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**TENNESSEE DEPARTMENT OF
ENVIRONMENT AND CONSERVATION**

**DIVISION OF REMEDIATION
OAK RIDGE OFFICE**

GROUNDWATER MONITORING REPORT

**ADDENDUM TO THE
ENVIRONMENTAL MONITORING REPORT**

January 2016- June 2017



June 2018

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List of Acronyms and Common Abbreviations

Ag	Silver
Al	Aluminum
Am	Americium
As	Arsenic
B	Boron
Ba	Barium
Be	Beryllium
Bi	Bismuth
Ca	Calcium
cc	cubic centimeter
Cd	Cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Cl ⁻	chloride
cm	centimeter
Cm	Curium
Co-60	Cobalt-60
COC	Contaminants of Concern
CRBR	Clinch River Breeder Reactor
Cs-137	Cesium-137
Cu	Copper
Cr	Chromium
DO	dissolved oxygen
DOE	U.S. Department of Energy
DoR-OR	Division of Remediation, Oak Ridge Office
Dup	duplicate
EMP	Environmental Monitoring Plan
EMR	Environmental Monitoring Report
EMWMF	Environmental Management Waste Management Facility
EPA	U.S. Environmental Protection Agency
ETTP	East Tennessee Technology Park
F ⁻	Fluoride
FFA	Federal Facility Agreement
FB	field blank
Fe	Iron
g	gram
GW	Ground Water
GWQC	Ground Water Quality Criteria
H-3	Tritium
HA	Health Advisory
Hg	Mercury
K	Potassium
kg	kilogram
km	kilometer
l, L	liter
LHAV	Lifetime Health Advisory Value

Li	Lithium
LSP	Lovely Spring
m	meter
m ³	cubic meter
MCL	Maximum Contaminant Level (for drinking water)
MDC	Minimum Detectable Concentration
MDL	Method Detection Limit
ML	Maximum Quantification Level
MeHg	methylmercury
mg	milligram
Mg	Magnesium
ml	milliliter
Mn	Manganese
mrem	1/1000 of a rem – millirem
mv	millivolt
N, S, E, W	North, South, East, West
Na	Sodium
NAWQA	National Water Quality Assessment Program
ng	nanogram
Ni	Nickel
NNSA	National Nuclear Security Administration
NO ₃ ⁻	Nitrate
NO ₂ ⁻	Nitrite
Np-237	Neptunium-237
NPDWR	National Primary Drinking Water Regulations
NTU	Nephelometric Turbidity Unit
OREIS	Oak Ridge Environmental Information System
ORNL	Oak Ridge National Laboratory
ORP	Oxidation Reduction Potential
ORR	Oak Ridge Reservation
Pb	Lead
PCB	polychlorinated biphenyls
pCi	1x10 ⁻¹² Curie (picoCurie)
pCi/L	picoCuries per liter
pCi/m ³	picoCuries per cubic meter
pH	Proportion of Hydrogen Ions (acid vs. base)
ppb	parts per billion
ppm	parts per million
PRG	Preliminary Remediation Goals
Pu	Plutonium
QA	Quality Assurance
QA/QC	quality assurance/quality control
QC	Quality Control
Ra	Radium
RSL	Regional Screening Levels
RWA#	Residential Well Number
Sb	Antimony

SMCL	Secondary MCLs (non-regulatory)
SOP	Standard Operating Procedure
SO ₄ ²⁻	Sulfate
SPG-#	Spring Sample Number
Sr-90	Strontium-90
SU	Standard Units
SW	Surface Water
SWSA#	Solid Waste Storage Area Number
Tc-99	Technetium-99
TCE	Trichloroethene
TDEC	Tennessee Department of Environment and Conservation
TDH	Tennessee Department of Health
TDS	Total Dissolved Solids
Th-232	Thorium-232
Tl	Thallium
TR	Target Risk
TWQC	Tennessee Water Quality Criteria
U.S.	United States
U-234	Uranium-234
U-235	Uranium-235
U-236	Uranium-236
U-238	Uranium-238
USGS	U. S. Geological Survey
V	Vanadium
VOC	Volatile Organic Compound
Y-12	U.S. Department of Energy Y-12 National Security Complex
Zn	Zinc
μS	microSiemens
μg	microgram
μrem	micro rem

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Executive Summary

The Tennessee Department of Environment and Conservation (TDEC), Division of Remediation, Oak Ridge Office (DoR-OR), submits this addendum to the annual Environmental Monitoring Report for the period January 1, 2016 through June 30, 2017 (TDEC 2018).

This addendum summarizes the three groundwater projects conducted from January 1, 2016 through June 30, 2017. Projects include:

- Background Residential Well Monitoring
- Offsite Residential Well Monitoring
- Spring Monitoring

The Background Residential Well Monitoring Project focuses on assessing water quality from residential groundwater wells located northeast of the reservation. Wells were selected that were located in similar rock units to the rock units found within possible ORR contamination sources. These samples were collected with the intent to evaluate fundamental chemical data, hydrogeologic characteristics and geochemical parameters that would be found in native groundwater. This dataset will be used to aid DOR-OR in estimating naturally occurring chemicals and radiological background concentration ranges, as they are regionally distributed in areas not potentially affected by operations at the ORR.

The Offsite Residential Well Monitoring Project collects samples from residential groundwater wells located outside the boundaries of the Oak Ridge Reservation. While downgradient groundwater flow is generally accepted as predominantly to the south and southwest of the ORR, samples were also collected from wells in an area north and northwest of Y-12 per resident request. The intent of this project is to protect human health and the environment by evaluating water quality in the areas surrounding the ORR by assessing if contaminants from ORR may have migrated beyond the boundaries of the reservation footprint.

The Spring Monitoring Project is the continuation of an ongoing project that assesses the ambient health of the groundwater, both up gradient (northeast) and downgradient (southwest) of the reservation, by collecting water quality parameters and samples from for historic “named” springs located both on and off the ORR and along geologic strike to the northeast and southwest. Findings are used as a baseline to help identify and characterize unplanned releases and to evaluate DOE monitoring and control measures that manage groundwater releases to the environment.

All three projects are intimately connected in that they all allow for DoR-OR to gauge the water quality of groundwater offsite of the ORR and the surrounding areas.

1.0 Background Residential Well Monitoring Project

1.1 Introduction

From January 1, 2016 to June 30, 2017, DoR-OR sampled and analyzed groundwater collected from residential wells located upgradient of the ORR. These samples were collected with the intent to evaluate fundamental chemical data, hydrogeologic characteristics and geochemical parameters that would be found in native groundwater. The area of investigation identified for the background study, includes locations that are upgradient (generally northeast) of the ORR which are thought to be independent from ORR influence, but are found along an inferred groundwater pathway that would flow toward the ORR (based on regional geologic units, as well as groundwater flow in the area that typically moves from northeast to southwest). The sample locations can be seen in Figures 1.1 and 1.2. This dataset will be used to aid DOR-OR in estimating the naturally occurring chemical and radiological background concentration ranges, as they should be regionally distributed. Sample sites were chosen from locations where the groundwater from the sampled wells would be in contact with similar rock types that exist on and downgradient of the ORR.

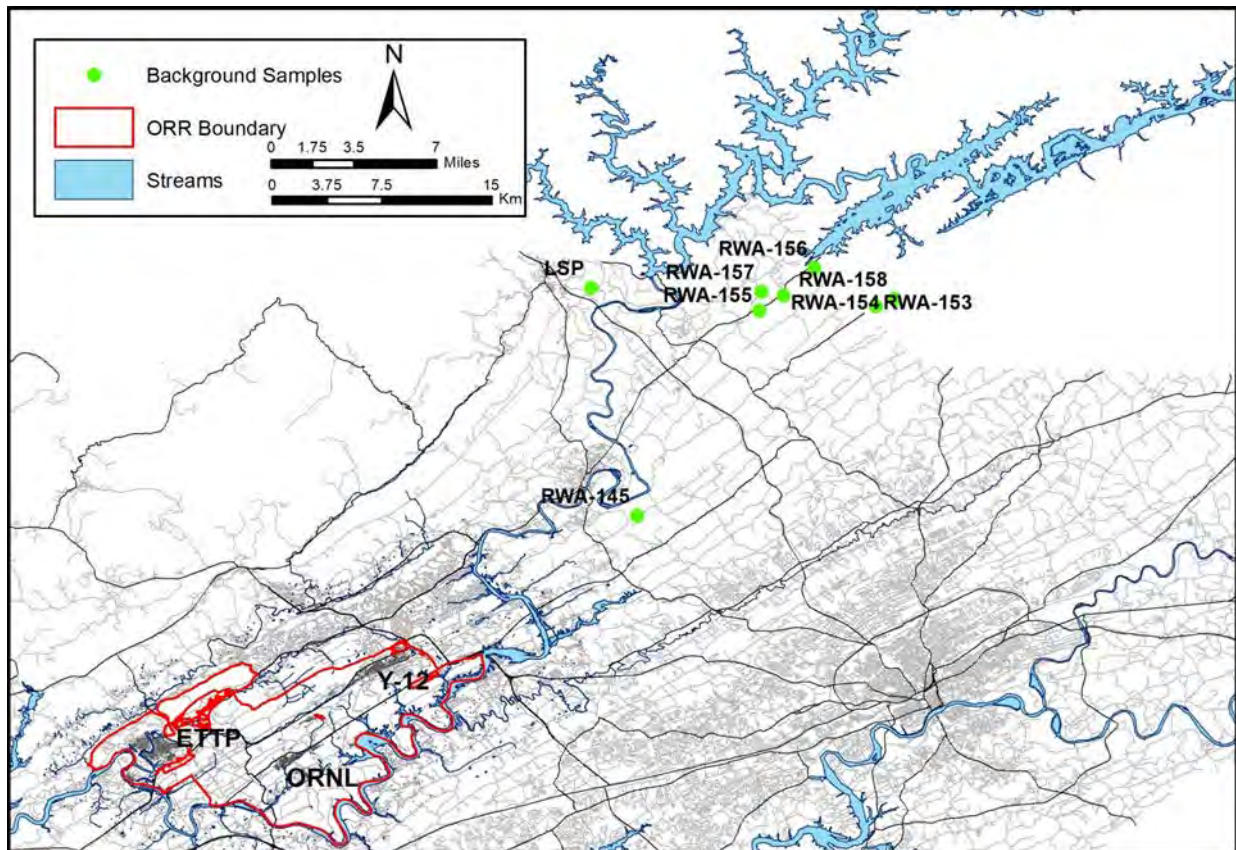


Figure 1.1: Background Residential Well Locations

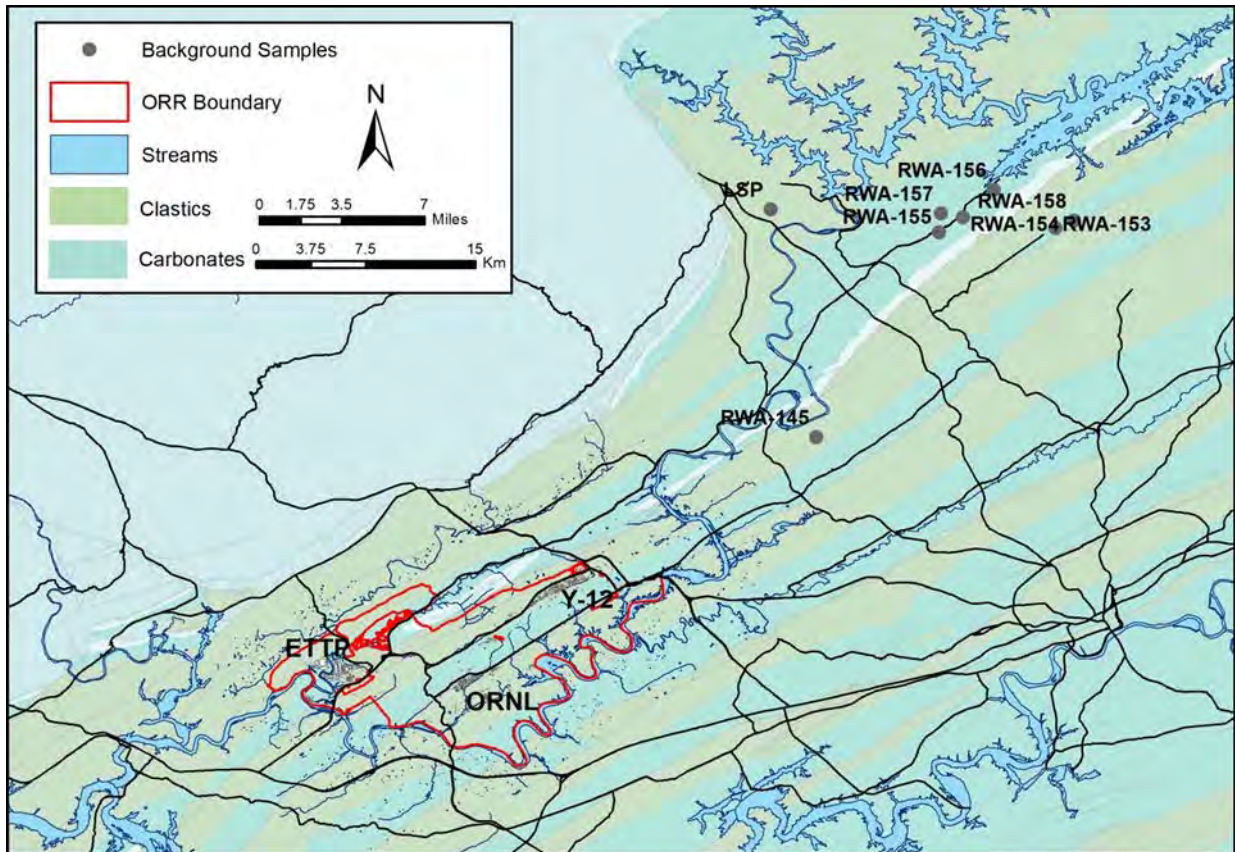


Figure 1.2: Background Well Locations with Respect to Rock Type

With this data, the expectation is to determine spatial (between wells) and temporal (over time) trends of background groundwater. This information will be used to provide comparison data between background water samples and offsite groundwater samples collected that may be impacted by ORR operations. This comparison will assist DOR-OR in the decision-making process while addressing cleanup goals under the Federal Facilities Agreement (FFA) and it will help fulfill TDEC’s mission of protecting human health and the environment. Groundwater data collected from locations downgradient (offsite) from the ORR from similar rock units may also be compared to these background values, to help determine if a potential release attributable to ORR facilities may have occurred.

1.2 Methods and Materials

Groundwater samples were collected from seven residential wells and one spring location all upgradient, between January 1, 2016 and June 30, 2017.

A consistently implemented groundwater sampling procedure (TDEC 2004) helped ensure data comparability between sampling events and between sites. A sample for quality assurance and quality control (QA/QC) was used to ensure the security and quality of the samples during collection and shipping to the laboratory for analysis.

Chemical data, hydrogeologic characteristics and geochemical parameters including pH, temperature, oxidation-reduction potential, and conductivity were measured at each well. This

information was collected to help estimate the naturally occurring chemical and or radiological background concentration ranges of groundwater as they are regionally distributed in the background area of study.

1.2.1 Sampling Techniques

Seven of the locations selected for background sampling were residential wells, i.e., wells with in-place plumbing. One location was a groundwater spring. The background sample locations are shown in Figures 1.1 and 1.2. All background location sampling done during this time frame was co-sampled with DOE. DoR-OR analyzed the background samples for the suite of groundwater characteristics and potential contaminants of concern listed in Table 1.2.1.2.

Prior to sampling the selected background locations, groundwater was purged (i.e. let run from the sample port for a certain amount of time until parameters stabilize). The goal of the purging process is to remove water that may have been standing in a holding tank or other location. This allows samplers to obtain a groundwater sample that is pulled directly from the surrounding groundwater aquifer.

1.2.1.1 Water Quality Parameters

Water quality indicator parameters were collected using a YSI Professional Plus Multiparameter Instrument during purging. Field parameters are the easiest indicators for determining when the formation water is being removed. Stabilization of parameters is required before samples may be collected for lab analysis. Field water quality parameter measurements were made at five minute intervals. Field parameter stabilization is defined as four consecutive readings within the criteria presented in Table 1.2.1.1 below. If field measurements have not stabilized after five well-volumes have been removed, then the project lead shall determine whether collecting a sample is appropriate.

Table 1.2.1.1: Water Quality Indicator Parameters

Measurement (units)	Normal Range	Acceptable Variability¹
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

1.2.1.2 Sample Collection

Samples are collected following stabilization of parameters, from a valve or cold water tap as close to the well as possible. Care was taken to collect samples where possible from ports located prior to any storage or pressure tanks or physical and chemical treatment system that might have been present. All hoses or other attachments that may have been connected to the well sampling port at the residential well locations were removed prior to sampling.

Samples were collected directly into the appropriate sample containers. The preferred order of sampling is: volatile organic compounds (VOCs), metals, inorganic analytes and then radiochemical analytes.

With the exception of the four 1-gallon containers for radionuclide analysis, all samples were stored on ice and out of direct sunlight prior to delivery to the state lab.

The eight background groundwater samples were sent to the Tennessee Department of Health Laboratory (TDH) in Nashville for analyses of the Table 1.2.1.2 analytes. Five of those eight groundwater samples also included sample aliquots that were shipped to the University of Arkansas, Department of Geosciences Stable Isotope Laboratory for analysis of stable nitrogen, oxygen, and deuterium (hydrogen) isotopes to determine the sources of nitrate in groundwater (i.e. industrial, soil, human/animal waste, and/or fertilizer) and the types or sources of recharge to groundwater. Those results will be reported in the 2018 DoR-OR EMR

The suite of analytes in this background study is consistent with the constituent suite being analyzed in the Offsite Residential Well Monitoring Project described in section 2.0 of this report. This correlation of analyses will support comparisons of groundwater quality between the Background and Offsite Residential Well Monitoring Projects.

Table 1.2.1.2: Groundwater Analyses List

Groundwater Analyte List for Background Locations		
VOCs		
EPA 8260 B list for low level detection ¹		
METALS		
aluminum	chromium	silver
antimony	iron	sodium
arsenic	lithium	strontium
barium	lead	thallium
beryllium	magnesium	uranium
boron	manganese	vanadium
cadmium	mercury	zinc
calcium	nickel	total hardness, as calcium carbonate
chromium	potassium	
copper	selenium	
INORGANICS		
calcium carbonate alkalinity	sulfate	oxygen-18 (in nitrate) ³
chloride	nitrate and nitrite	deuterium (in water) ³
fluoride	ammonia	oxygen-18 (in water) ³
total dissolved solids	nitrogen-15 (in nitrate) ³	
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

³ stable isotope data to be included in the next EMR

1.2.2 Regulatory Comparison Values

In order to understand the quality of groundwater in private wells, DoR-OR compares the results of the analyses to EPA standards. The U.S. EPA has established the National Primary Drinking Water Regulations (NPDWR) to maintain good quality of water in public water supplies. These criteria include Maximum Contaminant Levels (MCL)s and Secondary Maximum Contaminant Levels (SMCL)s.

- 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 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, TDEC DOR-OR uses other EPA criteria to assess well water quality. These guidelines include: EPA Lifetime Health Advisory Values (HAs), EPA Regional Screening Levels (RSLs), and EPA Preliminary Remediation Goals (PRGs). These levels are not enforceable for public water utilities, but they help to put the 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 and reflect EPA's assessment of the best available peer reviewed science.
- 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 site to identify levels at which a cleanup project aims to reach. PRGs are modified throughout a cleanup project as more site-specific information becomes available. PRGs are concentration levels that correspond to a specific cancer risk level of 10^{-6} . If a radionuclide exceeds a target risk (TR) of 10^{-6} , then the risk of a drinker contracting cancer is one in one million (1 in 1,000,000). For more information on EPA's drinking water standards, visit <https://www.epa.gov/dwstandardsregulations> or <https://www.epa.gov/risk>.

1.3 Results and Discussion

Historically, lack of an agreed upon background groundwater assessment for the ORR area has made it difficult to delineate what concentrations of constituents in groundwater should be considered background chemical constituent levels. In response to this problem, DoR-OR's Background Residential Monitoring Project has collected groundwater data, including fundamental geochemical parameters that are known to occur in natural groundwaters, as well as chemical groundwater parameters that include contaminants of concern in ORR legacy waste. Some of those constituents of concern from ORR legacy waste may also be present in the environment from worldwide nuclear and industrial activities. Analyzing the background well dataset will help DoR-OR better distinguish between what can be attributed to background levels or to additional man-made influences derived from ORR or other non-ORR activities.

1.3.1 Field Parameters

Temperature, electrical conductivity, pH, oxidation reduction potential (ORP), dissolved oxygen, and turbidity parameters were measured during the initial purging of the wells. Table 1.3.1 shows the final stable readings taken immediately prior to collecting samples at each sampling event.

RWA-157 is of interest, because it smelled strongly of hydrogen sulfide during purging and sampling. There are several wells across the region that DoR-OR has encountered that smell of hydrogen sulfide. This odor can often be attributed to its geologic setting in a marine shale formation of the Chickamauga Group; however, this smell can also potentially be attributed to contamination from organic compounds.

Table 1.3.1: Field Parameters for Background Wells

Field Parameters for Background Wells in 2016							
Well Name	Date	Temperature (°C)	Electrical Conductivity (µS/cm)	pH (SU)	Oxidation Reduction Potential	Dissolved Oxygen (mg/L)	Turbidity (NTU)
LSP	8/3/2016	17.5	381.9	7.55	74.4	9.9	
LSP	8/22/2016	17.7	397.6	7.00	384.5	9.82	0.91
RWA-145	9/17/2016	18.0	398.9	7.01	235.9	0.43	1.98
RWA-153	10/26/2016	15.6	315.5	7.30	253.3	5.09	0.32
RWA-154	11/3/2016	16.1	675	6.68	288.7	4.80	4.99
RWA-155	11/7/2016	16.0	552.9	6.97	268.7	1.33	3.81
RWA-156	11/8/2016	15.5	596.2	7.17	-82.6	0.98	0.24
RWA-157	11/9/2016	16.1	306.2	7.70	100.5	1.71	0.37
RWA-158 & 158 DUP	11/10/2016	15.3	393.5	7.46	-6.9	2.13	0.27

LSP-Lovely Spring

µs/cm-microSeimens per centimeter

mg/L-milligrams per Liter

SU - standard units

°C-Degrees Centigrade

mV-millivolts

NTU-Nephelometric Turbidity Unit

DUP-Duplicate

1.3.2 Volatile Organic Compound Results

Analysis of samples collected from the background locations LSP, RWA-145, RWA-153, RWA-154, RWA-155, RWA-156, RWA-157, and RWA-158, indicated no VOC exceedances at these locations. Results from the analysis of the Lovely Spring (LSP) sample collected on August 3, 2016 reported a very low-level Tetrachloroethene (PCE) detection (below EPA MCL) in the sample as well as in the associated quality control sample, (the correlating trip blank). Contamination in both samples suggest potential laboratory contamination of the sample. A new sample was collected to confirm the LSP PCE sampling results. That sample was sent to the TDH in Nashville for analyses on August 22, 2016 along with a new pre-filled trip blank from the laboratory. Those results reported no TCE in the subsequent sample or trip blank.

1.3.3 Metals and Inorganics Results

Table 1.3.3 lists which wells in the background study area had higher concentrations of analytes than their associated comparison values, during the sampling period between January 1, 2016 and June 30, 2017. Figures 1.1 and 1.2 show a close up view of background well locations sampled from January 1, 2016 and June 30, 2017 and in what rock type the wells are located.

Elevated concentrations of dissolved aluminum and iron were identified at one sampling location, and elevated sodium was identified at another location. The source of these elevated constituents is unknown. Although the concentrations are elevated above EPA SMCLs or HA levels, all of these elements are known to be both naturally occurring and are also found in man-made discharges from industry, agriculture and other urban activities such as leakage from sewers and septic tanks. No clustering of metals results can be identified at this time for the Background Residential Groundwater Monitoring Project.

1.3.4 Radionuclide Results

Background samples were analyzed for bismuth-214, lead-214, lead-212, thallium-208, gross alpha, gross beta, radium-226, radium-228, strontium-89, strontium-90, technicium-99 and tritium. Of those analyses, only lead-212 and radium-228 were found in concentrations above the EPA's PRG screening levels in the samples, Table 1.3.4.

1.3.5 Transuranic and Isotopic Uranium Results

Background well samples collected for this sampling event did not show any transuranic and uranium isotopic results above the November 2014 EPA PRG comparison values listed in Table 1.3.5.

Analyses of samples collected from wells RWA-153 and RWA-158 did indicate low levels (below comparison values) of plutonium-238 (Pu-238) in groundwater. Further investigation of these wells is ongoing because plutonium-238 is a man-made radionuclide.

Americium-241 (Am-241) was reported in the RWA-145 groundwater sample. Further investigation of this well is also ongoing, because this well is in relatively close proximity to the Chestnut Ridge Landfill, which can accept very low level radioactive waste under TDEC's Bulk Survey for Release program.

Detections of uranium-233/234 (U-233/234); uranium-235/236 (U-235/236) and uranium-238 (U-238) were also seen in multiple samples at levels below the EPA PRG comparison values.

1.4 Conclusions

Groundwater data collected from background locations from January 1, 2016 through June 30, 2017, provide important data to aid in the understanding the local hydrology and to generate a water quality baseline that could be used for comparison to the groundwater results obtained on-site and offsite of the ORR. The DOE collected offsite background data prior to beginning operations on the ORR. During this sampling event (January 2016 through June 2017), DOE co-sampled the wells selected for assessment in this Background Residential Well Monitoring Project. The seven residential wells and one spring sampled during this period are a snapshot in time, and therefore it is difficult to make predictions about spatial and temporal trend behavior of groundwater, as well as potential contaminant pathways. Trend predictions will be made as more data is collected.

The following concluding statements can be made:

- The data collected during this sampling period is representative of the aquifers that exist on and downgradient of the ORR and can be used for comparison with Offsite Residential Well Monitoring Project data collected from similar rock units.
- The data collected from one well indicated an unexplained detection of plutonium. Further investigation of this well is planned.
- Additional isotopic data, including stable nitrogen, and oxygen isotopes, (collected during this sampling event, but expected to be reported in the 2018 EMR), is necessary to understand groundwater constituents, sources and origins.

- This project will require long-term sampling to accomplish its goal of providing spatial and temporal trends for the behavior of the groundwater. Trends and trend predicitions will become more apparent with more data collected over time.

1.5 Recommendations

- Due to the rapid groundwater flow rates which can be observed in fractured carbonate, karst, and fractured clastic rock types (Worthington et al., 2000; Worthington, et. al, 2016), the groundwater quality at specific sampling locations in this study (and within these regional rock units) has the potential to change rapidly. This project should be continued in the future in order to obtain a more representative sampling of water quality data within those rocks. Additional monitoring will support incorporation of a larger statistical range of spatial and temporal data into the background dataset, allowing for a more complete assessment of background with future studies.
- Borehole logging with the USGS to geophysically, visually, and geochemically profile wells in strategic background locations may be appropriate. This effort would help in understanding residential well construction and would support identification of the water-producing rock types within the open borehole structure where residential water wells are typically constructed. This additional physical well information would assist with the interpretation of results from these wells.
- Additional isotopic data, including stable nitrogen, oxygen and deuterium (hydrogen) isotopes, is necessary to understand groundwater constituents, sources and origins.

Table 1.3.3: Background Metals and Inorganic Results

Offsite Metals and Inorganics Results (µg/L)																				
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-047	RWA-060	RWA-128	RWA-029	RWA-029 DUP	RWA-029 FB	RWA-047	CRBR-057	RWA-160	RWA-161	RWA-079	RWA-117	RWA-116	RWA-162	RWA-047	
Date					12/6/2016	12/8/2016	12/14/2016	12/19/2016	12/19/2016	12/19/2016	2/16/2017	6/5/2017	6/6/2017	6/14/2017	6/15/2017	6/19/2017	6/26/2017	6/27/2017	6/28/2017	
aluminum		50-200			810	U	U	U	7.2j	U	17,000	4.8j	30	1300	8.0j	6.6j	42	U	1,200	
antimony	6			6	U	U	U	U	U	U	0.63j	0.60j	2.5	U	U	U	U	U	U	
arsenic	10		0.052		U	U	U	U	U	U	U	U	2.1j	U	1.0j	U	U	U	U	
barium	2,000		3,800		300	170	90	14	13	U	270	10	14	36	8.3	60	120	17	360	
beryllium	4		4		U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	
boron			4,000	6000	12	U	7.3j	U	U	U	16	4.9j	3.2j	5.9j	320	550	27	U	14	
cadmium	5		9.2	5	0.33j	U	U	U	U	U	1.4	U	0.88j	U	U	U	U	U	0.41j	
calcium					61,000	36,000	49,000	46,000	46,000	U	65,000	58,000	45,000	33,000	410	2,200	69,000	41,000	58,000	
chromium	100				10	U	U	U	U	U	U	U	U	1.8j	U	U	U	1.6j	13	
cobalt			6													U				
copper	1,300	1000			150	6.8	3.0	2.8	1.5	U	68	4.5	2.9	3.3	13	3.1	2.2	7.2	32	
iron		300	14000		6,200	67	5.7j	9.4j	9.4j	U	80,000	U	410	780	150	47	55	39	8,500	
lead	15		15		24,000	1.8	0.56j	0.40j	0.39j	U	98	U	15	1.2	3.2	0.38j	U	5.5	41	
lithium			40		7,900	1.4	8.0	U	0.34j	U	9	3.1	U	2.4	34	63	4.6	U	7.8	
magnesium					6,100	20,000	20,000	8,000	28,000	U	8,000	3,700	29,000	17,000	120	1,500	30,000	28,000	7,300	
manganese		50		300	580	4.8	U	95	U	U	95	U	7.7	31	1.3	0.68j	3.3	1.1	630	
mercury	2		0.63	2	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	
nickel				100	1.8	2.5	2.5	38	1.3	U	38	1.3	4.2	1.8	3.5	U	3.5	1.6	5.1	
potassium					1,000	1,300	1300	3,800	210	U	38,000	210	1100	680	1,400	1,800	1,400	27,000	6,900	
selenium	50		100	50	U	U	U	U	U	U	U	U	U	U	U	U	U	0.92j	U	
silver		100	94	100	U	U	U	0.13j	U	U	0.13j	U	U	U	U	U	U	U	U	
sodium			20000	350	350	680	5,200	760	U	5,200	760	4,900	170,000	130,000	170,000	5,200	690	5,200		
strontium			stable 12,000	4,000	250	51	170	220	65	U	220	65	20	45	16	150	280	16	280	
thallium	2				U	U	U	0.85j	U	U	0.85j	U	U	U	U	U	U	U	U	
uranium	30				U	1.6	3.4	U	U	U	U	U	4.4	U	U	U	0.23j	0.56j	U	
vanadium			86		3.1j	4.7j	U	U	U	U	U	U	U	U	U	U	U	U	U	
zinc		5,000	6,000	2,000	370	580	19	5.9	5.9	U	6700	24	1700	6.1	130	U	28	16	830	
total hardness					180,000	170,000	200,000	230,000	230,000	U	190,000	160,000	230,000	150,000	300,000	11,000	300,000	2,800	180,000	
ammonia					U	U	U	U	U	U	U	U	U	U	25j	39j	U	U	U	
chloride		250,000			2,700	1,700j	2,200j	3,900	4,000	950j		2200j	14,000	1500j	1500j	22,000	5,900	3,300	2,600	
fluoride	4,000	2,000			51j	1,900	200	29j	0.029j	U		140	36j	150	68j	1400	720	32j	51j	
nitrate and nitrite	10,000			10,000	620	U	180	820	810	U		220	1,100	390	U	U	560	380	480	
sulfate		250,000			3,900	14,000	4,800	2,200j	2,200	U		3,300	6100	8,400	1500j	11,000	51,000	3,300	4,200	
total dissolved solids		500,000			220,000	190,000	210,000	220,000	230,000	U		176,000	231,000	221,000	322,000	394,000	319,000	206,000	241,000	
total alkalinity					170,000	160,000	190,000	220,000	220,000	U		162,000	189,000	160,000	281,000	364,000	240,000	227,000	189,000	

- EPA MCL Exceedance
- EPA SMCL Exceedance
- EPA RSL Exceedance
- EPA HA Exceedance
- Comparison Values used

DUP -Duplicate
FB -Field Blank
µg/L - micrograms per liter
J - Estimated Value
U - Undetected

Table 1.3.4: Background Well Radiological Results

Radiological Results for Background Wells. All units are in picocuries/L (pCi/L).													
Analyte	EPA National Primary Drinking Water Standards 2018 MCLs	EPA PRG tapwater TR=1E-6 Nov 2014	NBS Handbook 69 (correlation of pCi/L to 4mrem/year (TR=1E-4))	LSP	RWA-145	RWA-153	RWA-154	RWA-155	RWA-156	RWA-157	RWA-158	RWA-158 DUP	RWA-158 FB
Date	na	na	na	8/3/2016	9/7/2016	10/26/2016	11/3/2016	11/7/2016	11/8/2016	11/9/2016	11/10/2016	11/10/2016	11/10/2016
bismuth-214		270		27.7	44.5	12.5				22.2			
lead-214		150		20.1	51.6								
lead-212		2.1				22.2							
thallium-208						8.2							
Gross Alpha	15												
Gross Beta	50						3.6				6.8	4.8	
radium-226		0.14										0.84	
radium-228		0.05				0.59	0.57				0.62	0.53	
strontium-89			20		0.14	1.01		0.14					
strontium-90			8								0.33		
technetium-99			900										
tritium			20,000										

-above EPA PRG / RSL

LSP - Lovely Spring

DUP - Duplicate

FB -Field Blank

Table 1.3.5: Background Well Transuranic and Uranium Isotope Results

Transuranics and uranium isotopic results for 2016 background wells. All results are in pCi/L.										
Analyte	EPA PRG table Tapwater Nov 2014 (TR)=1E-6	LSP	RWA-145	RWA-153	RWA-154	RWA-155	RWA-156	RWA-157	RWA-158	RWA-158 DUP
Date		8/3/2016	9/7/2016	10/26/2016	11/3/2016	11/7/2016	11/8/2016	11/9/2016	11/10/2016	11/10/2016
americium-241	0.5		0.166 ± 0.075							
curium-242	1.40									
curium-243/244	Cm243=0.55; Cm244=0.62									
curium-245/246	Cm245=0.50; Cm246=0.51									
neptunium-237	0.84									
plutonium-238	0.4			0.263 ± 0.113					0.117 ± 0.071	0.195 ± 0.085
plutonium-239/240	Pu239=0.39; Pu240=0.39									
uranium-233/234	U233=0.73; U234=0.74		0.130 ± 0.053	0.247 ± 0.073	0.132 ± 0.064	0.198 ± 0.065		0.328 ± 0.105	0.277 ± 0.077	0.201 ± 0.070
uranium-235/236	U235=0.73; U236=0.78			0.042 ± 0.028		0.040 ± 0.028	0.044 ± 0.032		0.038 ± 0.028	0.033 ± 0.027
uranium-238	0.82	0.160 ± 0.112	0.085 ± 0.037	0.152 ± 0.050	0.160 ± 0.053	0.071 ± 0.037		0.192 ± 0.078	0.066 ± 0.037	
- EPA PRG / RSL Exceedance										

LSP - Lovely Spring

DUP -Duplicate

TR -Target Risk

pCi/L -picocuries/L

2.0 Offsite Residential Well Monitoring Project

2.1 Introduction

Portions of the ORR have been used for decades as regional burial grounds for hazardous and radioactive waste produced by DOE facilities. DOE radioactive waste was disposed of in landfills, shallow burial sites, unlined trenches, drain fields, waste pits, auger holes, grout sheets, concrete casks and above-grade vaults. Waste was disposed of in a variety of containers, some unpackaged, with varying degrees of documentation. Disposal included waste contaminated with inorganic and organic chemicals, including volatile and semivolatile organic compounds; beryllium, mercury, and other heavy metals; PCBs, laboratory and cleaning chemicals, biological waste, and inorganic salts. In many cases chemical waste had significant associated radioactivity.

Additionally, subsurface disposal on the ORR was also done at hydrofracture facilities with waste materials injected into shale units 200-300 meters below ground surface. The hydrofracture facilities originated as three test facilities. Two facilities were experimental (hydrofracture sites 1 and 2). Hydrofracture test site 3, became developmental and is now referred to in historic documentation as “the Old Hydrofracture Facility.” A fourth facility is referred to as “the New Hydrofracture Facility.” The third and fourth facilities combined have also been referred to, in some documentation, simply as “the ORNL Hydrofracture Facility” (Haase et al., 1987).

As a consequence of past DOE missions, groundwater beneath several areas of the ORR has become contaminated. Through the CERCLA cleanup process, measures have been implemented to attempt to isolate remaining contaminant sources from groundwater. Additional efforts are needed; however, to characterize and respond, where applicable, to ongoing legacy groundwater contamination challenges.

The Offsite Residential Well Monitoring Project collects samples from residential groundwater wells located outside the boundaries of the ORR. While downgradient groundwater flow is generally accepted as predominantly to the south and southwest of the ORR, samples were also collected from wells located to the north and northwest as well as to the east of the ORR to ensure complete evaluation of potential groundwater migration pathways that may exist in this region, including potential karst or fracture flow deviations from predominant regional groundwater flow direction. The intent of this project is to protect human health and the environment by evaluating water quality in the areas surrounding the ORR by assessing if contaminants from ORR may have migrated beyond the boundaries of the reservation footprint.

The Offsite Groundwater Residential Well Monitoring Project was designed also to support DoR-OR's evaluation of the distribution of potential contaminant pathways around ORR supporting the clean-up decision-making process under the FFA.

Groundwater flow in fractured rocks is rapid for carbonate, karst, and fractured clastic rocks (Worthington et al., 2000; Worthington, et. al, 2016). The implication of this is that the groundwater quality can change rapidly, and any geochemical parameter or contaminant concentration detected in groundwater may or may not be the highest or lowest

concentrations at that location, if sampled occasionally. Additionally, hydrologic characteristics in these settings mean that groundwater quality can fluctuate between geographically close locations. In accordance with the approved Environmental Monitoring Plan (EMP), DoR-OR has continued its Offsite Residential Well Monitoring Project in order to obtain a larger statistical distribution of spatial (between wells) and temporal (over time) data.

2.2 Methods and Materials

Groundwater samples were collected from twenty-five locations between August 23, 2016 and June 28, 2017 (Figures 2.1 and 2.2). A total of 30 sample suites were collected, including one location that was sampled three separate times due to elevated results. Three associated quality assurance and quality control (QA/QC) samples were also collected.

The area of investigation includes locations that are downgradient (generally south and southwest) of the ORR which are along inferred regional groundwater pathways away from the ORR. Samples were also collected from wells located to the north and northwest as well as to the east of the ORR in areas just beyond the ORR boundaries. Groundwater samples were collected from residential wells between January 1, 2016 and June 30, 2017 and were sent to the TDH Laboratory.

A consistently-implemented groundwater sampling procedure helped ensure data comparability between sampling events and between sites. A sample for QA/QC was used to ensure the security and quality of the samples during collection and shipping to the laboratory for analysis.

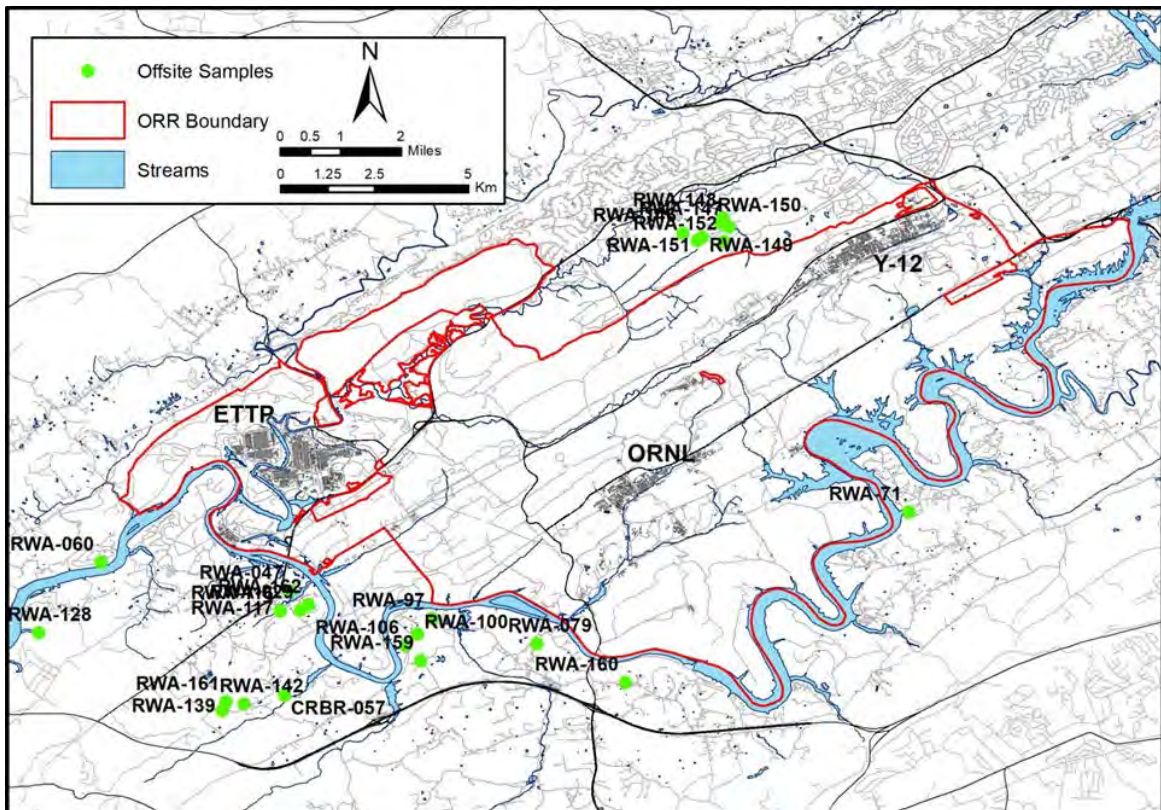


Figure 2.1: Offsite Sampling Locations

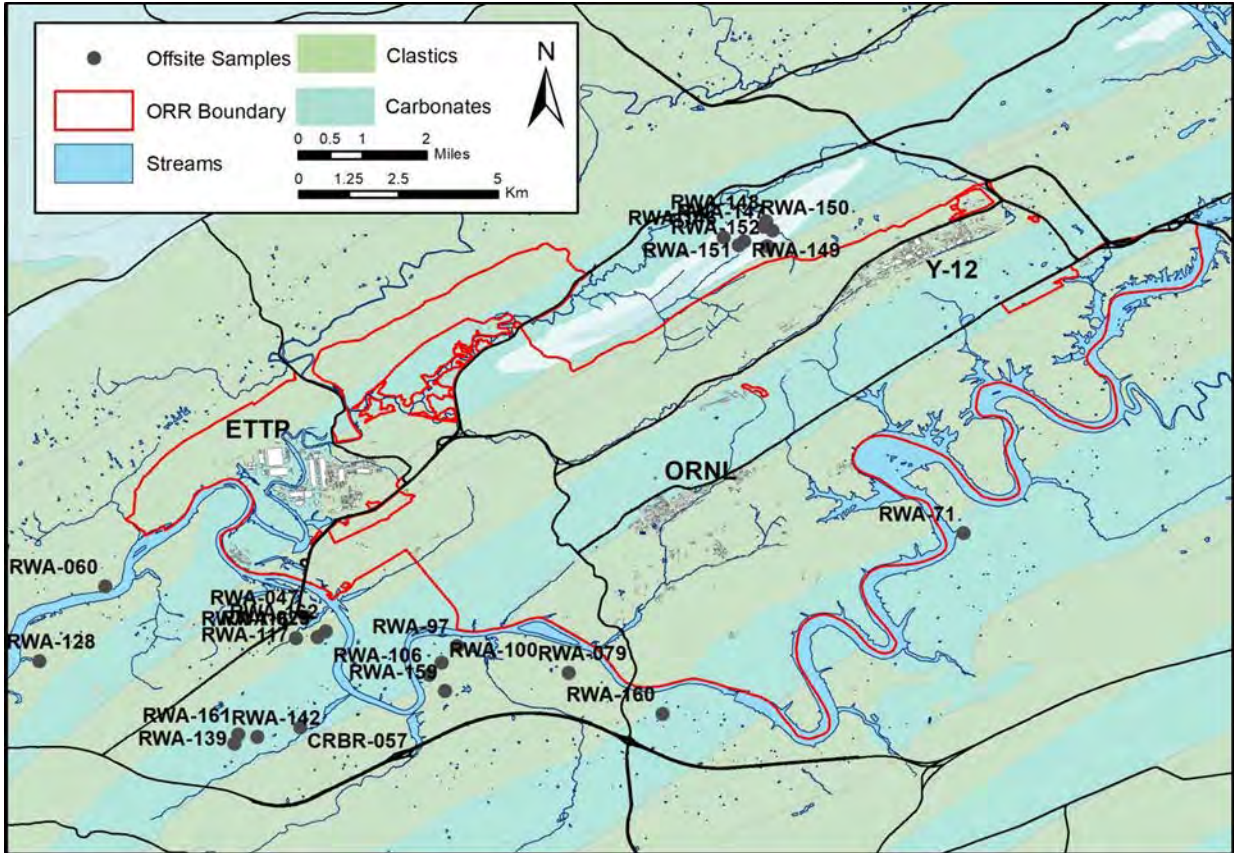


Figure 2.2: Offsite Sampling Locations with Geology

2.2.1 Sampling Techniques

The majority of the well locations selected for offsite sampling were residential wells, i.e., wells with in-place plumbing. The offsite sample locations are shown in Figures 2.1 and 2.2. Offsite sampling conducted during this time frame was periodically co-sampled with DOE. DoR-OR analyzed the samples for the suite of groundwater characteristics and potential contaminants of concern, Table 2.2.3.

Prior to sampling the selected locations, groundwater was purged (i.e. let run from the sample port for a certain amount of time until water quality parameters stabilize). The intent of the purging process is to remove water that may have been standing in a holding tank or other location and to allow samplers to obtain a groundwater sample that is pulled directly from the surrounding groundwater aquifer (i.e sampling “formation water”).

2.2.2 Water Quality Parameters

Water quality indicator parameters were collected using a YSI Professional Plus Multiparameter Instrument during purging. Field parameters are indicators used to determine when the formation water is being removed. Stabilization of parameters is required before samples may be collected for lab analysis. Field water quality parameter measurements were made at five minute intervals. Field parameter stabilization is defined as four consecutive readings within the criteria presented in Table 2.2.2.

Table 2.2.2: Water Quality Indicator Parameters

Measurement (units)	Normal Range	Acceptable Variability¹
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

¹Acceptable 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

2.2.3 Sample Collection

Samples are collected following stabilization of parameters, from a valve or cold water tap as close to the well as possible. Where possible, samples were collected from ports located prior to any storage, pressure tanks or physical and chemical treatment system that might have been present in the residential water system. This prevents impacts from system components such as water softener salts that may change the formation water chemistry. All hoses or other attachments that may have been connected to the well sampling port at the residential well locations were removed prior to sampling.

Samples were collected directly into the appropriate sample containers. The preferred order of sampling is: volatile organic compounds (VOCs), metals, inorganic analytes, and then radiochemical analytes.

With the exception of the four 1-gallon containers collected in each sample suite for radionuclide analysis, all samples were stored on ice and out of direct sunlight prior to Fed-Ex delivery at the state lab.

The groundwater samples were sent to the Tennessee Department of Health Laboratory (TDH) in Nashville for analyses of the analytes in Table 2.2.3. The twenty-five groundwater samples also included sample aliquots that were shipped to the University of Arkansas, Department of Geosciences Stable Isotope Laboratory for analysis of stable nitrogen, oxygen, and deuterium (hydrogen) isotopes to determine the sources of nitrate in groundwater (i.e. industrial, soil, human/animal waste, and/or fertilizer), and the types or sources of recharge to groundwater. Those results will be reported in the 2018 EMR.

The constituent suite analyzed in this offsite project is consistent with the constituent suite being analyzed in the Background Residential Well Monitoring Project described in section 1.0 of this report. This correlation of analyses will support comparisons of groundwater composition between these two projects.

Table 2.2.3: Groundwater Analyte List for Offsite Locations

Groundwater Analyte List for Offsite Locations		
VOCs		
EPA 8260 B list for low level detection ¹		
METALS		
aluminum	chromium	silver
antimony	iron	sodium
arsenic	lithium	strontium
barium	lead	thallium
beryllium	magnesium	uranium
boron	manganese	vanadium
cadmium	mercury	zinc
calcium	nickel	total hardness, as calcium carbonate
chromium	potassium	
copper	selenium	
INORGANICS		
calcium carbonate alkalinity	sulfate	oxygen-18 (in nitrate) ³
chloride	nitrate and nitrite	deuterium (in water) ³
fluoride	ammonia	oxygen-18 (in water) ³
total dissolved solids	nitrogen-15 (in nitrate) ³	
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

³ stable isotope data to be included in the next EMR

2.2.4 Regulatory Comparison Values

In order to understand the hydrochemical composition of groundwater in private wells, DoR-OR compares the results of the analyses to EPA standards. The U.S. EPA has established the National Primary Drinking Water Regulations (NPDWR) to maintain good quality of water in public water supplies. These criteria include Maximum Contaminant Levels (MCL)s and Secondary Maximum Contaminant Levels (SMCL)s.

- 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 items 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, DOR-OR uses other EPA criteria for comparison values for this project. These guidelines include: EPA Lifetime Health Advisory Values (HAs), EPA Regional Screening Levels (RSLs), and EPA Preliminary Remediation Goals (PRGs). These levels are not enforceable for public water utilities, but they can help put the 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 and reflect EPAs assessment of the best available peer reviewed science.
- 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 constituent which a cleanup project aims to reach.. PRGs are concentration levels that correspond to a specific 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

2.3 Results and Discussion

As part of the Federal Facilities Agreement (FFA), the Offsite Groundwater Monitoring Project looks for potential CERCLA legacy waste contaminants in residential wells and furthers the TDEC mission of protecting human health and the environment. The project expectations are to fulfill the DoR-OR Environmental Monitoring Plan (EMP) by co-sampling privately-owned water wells with DOE to better understand the distribution of potential contaminant pathways from the ORR.

The analytical results for this report were assessed with regards to potential for impact, by asking the following three questions:

1. Are ORR-related contaminants detected?
2. Are concentrations or activities above U.S. EPA identified criteria listed in the tables?
3. Can identified contaminants be attributed to DOE waste disposal activities?

Some radionuclides are present naturally in groundwater due to interactions with the atmosphere, soil, or bedrock. Therefore, one of the many challenges of the Offsite Residential Well Monitoring Project is to be able to definitively state that the radionuclides present in the reported results are man-made, natural or a mix of both. To support this assessment, twenty-five groundwater samples were shipped to the University of Arkansas Department of Geosciences Stable Isotope Laboratory for analysis of stable nitrogen, oxygen, and deuterium (hydrogen) isotopes in groundwater. These analyses will help to determine the nitrate signatures in the sample and identify possible recharge sources and recharge area. Results will be included in the next DoR-OR EMR.

Groundwater geochemistry was evaluated to characterize non-contaminant and contaminant-related water quality from similar rock types.

2.3.1 Field Parameters

Temperature, electrical conductivity, pH, oxidation reduction potential (ORP), dissolved oxygen and turbidity parameters were measured during the initial purging of the wells. Table 2.3.1 shows the final stable readings taken immediately prior to collecting samples at each sampling event.

EPA SMCL criteria for recommended pH concentrations in public drinking water, falls in a range between 6.5 and 8.5 standard units (SUs). Four wells sampled during the study period had pH levels that fell outside this range (see table 2.3.1). Naturally high pH values are uncommon in this regional geological setting (White et al., 1963). Of these four wells with pH values that did not correlate with the EPA SMCL guidance, the three wells with higher pH are located to the southwest of the ORR.

Table 2.3.1: Field Parameters for Offsite Wells

Field Parameters for Offsite Wells							
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-71	8/15/2016	16.0	333.0	7.58	176.9	6.54	0.14
RWA-106	8/23/2016	17.5	310.5	7.14	154.8	4.33	2.64
RWA-97	8/29/2016	18.3	786	8.68	-273.7	0.16	0.06
RWA-146	9/19/2016	18.1	1140	6.97	-51.8	0.21	0.85
RWA-147	9/20/2016	15.8	392.4	6.28	23.5	1.25	11.73
RWA-148	9/22/2016	14.8	625.0	7.26	-66.1	1.40	0.18
RWA-149	9/26/2016	17.8	504.5	7.02	348.5	1.73	4.05
RWA-150	9/27/2016	17.6	468.5	7.69	308.4	1.76	0.47
RWA-151	9/28/2016	16.2	786	7.10	-31.4	3.93	0.85
RWA-152 & RWA-152 DUP	10/5/2016	17.4	505.5	6.84	14.2	0.88	2.14
RWA-159	11/14/2016	15.8	544.3	7.38	-11.2	1.35	0.23
RWA-139	11/16/2016	15.4	397.4	7.43	283.5	2.67	0.01
RWA-142	11/17/2016	15.7	444.8	7.07	214.7	3.53	1.62
RWA-100	11/21/2016	14.3	247.3	7.43	247.1	7.32	0.01
RWA-047	12/6/2016	15.8	350.2	6.92	163.9	3.73	51.35
RWA-060	12/8/2016	16.0	345.6	7.53	159.2	1.37	2.08
RWA-128	12/14/2016	15.6	384.8	7.38	303.2	5.76	0.22
RWA-029 & RWA-029 DUP	12/19/2016	14.5	430.1	7.04	359.9	8.42	0.17
RWA-047	2/16/2017	17.0	218.7	7.07	189.5	2.38	72.73
CRBR-057	6/5/2017	16.1	271.4	7.30	143.0	7.03	0.02
RWA-160	6/6/2017	15.6	424.1	7.41	497.1	6.03	6.65
RWA-161	6/14/2017	15.3	191.6	7.55	154.1	5.67	4.03
RWA-079	6/15/2017	16.2	617	9.45	131.1	0.72	1.82
RWA-117	6/19/2017	16.2	746	8.92	-47.0	0.85	0.68
RWA-116	6/26/2017	15.0	502.4	7.33	156.1	2.83	0.77
RWA-162	6/27/2017	15.0	400.4	7.47	167.6	6.11	2.32
RWA-047	6/28/2017	17.6	353.2	6.97	138.0	2.42	2.49

-Outside EPA SMCL guidance
 °C -Degree Centigrade
 mV -milivolts
 NTU -Nephelometric Turbidity Unit
 µs/cm -microSeimens per centimeter
 mg/L -milligrams per liter
 SU - standard units
 DUP - Duplicate

2.3.2 Volatile Organic Compound Results

All offsite residential wells were analyzed for the EPA 8260 B list of Volatile Organic Compounds (VOCs). (<https://www.epa.gov/sites/production/files/2015-12/documents/8260b.pdf>) Because many VOCs were undetected in the results, only the wells with detections are listed in Table 2.3.2.

Two wells reported VOC detections during this sampling event; RWA-116 and RWA-160. No VOC constituent was identified to be above EPA MCL or RSL comparison criteria. No determination regarding potential sources of the identified constituents has been made.

Table 2.3.2 VOC Results

Offsite Volatile Organic Compound Results (µg/L)				
Analyte	EPA MCL	EPA RSL	RWA-160	RWA-116
acetone		14,000	1.74J	U
bromodichloromethane	80		4.84	U
bromoform	80		0.426J	U
carbon disulfide		810	0.136J	U
chlorodibromomethane	80		2.76	U
chloroform	80		12.4	0.0930J
2-butanone (MEK)		5,600	12.9	U
tetrachloroethene	5		0.289J	U
toluene	1,000		177	U

µg/L- micrograms per liter

J- Estimated Value

U-Undetected

2.3.3 Metals and Inorganics Results

Concentrations above comparison ranges for aluminum, iron, lithium, manganese and sodium were detected in offsite wells during this sampling event.

Lead was the only constituent of concern that was identified during the metals and inorganics sampling that fell above the EPA MCL guidance. RWA-160 reported a level of 15 micrograms/liter which is equivalent to the EPA MCL regulatory limit for lead of 15 micrograms/liter. Consistently, RWA-047 showed detections of lead above EPA MCLs during all three sampling events at this location (dates: December 6, 2016; February 16, 2017; June 28, 2017). Aluminum, manganese and iron were also detected in levels above the EPA SMCL values in well RWA-047 during all three sampling events that were conducted at this well.

Iron was found at levels detected above the EPA SMCL at eight well locations. Manganese was detected at levels above SMCLs at six locations but only exceeded the EPA tapwater RSLs and EPA health advisory recommended values at RWA-047. Preliminary analyses of RWA-047 indicates components of the elevated metals concentrations may be attributable to infrastructure rather than native groundwater.

Lithium was identified at levels above the EPA RSLs for tapwater in four locations.

Sodium was detected above the EPA health advisory in ten locations.

2.3.4 Radionuclide Results

Bismuth-214 and lead-214 were reported at wells RWA-029 and RWA-162 in concentrations above the November 2014 EPA PRGs for tapwater. RWA-146 also had concentrations of lead-214 detected above the EPA PRG for tapwater (see table 2.3.4). RWA-029 and RWA-162 are

both located on Chestnut Ridge, along Bear Creek Valley in the Knox Group. The Knox Group formation is a significant regional aquifer. Both wells RWA-029 and RWA-162 lie along geologic strike (and down-gradient) from the Chestnut Ridge Security Pits and other ORR facilities. RWA-146 is located off Tuskegee Drive in Oak Ridge, north of EMWMF on Pine Ridge. The results from these wells require further investigation.

2.3.5 Transuranic and Isotopic Uranium Results

Some radionuclides are present naturally in groundwater due to interactions with the atmosphere, hydrosphere, soil, or bedrock. Therefore, one of the many challenges of the Offsite Residential Well Project is an objective evaluation of the data and differentiation between man-made and naturally-occurring radionuclides and naturally-occurring nuclides that were and are used in the DOE-ORR processes.

Of the offsite wells sampled, one well had a low level detection of americium-241, five wells had low level detections of cesium-242, one well had a low level detection of neptunium-237. Five wells had low level detections of plutonium-238 and four wells had low level detections of plutonium-239/240, see Table 2.3.5. None of those transuranic detections exceeded the 2014 EPA PRGs for tapwater, though it should be noted that all these constituents are man-made.

All offsite wells sampled with the exception of three, showed detections of uranium in their water. Six of the 28 samples displayed uranium-233/234 levels potentially above a PRG screening limit for tapwater. Three samples had detections above the 2014 uranium-238 PRG for tapwater (See table 2.3.5). These uranium constituents could be from naturally occurring or man-made sources. No determination regarding potential sources of the identified constituents has been made at this time. Further investigation will continue.

2.4 Conclusions

The contamination of groundwater beneath several areas of the ORR and the potential pathways for contaminant migration beyond the ORR boundary makes it imperative to continue monitoring of the offsite residential wells. This Residential Well Monitoring Project is currently the primary system for monitoring groundwater in areas off the reservation that may be a primary or sole source of water for local residents in Roane, Anderson and Loudon counties.

Groundwater flow in fractured rocks can be rapid in bedrock aquifers (Worthington et al., 2000; Worthington, et. al, 2016). The results from residential wells sampled during this period represent a snapshot in time, not continuous monitoring. Groundwater quality in these settings can change rapidly. Hydrologic characteristics can fluctuate between geographically close locations, and therefore it is difficult to make predictions on potential contaminant pathways and sources of contamination with one sampling event of data. This TDEC DoR-OR EMR report documents mostly low-concentrations, low-activities and sporadic detections of contaminants that could potentially be a result of human activity. Some of these detections are 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. Appropriate analytical methods (for transuranics and uranium) are being researched by DoR-OR to improve the accuracy and precision of the results.

2.5 Recommendations

Recommendations for future work on this project include:

- DOR-OR recommends a continuation of the Offsite Residential Well Monitoring Project in order to obtain a larger statistical distribution of data between wells and over time.
- Borehole logging with the United States Geological Survey (USGS) to geophysically, visually, and geochemically profile wells in strategic offsite locations should be evaluated. This effort may support the correlation between results from the evaluation of residential groundwater that could be dependent on well construction and water-producing rock types identified in the open boreholes.
- Work at Oak Ridge by DOE and its contractors currently uses the “basin approach” to evaluate groundwater. In the terrain around the ORR, it is documented that the boundaries of groundwater basins are not coincident with surface water or topographic boundaries. DOR-OR recommends further delineation of groundwater basin boundaries. Basin delineation may require an understanding of the subtle differences of local flow paths and regional flow paths. Several different tracers may be used including water quality parameters, chemistry and natural isotopes, and injected substances such as fluorescent dyes.

Table 2.3.3: Offsite Metals and Inorganics Results

Offsite Metals and Inorganics Results (µg/L)																			
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-106	RWA-97	RWA-146	RWA-147	RWA-148	RWA-149	RWA-150	RWA-151	RWA-152	RWA-152 DUP	RWA-152 FB	RWA-159	RWA-139	RWA-142	RWA-100
Date					8/23/2016	8/29/2016	9/19/2016	9/20/2016	9/22/2016	9/26/2016	9/27/2016	9/28/2016	10/5/2016	10/5/2016	10/5/2016	11/14/2016	11/16/2016	11/17/2016	11/21/2016
aluminum		50-200			8.8j	U	U	19	U	140	U	U	37	U	U	8.5j	U	52	U
antimony	6			6	U	U	U	U	U	U	U	U	U	U	U	0.60j	U	U	U
arsenic	10		0.052		U	U	U	U	3.7j	U	0.95j	U	U	U	U	U	U	U	U
barium	2,000		3,800		89	3.3j	51	26	19	35	88	32	130	130	U	120	210	310	69
beryllium	4		4		U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
boron			4,000	6000	12	340	290	71	290	42	310	200	37	35	U	250	34	150	15
cadmium	5		9.2	5	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
calcium					43,000	1,800	97,000	41,000	31,000	59,000	21,000	87,000	50,000	50,000	U	39,000	43,000	51,000	51,000
chromium	100				3.0j	U	U	U	1.2j	2.2j	1.9j	U	U	U	1.7j	U	U	U	U
cobalt			6		0.32j										U				
copper	1,300	1000			15	2.6	3.2	2.0	3.0	14	2.4	6.8	20	18	U	1.7	2.5	4.0	0.97j
iron		300	14000		470	U	870	6100	350	150	49	94	310	310	U	130	U	28	U
lead	15		15		1.5	U	U	U	0.28j	5.3	U	U	U	U	U	U	U	U	U
lithium			40		10	52	37	24	23	11	18	48	24	39	U	39	17	10	6.5
magnesium					13,000	1,300	91,000	16,000	12,000	30,000	12,000	40,000	27,000	27,000	U	32,000	23,000	26,000	5,200
manganese		50		300	14	0.51j	16	220	19	3.8	5.5	46	230	220	U	10	U	1.4	U
mercury	2		0.63	2		U	U	U	U	U	U	U	U	U	U	U	U	U	U
nickel				100	2.7	U	6.1	17	1.2	2.2	1.0	2.9	3.3	2.3	U	2.3	1.5	1.7	4.5
potassium					2,400	1,600	5,300	3,600	5,600	1,500	3,500	3,100	3,300	3,200	U	3,200	2,900	3,700	2,000
selenium	50		100	50	U	1.6j	U	U	U	3.7j	U	U	U	U	U	U	U	U	U
silver		100	94	100	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
sodium				20000	2,800	190,000	30,000	9,200	94,000	6,300	64,000	21,000	13,000	37,000	U	37,000	2,900	18,000	2,600
strontium			stable 12,000	4,000	120	130	1,800	260	1400	260	320	1,400	180	160	U	4200	530	120	250
thallium	2				U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
uranium	30				U	U	0.29j	U	U	0.46j	U	0.61j	U	U	U	U	3.5	0.66j	U
vanadium			86		10	3.1j	U	U	U	U	U	3.5j	11	10	14	U	U	U	3.1j
zinc		5,000	6,000	2,000	70	2.6j	2.1j	20	9.3	33	4.0j	7.3	9.5	8.8	U	4.4j	1.2j	1.6j	1,600j
total hardness					160,000	10,000	620,000	170,000	120,000	270,000	99,000	380,000	240,000	240,000	U	200,000	200,000	150,000	180,000
ammonia					U	220	200	1,100	610		150	2,200	170	190	U	U	U	U	U
chloride		250,000			2,000j	77,000	3,100	1,800j	17,000	220j	2,800	2,000j	15,000	15000	950j	2200j	3,700	2700	2,000j
fluoride	4,000	2,000			74j	1,100	130	380	320	180	440	280	120	120	U	270	450	320	60j
nitrate and nitrite	10,000			10,000	160	U	U	U	U	700	370	150	U	U	U	U	450	330	U
sulfate		250,000			4,500	3,200	270,000	71,000	93,000	41,000	29,000	99,000	16,000	38,000	U	38,000	5,400	3500	3,200
total dissolved solids		500,000			210,000	460,000	810,000	260,000	390,000	220,000	260,000	470,000	U	16,000	290,000	320,000	210,000	250,000	170,000
total alkalinity					150,000	290,000	380,000	130,000	230,000	10,000	210,000	300,000	230,000	230,000	U	260,000	200,000	230000	140,000

	- EPA MCL Exceedance	DUP -Duplicate
	- EPA SMCL Exceedance	FB -Field Blank
	- EPA RSL Exceedance	µg/L - micrograms per liter
	- EPA HA Exceedance	J - Estimated Value
	- Comparison Values used	U - Undetected

Table 2.3.3 (continued)

Offsite Metals and Inorganics Results (µg/L)																			
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-047	RWA-060	RWA-128	RWA-029	RWA-029 DUP	RWA-029 FB	RWA-047	CRBR-057	RWA-160	RWA-161	RWA-079	RWA-117	RWA-116	RWA-162	RWA-047
Date					12/6/2016	12/8/2016	12/14/2016	12/19/2016	12/19/2016	12/19/2016	2/16/2017	6/5/2017	6/6/2017	6/14/2017	6/15/2017	6/19/2017	6/26/2017	6/27/2017	6/28/2017
aluminum		50-200			810	U	U	U	7.2j	U	17,000	4.8j	30	1300	8.0j	6.6j	42	U	1,200
antimony	6			6	U	U	U	U	U	U	0.63j	0.60j	2.5	U	U	U	U	U	U
arsenic	10		0.052		U	U	U	U	U	U	U	U	2.1j	U	1.0j	U	U	U	U
barium	2,000		3,800		300	170	90	14	13	U	270	10	14	36	8.3	60	120	17	360
beryllium	4		4		U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
boron			4,000	6000	12	U	7.3j	U	U	U	16	4.9j	3.2j	5.9j	320	550	27	U	14
cadmium	5		9.2	5	0.33j	U	U	U	U	U	1.4	U	0.88j	U	U	U	U	U	0.41j
calcium					61,000	36,000	49,000	46,000	46,000	U	65,000	58,000	45,000	33,000	410	2,200	69,000	41,000	58,000
chromium	100				10	U	U	U	U	U	U	U	U	1.8j	U	U	U	1.6j	13
cobalt			6													U			
copper	1,300	1000			150	6.8	3.0	2.8	1.5	U	68	4.5	2.9	3.3	13	3.1	2.2	7.2	32
iron		300	14000		6,200	67	5.7j	9.4j	9.4j	U	80,000	U	410	780	150	47	55	39	8,500
lead	15		15		24,000	1.8	0.56j	0.40j	0.39j	U	98	U	15	1.2	3.2	0.38j	U	5.5	41
lithium			40		7,900	1.4	8.0	U	0.34j	U	9	3.1	U	2.4	34	63	4.6	U	7.8
magnesium					6,100	20,000	20,000	8,000	28,000	U	8,000	3,700	29,000	17,000	120	1,500	30,000	28,000	7,300
manganese		50		300	580	4.8	U	95	U	U	95	U	7.7	31	1.3	0.68j	3.3	1.1	630
mercury	2		0.63	2	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
nickel				100	1.8	2.5	2.5	38	1.3	U	38	1.3	4.2	1.8	3.5	U	3.5	1.6	5.1
potassium					1,000	1,300	1300	3,800	210	U	38,000	210	1100	680	1,400	1,800	1,400	27,000	6,900
selenium	50		100	50	U	U	U	U	U	U	U	U	U	U	U	U	U	0.92j	U
silver		100	94	100	U	U	U	0.13j	U	U	0.13j	U	U	U	U	U	U	U	U
sodium				20000	350	350	680	5,200	760	U	5,200	760	4,900	170,000	130,000	170,000	5,200	690	5,200
strontium			stable 12,000	4,000	250	51	170	220	65	U	220	65	20	45	16	150	280	16	280
thallium	2				U	U	U	0.85j	U	U	0.85j	U	U	U	U	U	U	U	U
uranium	30				U	1.6	3.4	U	U	U	U	U	4.4	U	U	U	0.23j	0.56j	U
vanadium			86		3.1j	4.7j	U	U	U	U	U	U	U	U	U	U	U	U	U
zinc		5,000	6,000	2,000	370	580	19	5.9	5.9	U	6700	24	1700	6.1	130	U	28	16	830
total hardness					180,000	170,000	200,000	230,000	230,000	U	190,000	160,000	230,000	150,000	300,000	11,000	300,000	2,800	180,000
ammonia					U	U	U	U	U	U	U	U	U	U	25j	39j	U	U	U
chloride		250,000			2,700	1,700j	2,200j	3,900	4,000	950j	2200j	14,000	1500j	1500j	22,000	5,900	3,300	2,600	
fluoride	4,000	2,000			51j	1,900	200	29j	0.029j	U	140	36j	150	68j	1400	720	32j	51j	
nitrate and nitrite	10,000			10,000	620	U	180	820	810	U	220	1,100	390	U	U	560	380	480	
sulfate		250,000			3,900	14,000	4,800	2,200j	2,200	U	3,300	6100	8,400	1500j	11,000	51,000	3,300	4,200	
total dissolved solids		500,000			220,000	190,000	210,000	220,000	230,000	U	176,000	231,000	221,000	322,000	394,000	319,000	206,000	241,000	
total alkalinity					170,000	160,000	190,000	220,000	220,000	U	162,000	189,000	160,000	281,000	364,000	240,000	227,000	189,000	

- EPA MCL Exceedance
 - EPA SMCL Exceedance
 - EPA RSL Exceedance
 - EPA HA Exceedance
 - Comparison Values used

DUP -Duplicate
 FB -Field Blank
 µg/L - micrograms per liter
 J - Estimated Value
 U - Undetected

Table 2.3.4: Offsite Radiological Results

Radiological Results (pCi/L)												
Well Name	Date	bismuth-214	lead-214	thallium-208	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						
EPA PRG tapwater TR=1E-6 Nov 2014	NA	270	150				0.14	0.05				
NBS Handbook 69 (correlation of pCi/L to 4mrem/year (TR=1E-4))	NA								20	8	900	20,000
RWA-071	8/15/2016	116	111						0.46			
RWA-106	8/23/2016	123	125			5.2						
RWA-097	8/29/2016	18.9	18.5									
RWA-146	9/19/2016	212	213		2.70	7.3	0.98					
RWA-147	9/20/2016	152	131		1.51	0.6			0.85			
RWA-148	9/22/2016	25.0	17.7			5.4						99
RWA-149	9/26/2016	14.7							0.47			
RWA-150	9/27/2016	19.6	19.2							0.52	0.62	
RWA-151	9/28/2016					9.4						
RWA-152	10/5/2016	21.2	14.2	6.5		16.2		0.30				
RWA-152 DUP	10/5/2016	18.5	22.4			16.1		0.29			0.77	
RWA-159	11/14/2016					5.7		0.50			0.26	
RWA-139	11/16/2016				3.63	4.6	0.67					
RWA-142	11/17/2016											
RWA-100	11/21/2016							0.36				
RWA-047	12/6/2016		56.7					0.41				110
RWA-060	12/8/2016	56	59		3.98		0.46					
RWA-128	12/14/2016	23.6	30.4		4.72	4.2	0.75					
RWA-029	12/19/2016	245	223							0.32		110
RWA-029 DUP	12/19/2016	283	242					0.21		0.27		131
RWA-047	2/16/2017	43.5	31.5			9.4						66
CRBR-057	6/5/2017	61	57.0									
RWA-160	6/6/2017	22.7	27.3		7.76	9.3	1.27					
RWA-161	6/14/2017	20.9	22.0				0.460	0.39				
RWA-079	6/15/2017	12.3					0.69	0.39				
RWA-117	6/19/2017	45.2	49.1									
RWA-116	6/26/2017	50	56									
RWA-162	6/27/2017	300	280				0.570					
RWA-047	6/28/2017	29.9	27.0			9.9	0.460					
	- EPA MCL Exceedance	DUP -Duplicate										
	- EPA SMCL Exceedance	TR -Target Risk										
	- EPA PRG Exceedance	pCi/L - picoCuries per liter										
	- EPA HA Exceedance											

Table 2.3.5: Transuranic and Isotopic Uranium Results

Transuranic and Isotopic Uranium 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 PRG table for tapwater November 2014 (TR=1E-6)		0.5	1.4	Cm243=0.55; Cm 244=0.62	Cm245=0.50; Cm 244=0.51	0.84	0.4	Pu239=0.39 Pu240=0.39	U233=0.73 U234=0.74	U235=0.75 U236=0.78	0.82
RWA-106	8/23/2016								0.461 ± 0.108	0.048 ± 0.042	0.204 ± 0.065
RWA-97	8/29/2016										
RWA-146	9/19/2016		0.009 ± 0.022						0.034 ± 0.028	0.009 ± 0.027	0.021 ± 0.021
RWA-147	9/20/2016								0.364 ± 0.090	0.027 ± 0.022	0.159 ± 0.055
RWA-148	9/22/2016		0.000 ± 0.020						0.107 ± 0.041	0.043 ± 0.032	0.062 ± 0.029
RWA-149	9/26/2016								0.179 ± 0.059	0.075 ± 0.039	0.077 ± 0.038
RWA-150	9/27/2016						0.029 ± 0.064				
RWA-151	9/28/2016						0.138 ± 0.084		0.037 ± 0.050		0.006 ± 0.027
RWA-152	10/5/2016						0.111 ± 0.059		0.682 ± 0.151	0.013 ± 0.030	0.238 ± 0.076
RWA-152 DUP	10/5/2016								0.137 ± 0.060		0.059 ± 0.037
RWA-159	11/14/2016								0.095 ± 0.055	0.010 ± 0.028	
RWA-139	11/16/2016		0.005 ± 0.038						0.082 ± 0.046	0.032 ± 0.025	0.035 ± 0.028
RWA-142	11/17/2016							0.012 ± 0.031	1.62 ± 0.267	0.087 ± 0.043	1.22 ± 0.208
RWA-100	11/21/2016								0.432 ± 0.101	0.051 ± 0.030	0.216 ± 0.062
RWA-047	12/6/2016										0.070 ± 0.033
RWA-060	12/8/2016								1.00 ± 0.181	0.133 ± 0.050	0.475 ± 0.103
RWA-128	12/14/2016								1.51 ± 0.253	0.061 ± 0.035	1.12 ± 0.198
RWA-029	12/19/2016								0.137 ± 0.059		0.064 ± 0.040
RWA-029 DUP	12/19/2016								0.135 ± 0.058	0.048 ± 0.030	0.087 ± 0.040
RWA-047	2/16/2017								0.223 ± 0.102		
CRBR-057	6/5/2017	0.049 ± 0.032					0.121 ± 0.057	0.076 ± 0.043			
RWA-160	6/6/2017							0.056 ± 0.035	0.917 ± 0.303		1.23 ± 0.362
RWA-161	6/14/2017										0.133 ± 0.101
RWA-079	6/15/2017					0.031 ± 0.026		0.068 ± 0.040			0.088 ± 0.081
RWA-117	6/19/2017		0.013 ± 0.020				0.085 ± 0.055		0.282 ± 0.142		
RWA-116	6/26/2017								0.162 ± 0.116		0.129 ± 0.099
RWA-162	6/27/2017		0.034 ± 0.023						0.562 ± 0.225		0.342 ± 0.169
RWA-047	6/28/2017								0.166 ± 0.114		0.067 ± 0.070

- EPA MCL Exceedance
- EPA SMCL Exceedance
- EPA PRG Exceedance
- EPA HA Exceedance

- DUP -Duplicate
- TR -Target Risk
- pCi/L - picoCuries per liter

3.0 Spring Monitoring Project

3.1 Introduction

DoR-OR sampled and analyzed springs offsite of the ORR and its environs to gauge the composition and quality of groundwater. This project searched for historic named springs that can provide information on the ambient health of the groundwater on and off the ORR and along geologic strike to the northeast and southwest. Findings are used as a baseline to help identify and characterize unplanned releases of contaminants and to evaluate DOE monitoring and control measures that manage groundwater releases to the environment.

Springs were sampled according to standard operating procedures specified by EPA and TDEC (TDEC 2004). Parameters such as pH, temperature, oxidation-reduction potential, and conductivity were measured before sampling and were recorded in the field notes. Springs were sampled based on field observation of flow and safety considerations. The sampling period was for a single sampling event for each spring. The locations of the springs are shown in Figure 3.1. For clarity only those springs closest to the ORR are illustrated.

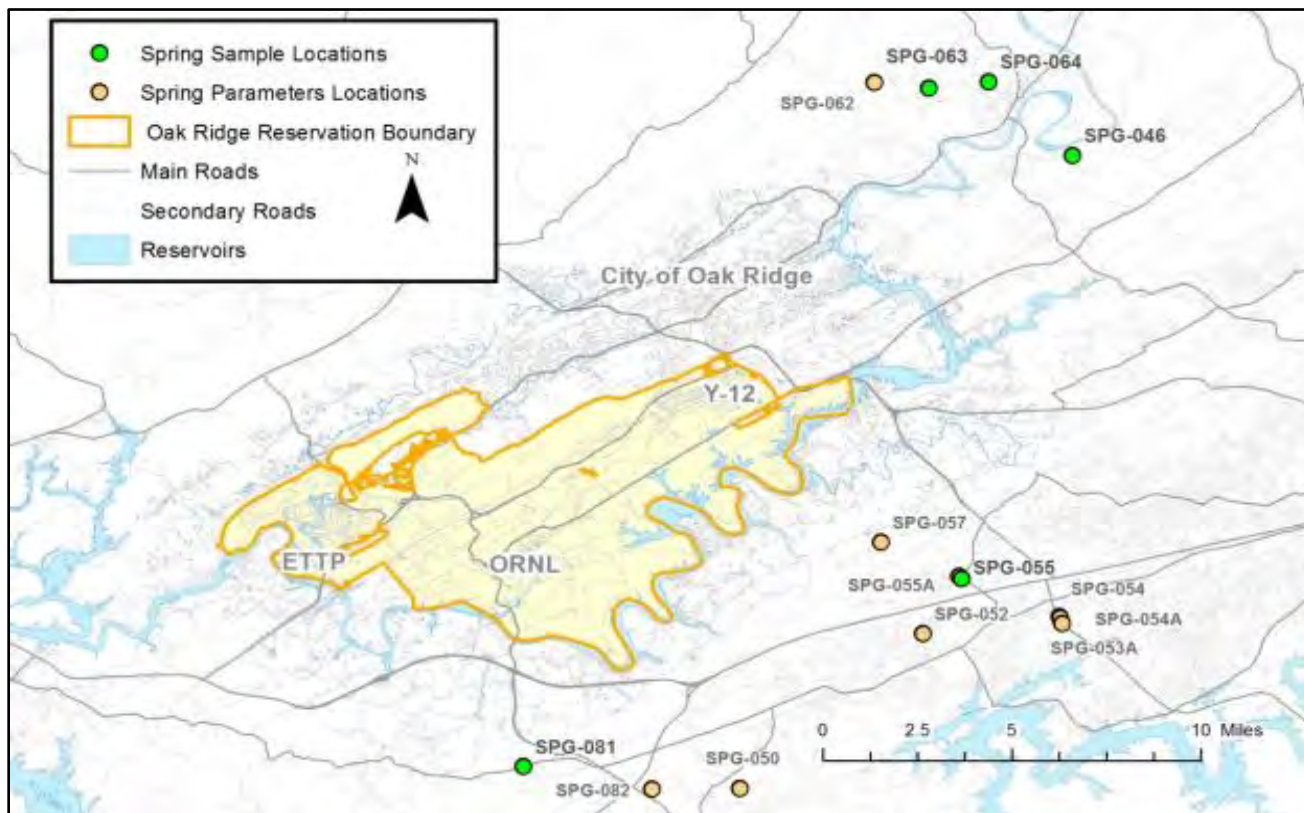


Figure 3.1: Spring Sampling and Parameter Locations

Table 3.1 identifies locations, analyses and sampling rationale as described below. Waters influenced by ETPP were analyzed for technetium-99. Waters influenced by ORNL were analyzed for strontium-89/90. If a spring shows a gross alpha activity greater than five picocuries/liter, then a radionuclide isotope-specific analysis for alpha emitters may be performed on the laboratory-archived sample.

Table 3.1: Spring Sampling Locations and Sampling Rationale

Spring Sampling Locations and Rationale				
Location No.	Analytes	Location	Sampling Rationale	Date Sampled
SPG-046	MIVR	Yarnell Spring	Characterization of basic water quality parameters and hydraulically upgradient from Y-12/ETTP	6/13/2017
SPG-063	MIVR	Shinlever Spring	Characterization of basic water quality parameters and hydraulically upgradient from ETPP	6/13/2017
SPG-064	MIVR	Pop Hollow Spring		6/13/2017
SPG-055	MIVR	Blue (Southeast) Spring	Characterization of basic water quality parameters and east of ORNL	6/21/2017
SPG-081	MIVR	Wampler's Spring	Characterization of basic water quality parameters and south of ORNL	6/21/2017

MIVR - Metals, Inorganics, Volatiles, and Radionuclides (Gross Alpha/Beta, Gamma Radionuclides, Strontium-90, Technetium-99, Tritium)

ETTP - East Tennessee Technology Park

ORNL - Oak Ridge National Laboratory

Field parameters were collected at 26 locations. Analyses at five also included cation and anion parameters, calcium, magnesium, sodium, potassium, chloride, sulfate, nitrate, bicarbonate (total alkalinity) and carbonate (total hardness) in order to calculate ionic charge balances, and to perform groundwater geochemical "fingerprints." A list of metals, shown in Table 3.1.2, was considered for analysis at all locations. Volatile organic compounds (VOCs) were analyzed from samples collected at all springs. Radiochemical requests for analysis are also shown in Table 3.1.2. The parameters for analysis are gross alpha and gross beta activity, gamma radionuclide activity, strontium-89, strontium-90 and technitium-99.

Samples were collected using approved TDEC and EPA sampling procedures. A sample for QA/QC was used to ensure the security and quality of the samples during collection and shipping to the laboratory for analysis. Organic free water was used as the trip blank for VOCs. Temperature control bottles were used in coolers shipped to the laboratory to ensure the samples did not arrive at the laboratory above six degrees centigrade (6°C).

3.2 Methods and Materials

3.2.1 Sampling Techniques

Spring samples were collected for the analyses of the sample parameters identified in Table 3.2.1. Samples were collected by dipping the bottles into the issuing water, being careful not to lose preservatives. In the event there was no room to dip a bottle, a clean one-liter unpreserved bottle was filled and the water transferred into the larger bottle. Dipping in this manner was not used to fill the volatile vials. A 60 cubic centimeter (cc) syringe and clean tubing collected water from the spring and the tip of the tubing was placed at least one inch below the surface of the water at the designated sampling location and was filled slowly by pulling back on the plunger. Sediment or other foreign materials were carefully excluded from entering into the syringe/tubing.

Standard Operating Procedures followed:

- Division of Water Pollution Control QS-SOP for Chemical & Bacteriological Sampling of Surface Water Revision 4 Effective Date, August 1, 2011
- EPA SESDPROC-301-R3 Groundwater Sampling, March 6, 2013
- TDEC DoR-OR SOP 101, Shipping Samples to the State Lab in Nashville, March 2, 2015

Table 3.2.1: Spring Sampling Analytes for Collected Samples

List of Analytes for Collected Samples		
METALS		
Aluminum	Iron	Nickel
Arsenic	Lead	Potassium
Barium	Lithium	Selenium
Cadmium	Magnesium	Sodium
Calcium	Manganese	Strontium
Chromium	Mercury	Uranium
INORGANICS		
Alkalinity as CaCO ₃ (total alkalinity)	Nitrate by IC	Nitrate and Nitrite
Boron	pH	
Chloride by IC	Residue, Dissolved	
Conductivity	Sulfate	
Hardness as CaCO ₃ (total hardness)		
RADIOLOGIC		
Gross Alpha/Beta by LSC	Strontium 89/90	Technetium-99
Gamma Radionuclides	Tritium	
VOLATILE ORGANIC COMPOUNDS		
EPA 8260B List of Analytes		

LSC = Liquid Scintillation Counting

IC = Ion Chromatography

EPA 8260 B = EPA laboratory method

3.2.2 Regulatory Comparison Values

In order to evaluate the hydrochemical composition of the spring water assessed for this project, DoR-OR compares the results of these spring water analyses to EPA National Primary Drinking Water Regulations (NPDWR). These criteria include Maximum Contaminant Levels (MCL)s and Secondary Maximum Contaminant Levels (SMCL)s.

- 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 items such as taste, odor and color, as well as the staining of teeth, clothing or fixtures. SMCLs are only guidelines for public water utilities.

3.3 Results and Discussion

There are no exceedances of the primary drinking water regulations (MCLs) in any samples collected. (Table 3.3.1). SMCL levels were exceeded in three springs. SPG-055 and SPG-081 contain two constituents above the regulatory limits for SMCLs. SPG-063's water exceeded the SMCL level for aluminum (200 µg /L) at 320 µg /L. SPG-081 also exceeded the aluminum criterion at 210 µg/L. Iron levels exceeded the criterion of 300 µg/L in SPG-055 (320 µg/L) and SPG-081 (380 µg/L). Manganese exceeded the criterion of 50 µg/L in the sample collected at SPG-055.

Table 3.3.2 shows the total number of samples, the number of analyte detections, the minimum and maximum concentrations of radiochemical activities, and EPA's NPDWR (MCL) and NSDWR (SMCL) levels. Several metals, (arsenic, cadmium, chromium, mercury, selenium and uranium) were not measured above their detection limits during analysis. Inorganic constituents consisting of metals and general inorganics are listed in Table 3.3.2.

3.3.1 Field Parameters

Field parameters are collected and recorded prior to sample collection, using a YSI® Professional Plus multi-parameter water quality instrument that reads temperature in degrees Celcius, dissolved oxygen in mg/L, specific conductivity in micro-Siemens, pH in standard units and oxidation reduction potential (ORP) in millivolts. Table 3.3.1 lists 21 spring locations where field parameters alone were collected (i.e. no additional sample analytes collected). The parameters measured give a snapshot of the water quality at those locations.

Table 3.3.1 Spring Sampling Summary of Water Parameters Measured

Location Number	Date Measured	pH (Std. Units)	Temperature (Celsius)	DO (mg/L)	ORP (mvolts)	Specific Conductivity (µS)
SPG-045	7/18/2016	7.11	16.6	9.21	232.2	382.9
SPG-046	7/18/2016	7.46	16.7	9.21	172.6	364.8
SPG-064	2/2/2017	7.81	13.6	10.31	627.9	243.8
SPG-063	2/2/2017	7.76	11.1	9.75	471.4	149.8
SPG-062	2/2/2017	7.72	9.4	12.26	430.5	255.6
SPG-057	2/27/2017	8.03	13.7	8.89	346.8	277.9
SPG-052	2/27/2017	7.62	12.1	10.51	350.2	449.9
SPG-082	2/27/2017	7.51	15.4	5.65	279.5	415.4
SPG-081	2/27/2017	7.58	14.3	6.65	331.4	298.4
SPG-054	3/6/2017	7.57	16.3	10.26	271.2	534.8
SPG-054A	3/6/2017	7.63	16.4	11.05	268.1	458.1
SPG-053A	3/6/2017	7.78	16.1	10.22	262.7	530.5
SPG-051	3/6/2017	DRY				
SPG-055A	3/6/2017	7.68	15.4	8.69	257.1	352.2
SPG-050	3/8/2017	7.82	16.3	10.27	317.1	341.7
SPG-055	3/8/2017	7.43	15.7	5.59	102.5	384.4
SPG-046	6/13/2017	7.88	13.5	9.81	211.6	196.3
SPG-064	6/13/2017	7.51	15.9	8.87	468.9	264.6
SPG-063	6/13/2017	7.1	17.1	6.47	351.3	164.7
SPG-055	6/21/2017	7.79	16.2	5.22	145.1	410.5
SPG-081	6/21/2017	7.7	14.6	7.64	223.8	317.2

DO = Dissolved Oxygen mg/L= milligrams per Liter

ORP = Oxidation Reduction Potential mvolts= millivolts

Specific Conductivity measured in microSiemens (µS)

3.3.2 Volatile Organic Compounds Results

VOCs are not naturally found in pristine waters in measurable amounts. EPA has set limits in regulations for finished water from public water systems. These regulations are NPDWR limits (MCLs). Primary standards protect public health by limiting the levels of contaminants in drinking water. Table 3.3.2 lists those VOCs (Organic Analytes) that were detected during analysis. The laboratory method for analysis was EPA's 8260B for drinking water constituents. (<https://www.epa.gov/sites/production/files/2015-12/documents/8260b.pdf>).

Five springs were sampled, no spring indicated VOCs above the NPDWR (MCL). There was one detection of chloroform in SPG-064 (1.88 µg /L) only identified in a quality control sample.

3.3.3 Metals and Inorganics Results

Table 3.3.2 lists the metals requested for analysis in the 2017 Environmental Monitoring Plan. The table also lists the maximum and minimum concentrations for the metals collected. For example, aluminum measurements ranged from 4.6 to 320 µg/L. No spring samples exceeded the EPA NPDWR (MCL) levels. Three analytes exceeded NSDWR (SMCL) levels; aluminum in two springs (SPG-063 and SPG-081), iron in two springs (SPG-055 and SPG-081) and manganese in spring SPG-055.

Of the 19 metals tested, six (arsenic, cadmium, chromium, mercury, selenium and uranium) were not detected in any of the five samples analyzed. Iron is a variable constituent and ranged from non-detect to 380 mg/L. The concentration of lead was detected in low concentrations in three of the five samples collected. Lithium was detected in two of the five spring samples. Manganese was detected in all samples (0.9-290 µg /L), with the highest concentration in Blue Spring (SPG-055). The concentration of manganese in SPG-055 was measured above the NSDWR (SMCL) of 50 µg/L at 290 µg/L. Nickel was seen in all samples, but well below the TDEC limit of 100 µg/L. See Table 3.3.2.

Analyses at all sampling locations included inorganic parameters, bicarbonate (alkalinity as calcium carbonate CaCO₃), and carbonate (hardness as CaCO₃). Non-metal inorganics are listed in Table 3.1.2. The analytes on the list are constituents found in natural water, and concentrations can be used to determine if the water is affected by manmade pollutants.

Bicarbonate ranged from 79.3 mg/L in SPG-063 to 214 mg/L in SPG-055. Carbonate ranged from 44 mg/L in SPG-063 to 150 mg/L in SPG-055. Chloride ranged from 1.7 mg/L in SPG-046 to 4.85 mg/L in SPG-055. Nitrate is measured to determine the effect from fertilizers and other chemicals. The NPDWR level (MCL) for nitrate is 10 mg/L. Nitrate in these springs ranged from 0.37 mg/L in SPG-046 to 1.3 mg/L in SPG-064. Sulfate ranged from a low of 4.8 mg/L to a high of 9.3 mg/L in SPG-081 and SPG-046 respectively. The NSDWR (SMCL) criterion for sulfate is 250 mg/L and at this level gives a salty taste to water. Total dissolved solids can be used to gauge how long water has been in the ground; the higher the concentration, the longer it has been underground. Total dissolved solids ranged from 96.0 mg/L in SPG-063 to 218 mg/L in SPG-055.

3.3.4 Radionuclides Results

Water from all five sampled springs was analyzed for radiological constituents. The analyses consisted of measuring the gross alpha activity, gross beta activity and the activity of gamma-emitting isotopes. Individual isotopes were also analyzed in samples. Technetium-99 was requested for analysis in all five samples. Strontium-89 and strontium-90 were analyzed in water from five springs and tritium was requested in all springs. Analytical results for the five samples have not been received from the laboratory to date as of the writing of this report.

Table 3.3.2: Spring Sampling Summary

ANALYTES	Number of Samples Analyzed	Number of Analytes Detected	Min. Conc./ Activity	Max. Conc./ Activity	EPA NPDWR (P) NSDWR (S)	Units
METALS ANALYTES						
Aluminum	5	5	4.6	320	50 - 200 S	µg/L
Arsenic	5	0	0	0	10 P	µg/L
Barium	5	5	3.4	91	2000 P	µg/L
Boron	5	5	4.8	11	No Criteria	µg/L
Cadmium	5	0	0	0	5 P	µg/L
Calcium	5	5	18	59	No Criteria	µg/L
Chromium	5	0	0	0	100 P	µg/L
Iron	5	5	0	380	300 S	µg/L
Lead	5	3	0	2.1	15 P	µg/L
Lithium	5	2	0	2.3	No Criteria	ug/L
Magnesium	5	5	7.6	20	No Criteria	mg/L
Manganese	5	5	0.9	290	50 S	µg/L
Mercury	5	0	0	0	2 P	µg/L
Nickel	5	5	0.8	2.3	100 TDEC	µg/L
Potassium	5	5	1.1	2.3	No Criteria	mg/L
Selenium	5	0	0	0	50 P	µg/L
Sodium	5	5	1.3	3	No Criteria	mg/L
Strontium	5	5	26	73	No Criteria	µg/L
Uranium	5	0	0	0	30 P	µg/L
INORGANIC ANALYTES						
Calcium Hardness BC	5	5	44	150	No Criteria	mg/L
Chloride by IC	5	5	1.7	4.85	250 S	mg/L
Nitrate and Nitrite	2	2	0.5	1	10 P	mg/L
Nitrate by IC	5	5	0.37	1.3	10 P	mg/L
Sulfate	5	5	4.8	9.3	250 S	mg/L
Total Alkalinity	5	5	79.3	214	No Criteria	mg/L
Total Dissolved Solids	5	5	96	218	500 S	mg/L
Total Hardness	1	1	91	91	No Criteria	mg/L
ORGANIC ANALYTES						
Chloroform	5	1	0.318	1.88	No Criteria	µg/L
1,2,4-Trichlorobenzene	5	1	0	0.675 B	No Criteria	µg/L
Carbon Disulfide	5	1	0	0.104 J	No Criteria	µg/L
Radiologic Analytes						
Analytical results were not received in time for inclusion in this report.						
QA/QC SAMPLES						
Chloroform	1	1	0.192 J	0.192 J	No Criteria	µg/L
1,2,4-Trichlorobenzene	1	1	0.662 B	0.662 B	No Criteria	µg/L

Max. - maximum

Conc. - concentration

µg/L = micrograms per liter

QA/QC = Quality Assurance/Quality Control

J = Estimated Concentration

TDEC = Determined by the State of Tennessee Rule

NPDWR (P) = National Primary Drinking Water Regulations

NSDWR (S) = National Secondary Drinking Water Regulations

Min. - minimum

mg/L - milligram per liter

B = Analyte identified in laboratory blank

IC = Ion Chromatography

3.4 Conclusions

DoR-OR sampled and analyzed groundwater from selected springs on the ORR and its environs to evaluate water composition and quality. This project sampled springs to collect information on the ambient health of the groundwater off the ORR and along geologic strike of the ORR to the northeast and southwest.

Since there are no regulations for natural groundwater concentrations of constituents, DoR-OR compared the results to the EPA's NPDWRs and NSDWRs. Results listed in Table 3.3.2 for the springs located off the ORR did not indicate constituents above the NPDWR (MCLs). There were a total of five exceedances of the NSDWRs (SMCLs) for aluminum, iron and manganese in three springs. SPG-055 had exceedances for manganese and iron. SPG-081 had exceedances for aluminum and iron and SPG-063 exceeded the NSDWR (SMCL) for aluminum only.

4.0 References

- FFA, May 1994. Federal Facility Agreement for the Oak Ridge Reservation, The United States Environmental Protection Agency Region IV and The United States Department of Energy and The Tennessee Department of Health and Environment. Federal Facility Agreement Under Section 120 of CERCLA and Sections 3008 (h) and 6001 of RCRA Docket No 89-04-FF.
- Haase et al., 1987. Closure of the Oak Ridge National Laboratory, Hydrofracture Facility: An Opportunity to Study the Fate of Radioactive Waste Disposal by Subsurface Injection, Proceedings International Symposium on Class V Well Technology, Washington, D.C., p. 512.
- NBS Handbook 69. NBS (National Bureau of Standards) Handbook 69 as amended August 1963, U.S. Department of Commerce.
- USEPA, March 2018. 2018 Edition of the Drinking Water Standards and Health Advisories Tables, EPA 822-F-18-001. Washington DC: Office of Water, US Environmental Protection Agency.
- White et al., 1963. Data of Geochemistry, Chapter F., Chemical Composition of Subsurface Waters United States Geological Survey, Paper 440, p. 67.
- Worthington et al., 2016. Enhancement of bedrock permeability by weathering, *Earth-Science Reviews*, 60:188-202.
- Worthington et al., 2000. Matrix, fracture and channel components of storage and flow in a Paleozoic limestone aquifer, p. 113-128, (*in*) Wicks, C.M. and Sasowsky, I.D., (eds) *Groundwater Flow and Transport in Carbonate Aquifers*, Balkema, Rotterdam.