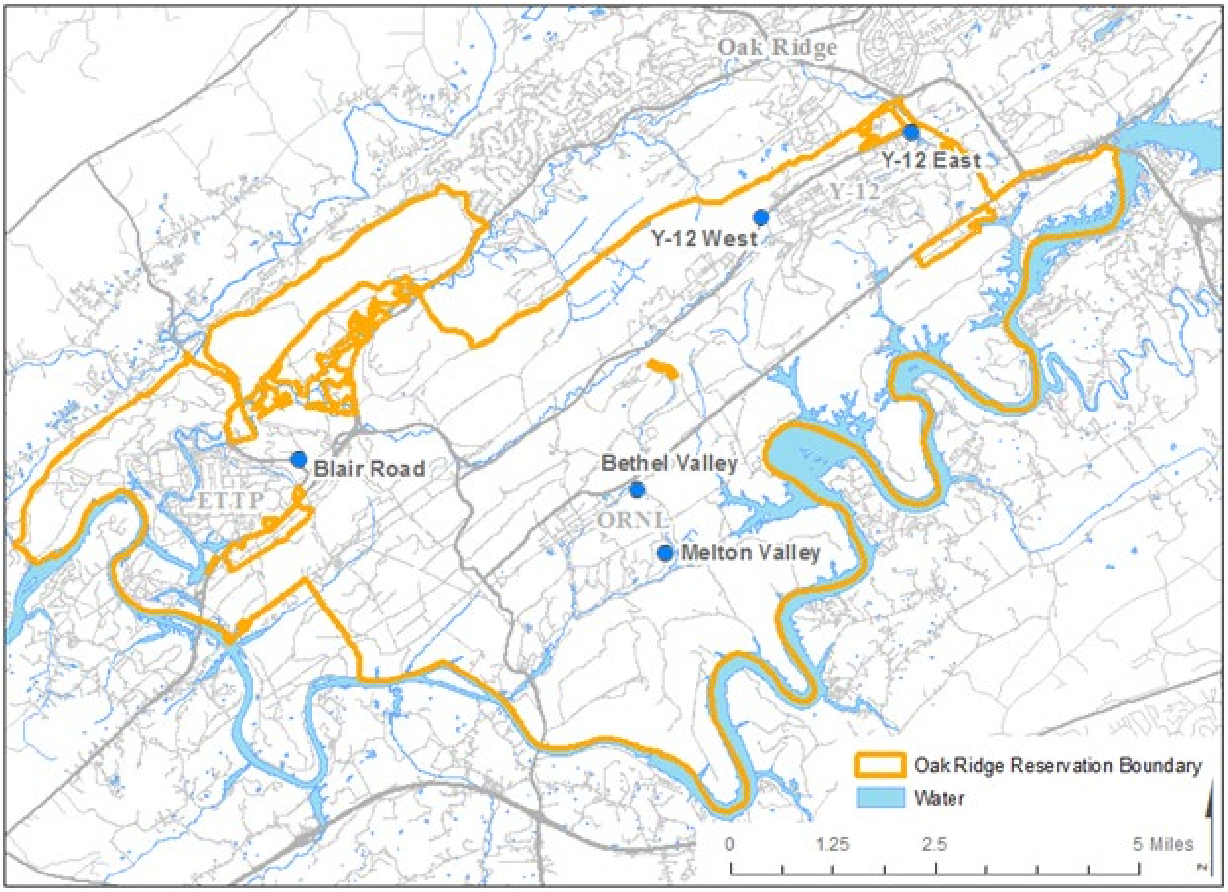


**Figure 8.1.1: Locations of RadNet Air Monitoring Stations on the ORR**

**Table 8.1.1: RadNet Air Monitoring Analyses and Frequencies**

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

The results of NAREL's analyses of the nationwide RadNet Air monitoring are available at NAREL's website in the Envirofacts RadNet searchable database.

Gross beta from the RadNet Air Monitoring Project is compared to background data from the RadNet Air monitor in Knoxville, Tennessee, and to the Clean Air Act (CAA) environmental limit for strontium-90, because it is a pure beta emitter with a conservative limit. The gross beta results provided by this project are useful on their own, as the detection limits are low. They are also useful as a screening tool because many gamma emitters also emit beta radiation.

### 8.1.6 Deviations from the Plan

Sampling was temporarily discontinued after March 23, 2020 due to COVID-19 concerns and no samples were collected through the end of June 2020. Consequently, data is only available from July 2019 through March 23, 2020. No other deviations from the planned sampling for this project resulted. However, the composites for 2017 for uranium and plutonium are still not available, so no results will be published or discussed in this EMR. When the results are available, they can be viewed online and will be discussed in the FY2021 Environmental Monitoring Report.

### 8.1.7 Results and Analysis

The results of NAREL's analyses of the nationwide RadNet Air sampling are available in the RadNet database on the Envirofacts website, via either a simple or a customized search. The new results shared in this report are from samples collected from July 2019 through March 23, 2020 for the RadNet Air stations on the ORR, though 2019 results as a whole are also discussed. Gross beta from the RadNet Air Monitoring Project on the ORR was compared to background data from the RadNet Air monitor in Knoxville, Tennessee, and to the CAA environmental limit for strontium-90, as it is a pure beta emitter with a conservative limit.

As seen in Figure 8.1.2, the results for the gross beta analysis of samples collected July 2019 through March 2020 were similar for each of the five ORR RadNet monitoring stations and were similar to the results reported for the Knoxville RadNet Air station (used as background for comparison). The fluctuations observed in the results (depicted in Figure 8.1.2) 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. Some of the differences between the RadNet Air stations on the ORR and the background station in Knoxville may be attributed to differences in weather and or collection schedules. The ORR gross beta results for the RadNet Air Monitoring Project from July 2019 through March 2020 were all well below 1.0 pCi/m$^3$, which is the screening level that triggers further analysis.

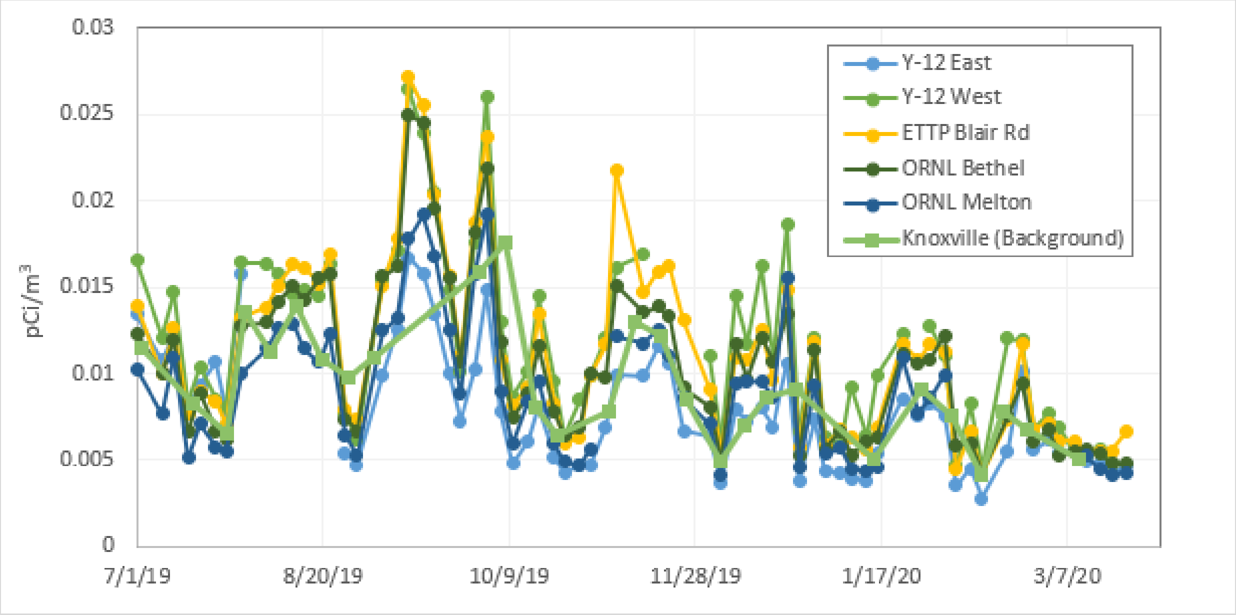


**Figure 8.1.2: RadNet Air Monitoring Project Gross Beta Results July 2019 - March 2020**

Note: This figure is intended to convey the correlation of the results for the various monitoring stations, not to depict individual results. Individual measurements are available online from EPA.

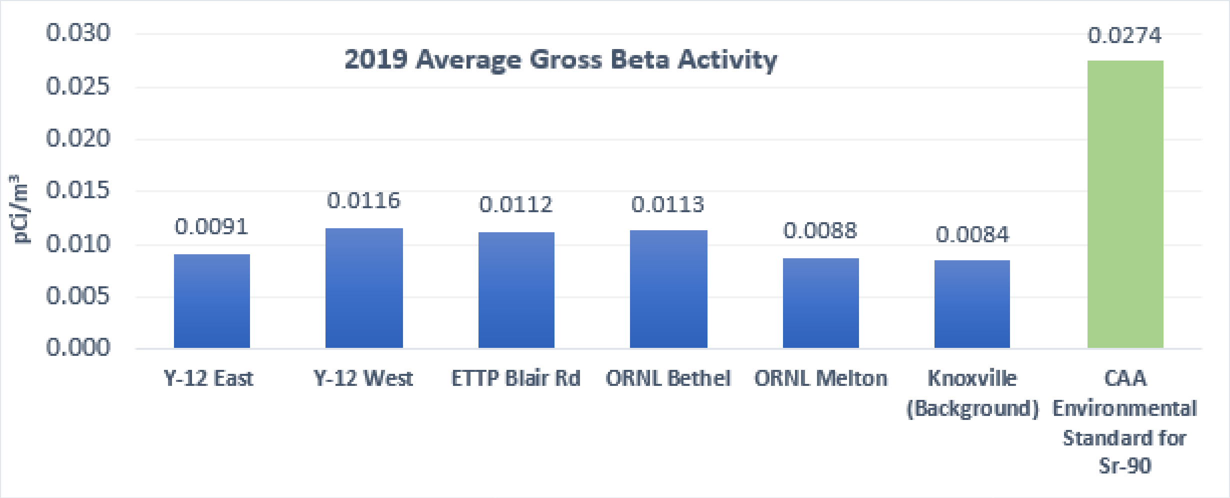


**Figure 8.1.3: 2019 RadNet Air Monitoring Program Average Gross Beta Results**

Note: Typical background values for gross beta range from 0.005 to 0.1 pCi/m$^3$ (ORISE, 1993). The standards provided by the Clean Air Act apply to the dose above background; therefore, the standard provided for reference in this figure has been adjusted to include the average of the background measurements taken from the RadNet station in Knoxville for 2019 (CAA value for Sr-90 [0.019 pCi/m$^3$] + annual average gross beta at a background location=CAA environmental standard for Sr-90). The CAA's Environmental Limit for strontium-90 is used as a screening mechanism and is provided here for comparison. It is unlikely that this isotope contributes a major proportion of the gross beta activity reported for the samples**.**

Figure 8.1.3 depicts the 2019 average gross beta results for each of the five stations in the ORR RadNet Air Program, the average background concentration measured at the Knoxville RadNet location, and the CAA environmental limit for strontium-90.

The CAA specifies that exposures to the public from radioactive materials released to the air from DOE facilities shall not cause members of the public to receive an effective dose equivalent to greater than 10 mrem above background measurements in a year. For point-source emissions, compliance with this standard is generally determined with air dispersion models that predict the dose at offsite locations. The CAA also provides environmental concentrations for radionuclides equivalent to a dose of 10 mrem in a year (EPA 2010) to determine compliance.

To evaluate the RadNet data, the RadNet Air Monitoring Project compares the average gross beta results reported for the project to the CAA limit for strontium-90, which has one of the most stringent standards of the beta-emitting radionuclides. The CAA standards apply to the dose above background, so the limit represented in Figure 8.1.3 was adjusted to include the average gross beta measurement taken at the RadNet station in Knoxville, as a background. It is important to note 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 2019 results at all the RadNet Air stations are mostly comparable (results showed that sites responded in a similar pattern during each sampling period), the average gross beta results for the ORR RadNet Air Monitoring Project in 2019 were lower at the ORNL Melton and Y-12 East locations. The station with the highest gross beta average for 2019 on the ORR (the Y-12 West location) was just slightly greater than the gross beta average seen at the ETTP Blair Road and ORNL Bethel locations. The average results from each of the ORR RadNet monitoring stations fall below the strontium-90 limit (Figure 8.1.3).

None of the gross beta results reported for the RadNet Air Monitoring project on the ORR from July 2019 through March 2020 exceeded the screening level (1.0 pCi/m$^3$) which would have led to additional analysis by gamma spectrometry.  The average minimum detectable concentration (MDC) was 0.000358 pCi/ m$^3$ for the ORR locations from 2010 through 2019. So, while 1 pCi/m$^3$ is the screening level which triggers further analysis by EPA, concentration levels of about 0.000358 pCi/m$^3$ and higher can be detected and compared. The actual MDC for each sample is sample specific, but usually isn't far from the mean MDC listed.

The analysis for uranium and plutonium on annual composite samples is performed every four years. The most recent composite results available were from 2013, which were presented in a prior report, with all values for each isotope below the limits established by the CAA. However, the composites for 2017 are not yet available.

### 8.1.8 Conclusions

The gross beta results for each of the five RadNet Air monitoring stations exhibited similar trends and concentration levels for the period July 2019 through March 2020. All the data during this time period was well below the value which would warrant further analysis and does not indicate that activities on the ORR pose a significant impact on the environment or public health.

### 8.1.9 Recommendations

Continued ORR air monitoring for radiological contamination through this and other programs is recommended in order to ensure that air quality is protective of human health and the environment. This is especially important because of the demolition of contaminated buildings, movement of contaminated soils, operations, and other continued activities on the ORR. These activities all have the potential to impact air quality. In the event of a release either on or off the ORR, the RadNet Air Monitoring project would provide valuable information relating to the extent of radiological contamination in the air before, during, and after the event.

The RadNet Air Monitoring Project is a valuable addition to other ORR air monitoring. First, annual sampling via the RadNet Air Project collects and analyzes more samples than DOE air monitoring (twice weekly samples with over 100 samples analyzed yearly from each of five locations on the ORR). Second, gross beta analysis is not only used as a screening tool with further analysis when levels exceed 1.0 pCi/ m$^3$, but it also can detect much lower levels with low sample specific MDCs, so it can be very effective at detecting elevated gross beta levels as well as variation. Third, because gross beta analysis works as a screening tool since few isotopes of interest are pure gamma or pure beta emitters, if there were a release on the ORR, it is likely there would also be some beta radiation emitted either directly or from daughter products. Consequently, this program is likely to be able to see an increase in radiological levels in air and be able to better pinpoint the time of release due to analysis of twice weekly samples versus the quarterly compositing of weekly air filters done by DOE.

### 8.1.10 References

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U.S. Environmental Protection Agency (1988). Environmental Radiation Ambient Monitoring System (ERAMS) Manual. EPA 520/5-84-007, 008, 009.

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Envirofacts RadNet Searchable Database:

search https://enviro.epa.gov/enviro/erams_query_v2.simple_query

customized search https://www.epa.gov/enviro/radnet-customized-search

## 8.2 RADNET PRECIPITATION MONITORING

### 8.2.1 Background

Nationwide, the RadNet Precipitation Monitoring Project measures radioactive contaminants that are carried to the earth's surface by precipitation. On the Oak Ridge Reservation (ORR), the RadNet Precipitation Monitoring Project provides radiochemical analysis of precipitation samples taken from monitoring stations at three locations. Samples are collected by the Tennessee Department of Environment and Conservation (TDEC) and gamma analysis is performed on monthly composite samples at EPA's National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama. Additional analysis may be conducted by NAREL if a radiological release is known or is indicated by monthly gamma analysis results. While there are no regulatory standards that apply directly to contaminants in precipitation, the data from this project provide an indication of the presence of radioactive materials that may not be evident in the particulate samples collected by the TDEC or Department of Energy (DOE) air monitors.

The Environmental Protection Agency (EPA) has provided three RadNet precipitation monitors which are co-located with a RadNet air station at each of the three ORR sites. The first precipitation monitor is located at Oak Ridge National Laboratory (ORNL) in Melton Valley, in the vicinity of ORNL's High Flux Isotope Reactor and the Solid Waste Storage Area burial grounds. The second precipitation monitor is located off Blair Road to monitor contaminants from demolition activities at East Tennessee Technology Park (ETTP). The third station is located at the east end of the Y-12 National Security Complex (Y-12). In addition to monitoring Y-12, this station could potentially provide an indication of radioisotopes traveling toward the City of Oak Ridge from ORNL or Y-12. Analysis for gamma radionuclides is performed on the monthly composite samples for each of the three precipitation monitoring locations.

### 8.2.2 Problem Statements

The three sites on the ORR, ORNL, Y-12, and ETTP, have the potential to release radioactive contaminants into the air from previous and current operations as well as from the deterioration of contaminated buildings and the decontamination and decommissioning of these facilities.

This project measures any radioactive constituents that are carried to the earth's surface by precipitation. The data provides an indication of the presence of radioactive materials that may not be evident in the particulate samples collected by air monitors.

### 8.2.3 Goals

This project looks at the results from RadNet precipitation monitoring of gamma radionuclides to assure the public that human health and the environment are being protected.

The results from the project can be used to:

- Identify anomalies in gamma concentrations in precipitation on the ORR
- Assess the significance of precipitation in contaminant pathways
- Evaluate contamination control measures during D&D or remediation activities on the ORR
- Compare precipitation concentrations from the ORR with other locations in the nationwide EPA RadNet Program
- Determine levels of local contamination in the event of a nuclear incident

### 8.2.4 Scope

Three precipitation samplers are used to monitor the precipitation for potential radiological contamination. Each sampler is co-located at a RadNet air station at each of the three ORR sites. One sampler is located at the east end of the Y-12 plant. One unit is located at ETTP, off Blair Road. The third sampler is located at ORNL in Melton Valley. These locations are shown in Figure 8.2.1. The three precipitation samplers co-located with the RadNet Air samplers on the ORR were sampled Mondays and Thursdays, except when skipped due to a holiday. The precipitation samples are composited monthly at the EPA laboratory and analyzed for gamma radionuclides. Additional analysis on individual samples would likely be run in the event of elevated findings or for a nuclear release.

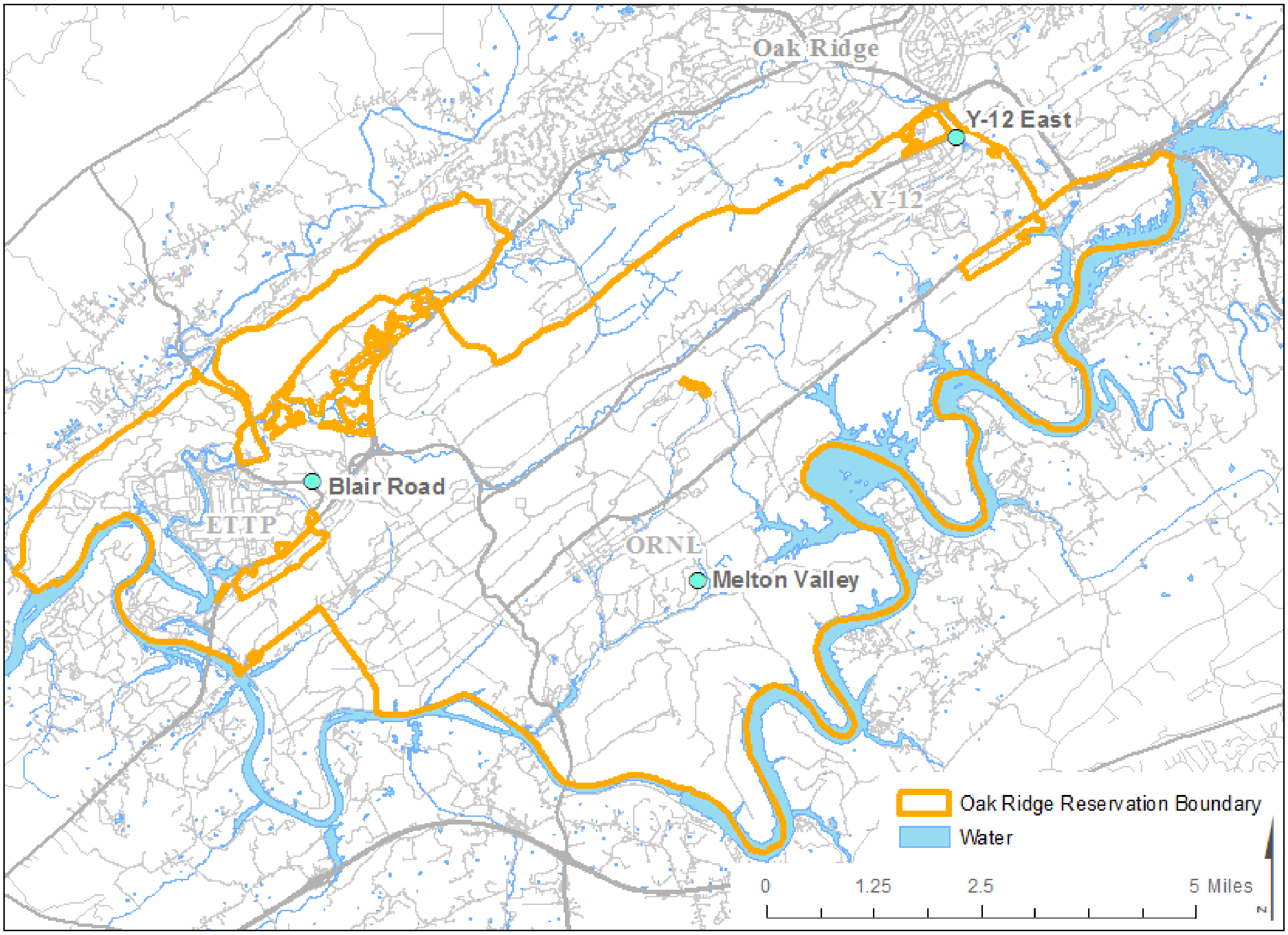

**Figure 8.2.1: Locations of the RadNet Precipitation samplers on the ORR**

### 8.2.5 Methods, Materials, Metrics

The three precipitation samplers provided by EPA's RadNet Air Monitoring Program (locations shown in Figure 8.2.1) were used to collect samples for the RadNet Precipitation Monitoring Project. Each sampler drains precipitation that falls on a 0.5 square meter fiberglass collector into a five-gallon collection bucket. Each sample is measured, then collected from the bucket (into a four-liter container) and sent to EPA when a minimum of two liters of precipitation has accumulated, or less when it is the final sample of the month. Each sample is processed as specified by EPA (EPA, 1988; EPA, 2017) and then shipped to NAREL in Montgomery, Alabama, for analysis. NAREL composites the samples collected during a month for each station and analyzes each composite for gamma radionuclides. 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. Additional analysis may be conducted if there is a known radiological release or if it is indicated by monthly gamma analysis results.

No regulatory limits for radiological contaminants in precipitation exist, so the results of the gamma analyses were compared to drinking water limits established by the EPA as conservative reference values. EPA's Radionuclides Rule for drinking water allows gross alpha levels of up to fifteen picocuries per liter (pCi/L), while beta and gamma emitters are limited to four millirem (mrem) per year and are radionuclide specific. Table 8.2.1 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. Results from the ORR-located RadNet precipitation monitoring stations 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 8.2.1: EPA Drinking Water Limits (MCLs) for Select Isotopes**

| Isotope | EPA limit (pCi/L) |
|---|---|
| Barium-140 (Ba-140) | 90 |
| Beryllium-7 (Be-7) | 6,000 |
| Cobalt-60 (Co-60) | 100 |
| Cesium-134 (Cs-134) | 80 |
| Cesium-137 (Cs-137) | 200 |
| Tritium (H-3) | 20,000 |
| Iodine-131 (I-131) | 3 |

This project report was prepared to assist with the State of Tennessee's commitments under the Environmental Surveillance Oversight Agreement (ESOA) for the ORR. In accordance with that agreement, a portion of the time spent on this project will be in reviewing the DOE Environmental Monitoring Plan (EMP) and Annual Site Environmental Report (ASER) for the ORR and/or applicable FFA remedy documents. This project may evaluate data from various sources to include, but not limited to, data uploaded to the Oak Ridge Environmental Information System (OREIS), data provided to or collected by other State regulatory agencies, split sampling with DOE parties, or independent sampling in accordance with accepted standard procedures. Information analyzed by the TDEC Division of Remediation, Oak Ridge Office (DoR-OR) will be used to make recommendations to existing DOE environmental surveillance programs.

### 8.2.6 Deviations from the Plan

The results in this report would normally cover July 2019 through June 2020 but are only available through March 2020 as sampling was temporarily discontinued for April, May, and June for 2020 due to COVID-19 concerns. Consequently, the data from January 2019 through March 2020 will be discussed in order to cover at least a full year as well as show results from data that was not yet available last year.

### 8.2.7 Results and Analysis

The results of NAREL's analyses of the nationwide RadNet Precipitation sampling are available in the RadNet database on the Envirofacts website (EPA, 2020), via either a simple or a customized search. The gamma isotopes identified from January 2019 through March 2020 sampling results from the ORR include beryllium-7, bismuth-212, cesium-137, cobalt-60, potassium-40, radium-228, thorium-228, and uranium-235. For all isotopes except beryllium-7, potassium-40, and radium-228, the reported results for each isotope were all less than the minimum detectable concentration (MDC). 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.*" The ORR beryllium-7, potassium-40, and radium-228 results are discussed below.

The average result for beryllium-7 for the three ORR samplers from January 2019 through March 2020 was 70.7 pCi/L, compared to an average MDC of 51.1 pCi/L. The national average for beryllium-7 for the same time period was 60.7 pCi/L. The highest beryllium-7 result for the ORR stations during this time period was 156 pCi/L. When compared to the conservative EPA drinking water limit for beryllium-7 of 6,000 pCi/L, the values seen in the monthly composite precipitation samples on the ORR are relatively small.

While most of the potassium-40 results were below detection limits from January 2019 through March 2020, two of the forty-five samples did show detectable levels, both at the ORNL Melton location. Two other stations in Tennessee also reported detectable levels of potassium-40, one in Knoxville and one in Nashville. Both ORR potassium-40 results were greater than, but just over, sample specific detection limits. Potassium-40 is a naturally occurring radionuclide and does not have a drinking water limit.

Three of the ORR RadNet precipitation results from January 2019 through March 2020 showed radium-228 levels greater than sample specific detection limits. Only one of these was during FY2020, which started July 1, 2019. One of these results was reported last year and the other was not yet available when the last report was written. Radium is naturally occurring and found in the earth at trace levels as well as in the air.

### 8.2.8 Conclusions

Overall, the highest values seen in the composited monthly precipitation samples for each of the three ORR stations were all below the MCLs set by the EPA for drinking water. While there are no regulatory limits for radionuclides in precipitation, the comparison to EPA's drinking water limits were used as conservative reference values. All results for bismuth-212, cesium-137, cobalt-60, thorium-228, and uranium-235 for this time period were less than the MDCs**.** The data during this time period 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 from January 2019 through March 2020.

### 8.2.9 Recommendations

Continued monitoring of the ORR precipitation for radiological contamination via the ORR RadNet Precipitation project is recommended in order to ensure that contamination in precipitation seen on the ORR does not present risk to human health and the environment. This is especially important as the demolition of older buildings continues at the ORR sites. Current operations also have the potential to impact precipitation contaminant levels. In the event of an emergency either on or off the ORR, this program would also provide valuable data relating to the extent of radiological contamination in the air and precipitation before, during, and after an event.

### 8.2.10 References

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user guide https://www.epa.gov/enviro/radnet-search-user-guide