Annual Groundwater Monitoring and Corrective Action Report

Tennessee Valley Authority
Bull Run Fossil Plant Fly Ash Stilling Pond 2C and Sluice Channel and Main Ash Pond CCR Units

Prepared for:
Tennessee Valley Authority
1101 Market Street
Chattanooga, TN 37402

Prepared by:
Stantec Consulting Services Inc.

July 31, 2020

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Reference: **Annual Groundwater Monitoring and Corrective Action Report**
TVA Bull Run Fossil Plant Fly Ash Stilling Pond 2C and Sluice Channel and Main Ash Pond CCR Unit

This report documents groundwater monitoring activities during 2019 through July 31, 2020, as required under the federal coal combustion residuals (CCR) rule (the CCR Rule) pursuant to 40 CFR § 257.90(e) at the Tennessee Valley Authority (TVA) Bull Run Fossil Plant (BRF) Fly Ash Stilling Pond 2C and Sluice Channel and Main Ash Pond CCR Unit. These CCR Units are inactive CCR surface impoundments (i.e., vacatur units) under the CCR Rule and are subject to the deadlines set forth in 40 CFR § 257.100. In accordance with 40 CFR § 257.100(e)(5)(ii), TVA prepared the initial Annual Groundwater Monitoring and Corrective Action Report on August 1, 2019 and must prepare reports annually thereafter.

An overview of the status of the groundwater monitoring and corrective action program for the Fly Ash Stilling Pond 2C and Sluice Channel and Main Ash Pond CCR Units is provided below.

- At the start of the current 2019-2020 annual reporting period[1], the Fly Ash Stilling Pond 2C and Sluice Channel and Main Ash Pond CCR Units were operating under a detection monitoring program in accordance with 40 CFR § 257.94. The detection monitoring program for the Fly Ash Stilling Pond 2C and Sluice Channel and Main Ash Pond CCR Units was initiated on April 17, 2019 during the initial 2018-2019 reporting period.

- Results from the 2019 detection monitoring sampling event identified statistically significant increases (SSIs) of Appendix III constituents above background levels observed at the downgradient monitoring wells in the CCR Rule certified groundwater monitoring system. As a result, an alternate source demonstration (ASD) was initiated for the Fly Ash Stilling Pond 2C and Sluice Channel and Main Ash Pond CCR Units on July 16, 2019 and was completed on October 15, 2019. The Appendix III ASD was unable to establish that the SSIs were the result of another source or the result of an error.

- An assessment monitoring program was established on January 13, 2020 in accordance with 40 CFR § 257.94(e)(1) and 40 CFR § 257.95(a). Groundwater protection standards (GWPS) were established on April 14, 2020 in accordance with 40 CFR § 257.95(d)(2) and a statistical evaluation of whether there were statistically significant levels (SSLs) of Appendix IV constituents above GWPS was completed on July 14, 2020. At the end of this 2019-2020 annual reporting period, the Fly Ash Stilling Pond 2C and Sluice Channel and Main Ash Pond CCR Units were being evaluated under an assessment monitoring program in accordance with 40 CFR § 257.95.

- During the 2020-2021 annual reporting period, an ASD for Appendix IV constituents will be performed to evaluate the SSLs over groundwater protection standards in accordance with 40 CFR § 257.95(g)(3)(ii). If the Appendix IV ASD is unable to establish that the SSLs were the result of another source or the result of an error, then an Assessment of Corrective Measures will be initiated pursuant to 40 CFR 257.95(g)(4), and in accordance with 40 CFR § 257.95(g)(3)(i) and 40 CFR § 257.96.

[1] The current 2019-2020 reporting period began on August 2, 2019 and concludes on July 31, 2020.

- Since an assessment of corrective measures has not yet been initiated for these CCR Units, a groundwater a remedy has not been selected and corrective actions have not been initiated pursuant to 40 CFR § 257.97 and 40 CFR § 257.98 for the Fly Ash Stilling Pond 2C and Sluice Channel and Main Ash Pond CCR Units during the current 2019-2020 annual reporting period discussed herein.

TVA has established a multiunit groundwater monitoring system and program at the BRF Fly Ash Stilling Pond 2C and Sluice Channel and Main Ash Pond CCR Units in accordance with 40 CFR § 257.91. TVA conducted a statistical analysis of the 2019 detection monitoring groundwater sampling data in accordance with 40 CFR § 257.93(h), which concluded that there were statistically significant increases (SSIs) over background levels for certain Appendix III constituents. The results were included in Table 1 of the Initial Annual Groundwater Monitoring and Corrective Action Report, which was placed on the CCR Compliance Data and Information website (https://www.tva.com/environment/environmental-stewardship/coal-combustion-residuals/bull-run). Additional detection monitoring groundwater sampling results are included in Table 1 of this 2019-2020 Annual Groundwater Monitoring and Corrective Action Report in accordance with 40 CFR § 257.94(b). During 2019-2020, TVA performed the following groundwater monitoring activities:

- Performed an alternate source demonstration for the SSIs over background levels of Appendix III constituents in accordance with 40 CFR § 257.94(e)(2).
- Performed error checking and investigated whether the SSIs over background resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality as specified in 40 CFR § 257.94(e)(2).
- Established an assessment monitoring program in accordance with 40 CFR § 257.94(e)(2) because the Appendix III alternate source demonstration was unable to establish that the SSIs were the result of another source or the result of an error.
- Placed notification of the establishment of the assessment monitoring program in the facility operating record in accordance with 40 CFR § 257.94(e)(3) and 257.105(h)(5); provided notification to the State of Tennessee in accordance with 40 CFR § 257.106(h)(4); and placed notification on the TVA CCR Rule Compliance Data and Information website (https://www.tva.com/environment/environmental-stewardship/coal-combustion-residuals/bull-run) in accordance with 40 CFR § 257.107(h)(4).
- Sampled and analyzed groundwater in the certified groundwater monitoring system for Appendix IV constituents in accordance with 40 CFR § 257.95(b).
- Sampled wells in the certified groundwater monitoring system and analyzed samples for CCR constituents (Appendix III and Appendix IV constituents) in accordance with 40 CFR § 257.95(d)(1).
- Placed the sampling results in the operating record as required by 40 CFR § 257.95(d)(1) and 257.105(h)(6). Additionally, these results are included in Table 2 of this 2019-2020 Annual Groundwater Monitoring and Corrective Action Report in accordance with 40 CFR § 257.95(d)(3).
- Established groundwater protection standards in accordance with 40 CFR § 257.95(d)(2) and included the standards in this 2019-2020 Annual Groundwater Monitoring and Corrective Action Report in accordance with 40 CFR § 257.95(d)(3).
- Completed an evaluation of whether one or more Appendix IV constituents are detected at SSLs above the established groundwater protection standards in accordance with 40 CFR § 257.95(g).
- Performed field and desktop site characterization investigations to improve the BRF Conceptual Site Model (CSM).
- Continued TVA's third-party Quality Assurance Program to evaluate and improve groundwater analytical data using best practices concerning field methods and validation techniques, as well as the application of the most appropriate statistical methods.

- Reviewed new data as it became available to maintain compliance with 40 CFR § 257.90 through 257.98.
- Complied with recordkeeping requirements as specified in 40 CFR § 257.105(h), notification requirements specified in 40 CFR § 257.106(h), and internet requirements specified in 40 CFR § 257.107(h).

The projected key activities for the next reporting period are:

- Perform an alternate source demonstration for the SSLs over groundwater protection standards (Appendix IV constituents) in accordance with 40 CFR § 257.95(g)(3)(ii).
- Initiate characterization of the nature and extent in accordance with 40 CFR § 257.95(g)(1) if the Appendix IV alternate source demonstration performed under 40 CFR § 257.95(g)(3)(ii) is not successful.
- Place notification of the exceedances of established groundwater protection standards in the facility operating record in accordance with 40 CFR § 257.95(g) and 257.105(h)(8); provide notification to the State of Tennessee in accordance with 40 CFR § 257.106(h)(6); and place notification on the CCR Compliance Data and Information website (https://www.tva.com/environment/environmental-stewardship/coal-combustion-residuals/bull-run) in accordance with 40 CFR § 257.107(h)(6).
- Notify all persons who own land or reside on land that directly overlies any part of the plume of contaminants if contaminants have migrated off-site in accordance with 40 CFR § 257.95(g)(2) if the Appendix IV alternate source demonstration performed under 40 CFR § 257.95(g)(3)(ii) is not successful.
- Initiate Assessment of Corrective Measures pursuant to 40 CFR 257.95(g)((4) if the Appendix IV alternate source demonstration performed under 40 CFR 257.95(g)(3)(ii) is not successful.
- Continue semiannual assessment monitoring at the certified groundwater monitoring system consistent with 40 CFR § 257.95.
- Perform further field and desktop site characterization investigations to improve the BRF CSM.
- Continue TVA's third-party Quality Assurance Program to evaluate groundwater analytical data using best practices concerning field methods and validation techniques, as well as the application of the most appropriate statistical methods.
- Review new data as it becomes available and implement changes to the groundwater monitoring program as necessary to maintain compliance with 40 CFR § 257.90 through 257.98.
- Comply with recordkeeping requirements as specified in 40 CFR § 257.105(h), notification requirements specified in 40 CFR § 257.106(h), and internet requirements specified in 40 CFR § 257.107(h).

GROUNDWATER MONITORING SYSTEM

The certified groundwater monitoring system for the BRF Fly Ash Stilling Pond 2C and Sluice Channel and Main Ash Pond CCR Units consists of one background well (2), one up-gradient well (BRF-104)[2] and seven downgradient wells (47, 48, 49, 50, 10-51, 10-52, and S). Figure 1 is an aerial photograph that shows the groundwater monitoring well locations. The Fly Ash Stilling Pond 2C and Sluice Channel and Main Ash Pond share a common, multiunit groundwater monitoring system.

[2] The groundwater monitoring system contains one background well (2) representing conditions unaffected by CCR and one upgradient well (BRF-104) (40 CFR § 257.91(a)(1) and 257.91(c)(1)). Well BRF-104 was not used to calculate background concentrations due to potential influence from other sources. This has no effect on the statistical analysis and reliability of the determinations in this report.

No monitoring wells in the CCR system were installed or decommissioned during this reporting period. The certification of the groundwater monitoring system required under 40 CFR § 257.91(f) is included in the facility operating record and on the TVA CCR Rule Compliance Data and Information website: (https://www.tva.com/environment/environmental-stewardship/coal-combustion-residuals/bull-run).

GROUNDWATER SAMPLING AND LABORATORY ANALYTICAL TESTING

A groundwater sampling and analysis program was developed and includes procedures and techniques for sample collection, sample preservation and shipment, analytical procedures, chain-of-custody control, and, quality assurance and quality control (QA/QC) required by 40 CFR § 257.93(a). The groundwater monitoring program includes sampling and analysis procedures designed to provide monitoring results that are an accurate representation of groundwater quality at background and downgradient wells.

The second round of detection monitoring and a retest event were completed in compliance with 40 CFR § 257.94. Detection monitoring groundwater sampling results are summarized in Table 1. The first round of assessment monitoring and a retest event were completed in compliance with 40 CFR § 257.95. Assessment monitoring groundwater sampling results are summarized in Table 2. A summary of groundwater sample locations, well designations, analytes sampled, sampling dates, and monitoring program status is provided in Table 3.

Groundwater elevations were measured in each monitoring well immediately prior to purging as required by 40 CFR § 257.93(c). Groundwater elevations and Clinch River surface water elevations are summarized in Table 4. Groundwater flow directions were determined for each sampling event, and a generalized depiction of groundwater flow direction is illustrated on Figure 2. The groundwater directional flow at BRF is influenced by the Clinch River to the west, and Bull Run Creek to the south of the Fly Ash Stilling Pond 2C and Sluice Channel and Main Ash Pond. The primary groundwater flow direction is to the south-southwest toward the Clinch River and Bull Run Creek. The uppermost aquifer at the BRF Fly Ash Stilling Pond 2C and Sluice Channel and Main Ash Pond CCR Units consists primarily of alluvium along the Clinch River and Bull Run Creek and overburden east of the CCR units.

Testing for hydraulic conductivity at the background and downgradient groundwater monitoring wells, as summarized in Table 5, was determined by a 2019 hydrogeologic evaluation (Terracon, 2019). Testing data indicates that the uppermost saturated zone has a geometric mean hydraulic conductivity of 5.00×10^{-4} centimeters per second (cm/sec). Linear groundwater flow velocity was calculated for the uppermost aquifer using:

- the geometric mean hydraulic conductivity calculated from hydraulic testing;
- horizontal hydraulic gradients measured during the implementation of the groundwater sampling and analysis program, ranging from 0.0044 to 0.0056 feet per foot (ft/ft); and,
- an effective porosity of 10% (TVA, 2015).

The average linear flow velocity in the uppermost aquifer ranges from approximately 22.9 to 28.9 feet per year. The rate and direction of groundwater flow for each groundwater sampling event is summarized in Table 6 in accordance with 40 CFR § 257.93(c).

STATISTICAL ANALYSIS OF GROUNDWATER DATA

The groundwater monitoring data for the assessment monitoring event and retest event were evaluated using statistical procedures as required by 40 CFR § 257.93(f) through 257.93(h). The statistical method certification is included in the facility operating record and the TVA CCR Rule Compliance Data and Information website. Groundwater protection standards were established in accordance with 40 CFR § 257.95(h), as the larger of published regulatory limits or screening criteria (e.g., maximum contaminant levels (MCLs) and upper tolerance limits (UTLs) derived from background. Maximum contaminant levels may or may not be considered the appropriate groundwater protection standard depending on background well concentrations for each Appendix IV[3] constituent[4]. The 2019-2020 Statistical Analysis Report is included in Appendix A. The sampling results used to identify potential groundwater protection standards exceedances were obtained[5]. Comparisons were made against a fixed groundwater protection standard via a confidence interval or confidence interval band. None of the individual compliance point measurements were directly compared against the groundwater protection standard. The Appendix IV monitoring data collected in 2019 and 2020 were used to construct the confidence interval bands. Cross-sections of each confidence interval band were then compared to the groundwater protection standard for the most recent assessment monitoring event for the purpose of identifying any SSLs. A well-constituent pair is considered out of compliance only if its average constituent levels, as estimated via the confidence interval cross-section, currently exceed the groundwater protection standard. During Assessment Monitoring, arsenic SSLs were recorded at wells 49 and 10-52, cobalt SSLs were recorded at wells 48 and 49, lithium SSLs were recorded at wells 47 and 49, and a molybdenum SSL was recorded at well 49.

NARRATIVE DISCUSSION OF ANY TRANSITION BETWEEN MONITORING PROGRAMS

In July 2019, TVA evaluated the groundwater monitoring data for SSIs over background levels for the constituents listed in Appendix III[6] as required by 40 CFR § 257.93(h). The groundwater analytical results from the initial round of detection monitoring and a retest event indicated SSIs of Appendix III CCR constituents at the downgradient monitoring wells. TVA performed error checking and investigated whether the SSI over background resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality as specified in 40 CFR § 257.94(e)(2). TVA also performed investigations to evaluate whether a source other than the CCR materials contained within the BRF Fly Ash Stilling Pond 2C and Sluice Channel and Main Ash Pond CCR Units was the cause of the SSIs. The alternate source

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[3] Appendix IV CCR Constituents: antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, fluoride, lead, lithium, mercury, molybdenum, selenium, thallium, and radium 226 and radium 228 combined

[4] USEPA has published MCLs or alternate regulatory limits for each of the Appendix IV constituents. Consequently, in most cases the groundwater protection standard is equal to the MCL. However, there may be cases where background levels of a constituent exceed the MCL. In these instances, an alternate groundwater protection standard must be derived from on-site background levels. On July 30, 2018, EPA provided alternate regulatory limits (i.e., potential groundwater protection standards) for four of the Appendix IV chemical Constituents of Interest (COIs) for which the agency has not assigned MCLs to date. In the absence of MCLs or site-specific groundwater protection standards, those may be used in place of background levels under 40 CFR § 257.95(h)(2). Specifically, those alternate COIs include threshold values at the following health-based levels: 1.) Cobalt - 6 µg/L; 2.) Lithium - 40 µg/L; 3.) Molybdenum – 100 µg/L; and, 4.) Lead - 15 µg/L.

[5] Baseline data from designated background wells collected through March 2020 were grouped and checked for possible outliers. The grouped baseline data (excluding confirmed outliers) were analyzed to evaluate whether they could be fit to a known statistical model to compute or construct an Upper Tolerance Interval (UTL). These UTLs were compared against the promulgated regulatory limits to determine the site-specific GWPS. The CCR rule requires a minimum of two semiannual sampling events per well once the required background data has been obtained. In 2019-2020, the second detection monitoring event and the initial assessment monitoring event were each followed by retesting groundwater sampling events.

[6] Appendix III CCR Constituents: boron, calcium, chloride, fluoride, pH, sulfate and total dissolved solids (TDS).

demonstration study did not demonstrate the SSIs were a result of error or another source. An Assessment Monitoring Program was established and implemented as specified in 40 CFR § 257.95. Notification of the assessment monitoring program was provided to the State of Tennessee and placed on the TVA CCR Rule Compliance Data and Information website (https://www.tva.com/environment/environmental-stewardship/coal-combustion-residuals/bull-run) in accordance with 40 CFR § 257.106(h)(4) and 40 CFR § 257.107(h)(4), respectively.

In accordance with assessment monitoring program requirements, TVA collected groundwater samples from wells in the certified groundwater monitoring system and analyzed the samples for Appendix IV constituents in accordance with 40 CFR § 257.95(b) within 90 days of triggering assessment monitoring. Subsequent sampling and analysis of all wells in the certified groundwater monitoring system for Appendix III and IV constituents occurred in accordance with 40 CFR § 257.95(d)(1). Appendix III and IV constituent concentrations were placed in the facility operating record in accordance with 40 CFR § 257.105(h)(6) and are summarized in Table 2. Groundwater protection standards were established in accordance with 40 CFR § 257.95(d)(2) and are summarized in Table 7. In July 2020, an evaluation of whether there are SSLs over established groundwater protection standards for one or more Appendix IV constituents was completed in accordance with 40 CFR § 257.95(g). Although not required to be included in this 2019-2020 Annual Report, during Assessment Monitoring, arsenic SSLs were recorded at wells 49 and 10-52, cobalt SSLs were recorded at wells 48 and 49, lithium SSLs were recorded at wells 47 and 49, and a molybdenum SSL was recorded at well 49.TVA will continue to review new data as it becomes available and implement changes to the groundwater monitoring program as necessary to maintain compliance with 40 CFR § 257.90 through 257.98.

LIMITATIONS

This document entitled Annual Groundwater Monitoring and Corrective Action Report was prepared by Stantec Consulting Services Inc. ("Stantec") for the Tennessee Valley Authority (the "Client"). The material in it reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec relied upon data and information supplied to it by the client.

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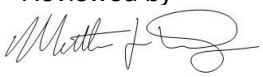

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References:

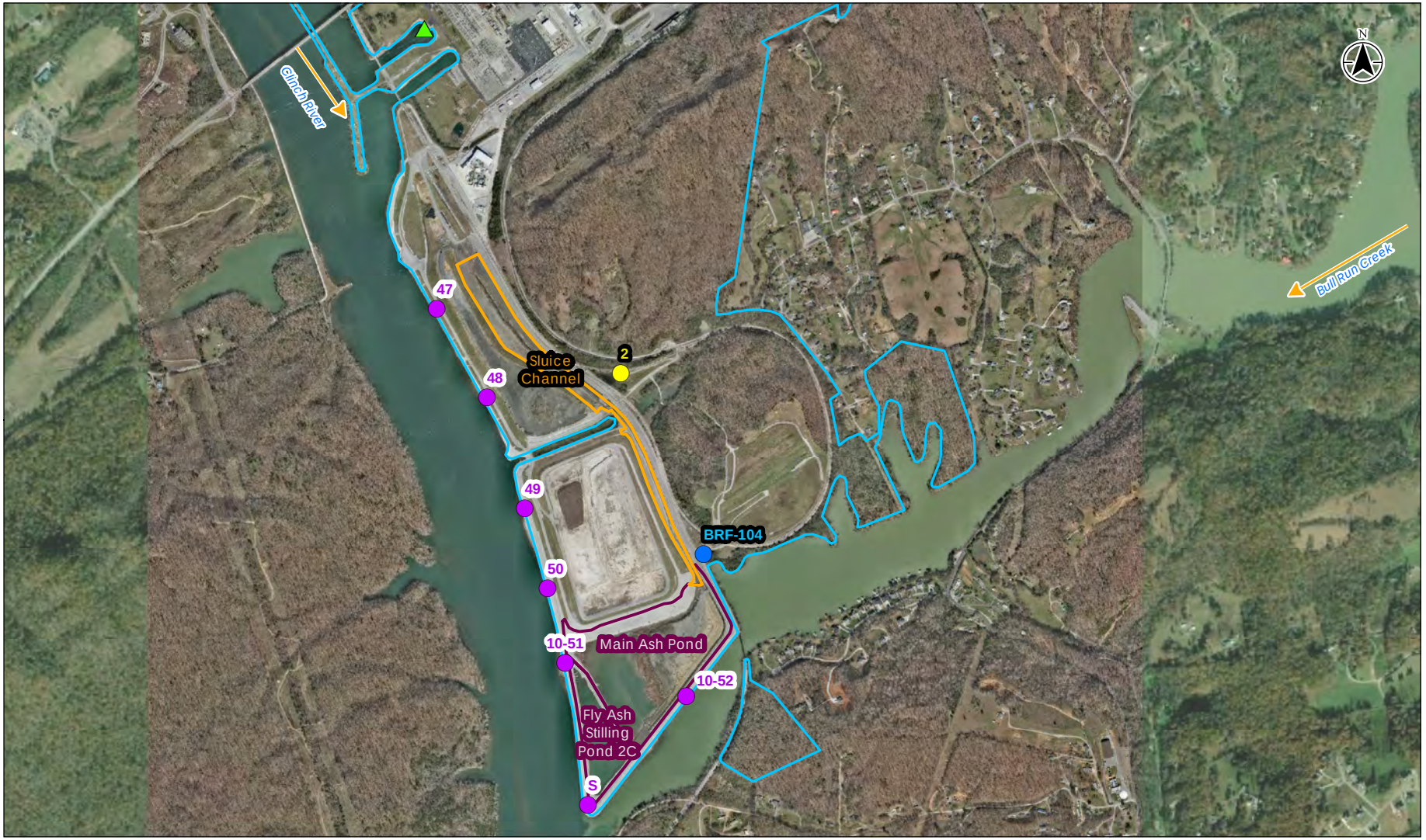
Tennessee Valley Authority (TVA), 2015. Groundwater Assessment Monitoring Report. Nashville, TN. October 20, 2015.

Terracon Consultants, Inc. (Terracon), 2019. Aquifer Testing Results, TVA CCR Rule, Bull Run Fossil Plant. July 2019.

Attachments:

Figure 1	Map with CCR Unit Background and Downgradient Wells
Figure 2	Generalized Groundwater Flow Direction Map
Table 1	Detection Monitoring Groundwater Sampling Results
Table 2	Assessment Monitoring Groundwater Sampling Results
Table 3	Groundwater Sampling Summary
Table 4	Groundwater and Surface Water Elevation Summary
Table 5	Hydraulic Conductivity Data Summary
Table 6	Rate and Direction of Groundwater Flow Summary
Table 7	Groundwater Protection Standards
Appendix A	Statistical Analysis Report for Bull Run Fossil Plant, 2020 CCR Program - Vacatur Unit

FIGURES



- Downgradient Well
- Background Well
- Upgradient Well
- Staff Gauge
- Surface Water Flow Direction
- TVA Property Boundary
- CCR Unit Area (Approximate)
- Sluice Channel (Approximate)

0 1,250 2,500 Feet

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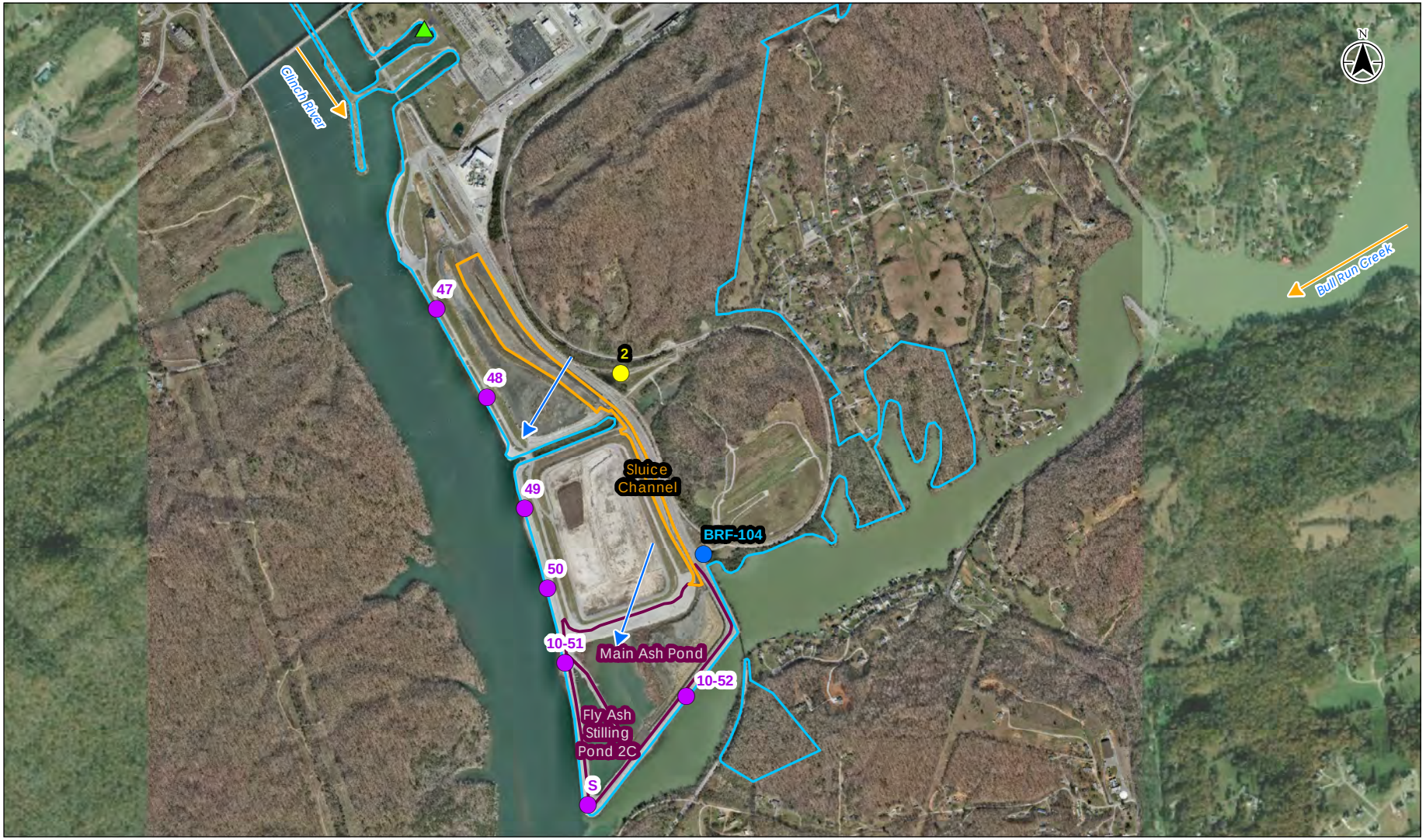
Notes
1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery Source: Tucker Mapping Solutions, INC (2017-03-16) and Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Project Location	182603523
Claxton Anderson County, Tennessee	Prepared by LMB on 2020-06-05 Technical Review by BS on 2020-06-05 Independent Review by TR on 2020-06-05

Client/Project
Tennessee Valley Authority
Bull Run Fossil Plant
CCR Rule

Figure No.
1

Title
Map with CCR Unit Background and Downgradient Wells



- Downgradient Well
- Background Well
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- Surface Water Flow Direction
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Groundwater flow directions are based on Clinch River Elevations and groundwater elevations from CCR and Non-CCR monitoring wells.

Project Location	182603523
Claxton Anderson County, Tennessee	Prepared by LMB on 2020-06-25 Technical Review by BS on 2020-06-25 Independent Review by TR on 2020-06-25

Client/Project
Tennessee Valley Authority
Bull Run Fossil Plant
CCR Rule

Figure No.
2

Title
Generalized Groundwater Flow Direction Map

TABLES

Monitoring Well		10-51			
Sample Date		07-Aug-19		13-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	292		231	
Calcium	µg/L	141000		141000	
Anions					
Chloride	mg/L	87.9		90.0	
Fluoride	mg/L	0.0880	J	< 0.0620	U*
Sulfate	mg/L	11.2		7.87	
General Chemistry					
Total Dissolved Solids	mg/L	610		524	
Field Parameters					
Temperature, Water	DEG_C	20.7		17.5	
Turbidity (field)	NTU	3.61		1.04	
ORP	mV	47.0		78.2	
Specific Conductivity (field)	mS/cm	0.84		0.77	
Dissolved Oxygen	mg/L	0.19		0.49	
pH (field)	SU	6.68		6.69	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Monitoring Well		10-52			
Sample Date		07-Aug-19		13-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	< 231	U*	208	
Calcium	µg/L	107000		117000	
Anions					
Chloride	mg/L	3.33		5.51	
Fluoride	mg/L	0.0300	J	< 0.0603	U*
Sulfate	mg/L	0.457	J	< 0.477	U*
General Chemistry					
Total Dissolved Solids	mg/L	380		372	
Field Parameters					
Temperature, Water	DEG_C	17.8		16.1	
Turbidity (field)	NTU	2.71		3.63	
ORP	mV	-111.2		-81.1	
Specific Conductivity (field)	mS/cm	0.72		0.66	
Dissolved Oxygen	mg/L	0.16		0.36	
pH (field)	SU	6.60		6.76	

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Monitoring Well		2			
Sample Date		05-Aug-19		12-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Background		Background	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	64.8	J	< 128	U*
Calcium	µg/L	138000		168000	
Anions					
Chloride	mg/L	3.39		3.28	
Fluoride	mg/L	0.0860	J	< 0.263	U
Sulfate	mg/L	188		193	
General Chemistry					
Total Dissolved Solids	mg/L	725		692	
Field Parameters					
Temperature, Water	DEG_C	19.1		15.6	
Turbidity (field)	NTU	0.42		1.18	
ORP	mV	2.4		-1.1	
Specific Conductivity (field)	mS/cm	0.99		0.97	
Dissolved Oxygen	mg/L	0.20		0.35	
pH (field)	SU	6.53		6.93	

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Monitoring Well		47			
Sample Date		08-Aug-19		14-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	1350		1590	
Calcium	µg/L	266000		280000	
Anions					
Chloride	mg/L	5.45		4.64	
Fluoride	mg/L	0.205		0.337	
Sulfate	mg/L	747		664	
General Chemistry					
Total Dissolved Solids	mg/L	1290		1430	
Field Parameters					
Temperature, Water	DEG_C	20.5		18.0	
Turbidity (field)	NTU	7.58		15.1	
ORP	mV	-63.2		-66.0	
Specific Conductivity (field)	mS/cm	1.56		1.39	
Dissolved Oxygen	mg/L	0.10		0.26	
pH (field)	SU	6.56		6.72	

Notes:

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mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Monitoring Well		48			
Sample Date		05-Aug-19		14-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	1380		1130	
Calcium	µg/L	429000		272000	
Anions					
Chloride	mg/L	1.85	J	1.87	
Fluoride	mg/L	0.169	J	0.180	
Sulfate	mg/L	971		629	
General Chemistry					
Total Dissolved Solids	mg/L	1860		1250	
Field Parameters					
Temperature, Water	DEG_C	20.6		16.9	
Turbidity (field)	NTU	16.6		29.6	
ORP	mV	-34.6		7.5	
Specific Conductivity (field)	mS/cm	2.03		1.24	
Dissolved Oxygen	mg/L	0.14		0.31	
pH (field)	SU	6.49		6.67	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Monitoring Well		49			
Sample Date		06-Aug-19		14-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	2040		20200	
Calcium	µg/L	598000		583000	
Anions					
Chloride	mg/L	449		447	
Fluoride	mg/L	1.25		1.00	
Sulfate	mg/L	1250		1280	
General Chemistry					
Total Dissolved Solids	mg/L	3150		2940	
Field Parameters					
Temperature, Water	DEG_C	18.9		17.6	
Turbidity (field)	NTU	6.91		7.59	
ORP	mV	-52.1		-47.3	
Specific Conductivity (field)	mS/cm	3.44		2.95	
Dissolved Oxygen	mg/L	0.05		0.07	
pH (field)	SU	6.70		6.65	

Notes:

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J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Monitoring Well		50			
Sample Date		06-Aug-19		15-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	224		248	
Calcium	µg/L	202000		198000	
Anions					
Chloride	mg/L	27.2		39.8	
Fluoride	mg/L	0.149		0.133	
Sulfate	mg/L	59.5		54.8	
General Chemistry					
Total Dissolved Solids	mg/L	784		710	
Field Parameters					
Temperature, Water	DEG_C	18.8		16.9	
Turbidity (field)	NTU	4.22		3.38	
ORP	mV	-32.6		12.3	
Specific Conductivity (field)	mS/cm	1.15		1.06	
Dissolved Oxygen	mg/L	0.14		0.23	
pH (field)	SU	6.65		6.73	

Notes:

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mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Monitoring Well		BRF-104			
Sample Date		06-Aug-19		12-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Upgradient		Upgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	1360		2180	
Calcium	µg/L	116000		145000	
Anions					
Chloride	mg/L	23.3		53.9	
Fluoride	mg/L	0.179		< 0.159	U*
Sulfate	mg/L	70.1		93.2	
General Chemistry					
Total Dissolved Solids	mg/L	485		518	
Field Parameters					
Temperature, Water	DEG_C	19.5		20.4	
Turbidity (field)	NTU	1.48		0.93	
ORP	mV	110.6		92.5	
Specific Conductivity (field)	mS/cm	0.65		0.75	
Dissolved Oxygen	mg/L	0.39		0.43	
pH (field)	SU	6.63		6.73	

Notes:

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J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Table 1 - Detection Monitoring Groundwater Sampling Results

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA Bull Run Fossil Plant

Monitoring Well		S			
Sample Date		07-Aug-19		13-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	< 98.4	U*	97.4	
Calcium	µg/L	42100		50900	
Anions					
Chloride	mg/L	8.91		11.0	
Fluoride	mg/L	0.0575	J	< 0.0709	U*
Sulfate	mg/L	23.8		26.2	
General Chemistry					
Total Dissolved Solids	mg/L	263		199	
Field Parameters					
Temperature, Water	DEG_C	18.7		16.5	
Turbidity (field)	NTU	30.8		40.4	
ORP	mV	292.3		110.7	
Specific Conductivity (field)	mS/cm	0.303		0.298	
Dissolved Oxygen	mg/L	0.28		0.30	
pH (field)	SU	5.89		6.08	

Notes:

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mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Monitoring Well		10-51			
Sample Date		05-Feb-20		18-Mar-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.378	U	< 0.378	U
Arsenic	µg/L	< 0.313	U	< 0.313	U
Barium	µg/L	107		119	
Beryllium	µg/L	< 0.182	U	< 0.182	U
Boron	µg/L	344		< 275	U*
Cadmium	µg/L	< 0.217	U	0.610	J
Calcium	µg/L	146000		154000	
Chromium	µg/L	< 1.53	U	< 1.53	U
Cobalt	µg/L	0.379	J	0.476	J
Lead	µg/L	0.152	J	< 0.128	U
Lithium	µg/L	7.33		6.44	
Mercury	µg/L	< 0.101	UR	< 0.101	U
Molybdenum	µg/L	< 0.610	U	< 0.610	U
Selenium	µg/L	< 1.51	U	< 1.51	U
Thallium	µg/L	0.432	J	< 0.148	U
Radium 226 + Radium 228	pCi/L	< 0.972	U	< 0.0341	U
Anions					
Chloride	mg/L	102		121	
Fluoride	mg/L	0.0829	J	< 0.0288	U*
Sulfate	mg/L	6.09		14.3	
General Chemistry					
Total Dissolved Solids	mg/L	535		607	
Field Parameters					
Temperature, Water	DEG_C	16.5		17.0	
Turbidity (field)	NTU	0.69		0.41	
ORP	mV	50.0		35.5	
Specific Conductivity (field)	mS/cm	1.03		0.78	
Dissolved Oxygen	mg/L	0.35		0.57	
pH (field)	SU	6.64		6.71	

Notes:

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mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Table 2 - Assessment Monitoring Groundwater Sampling Results

Monitoring Well		10-52			
Sample Date		04-Feb-20		18-Mar-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.378	U	< 0.378	U
Arsenic	µg/L	31.7		28.1	
Barium	µg/L	659		643	
Beryllium	µg/L	< 0.182	U	< 0.217	U*
Boron	µg/L	< 217	U*	< 196	U*
Cadmium	µg/L	< 0.217	U	< 0.217	U
Calcium	µg/L	111000		105000	
Chromium	µg/L	< 1.53	U	< 1.53	U
Cobalt	µg/L	1.91		2.01	
Lead	µg/L	0.159	J	< 0.128	U
Lithium	µg/L	4.96	J	< 3.39	U
Mercury	µg/L	< 0.101	UR	< 0.101	U
Molybdenum	µg/L	0.711	J	0.698	J
Selenium	µg/L	< 1.51	U	< 1.51	U
Thallium	µg/L	0.305	J	< 0.148	U
Radium 226 + Radium 228	pCi/L	< 0.824	U	1.58	J
Anions					
Chloride	mg/L	5.41		5.41	
Fluoride	mg/L	0.0528	J	< 0.0288	U*
Sulfate	mg/L	< 0.380	U	< 0.705	U*
General Chemistry					
Total Dissolved Solids	mg/L	415		517	
Field Parameters					
Temperature, Water	DEG_C	16.5		16.2	
Turbidity (field)	NTU	1.49		0.80	
ORP	mV	-104.5		-59.7	
Specific Conductivity (field)	mS/cm	0.86		0.61	
Dissolved Oxygen	mg/L	0.13		0.35	
pH (field)	SU	6.61		6.69	

Notes:

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U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Table 2 - Assessment Monitoring Groundwater Sampling Results

Monitoring Well		2			
Sample Date		03-Feb-20		17-Mar-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Background		Background	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.378	U	< 0.378	U
Arsenic	µg/L	< 0.313	U	< 0.313	U
Barium	µg/L	40.9		44.0	
Beryllium	µg/L	< 0.182	U	< 0.182	U
Boron	µg/L	65.8	J	< 68.3	U*
Cadmium	µg/L	< 0.217	U	< 0.217	U
Calcium	µg/L	181000		162000	
Chromium	µg/L	< 1.53	U	< 1.53	U
Cobalt	µg/L	0.604		0.914	
Lead	µg/L	< 0.128	U	< 0.128	U
Lithium	µg/L	18.8		16.1	
Mercury	µg/L	< 0.101	U	< 0.101	U
Molybdenum	µg/L	< 0.610	U	< 0.610	U
Selenium	µg/L	< 1.51	U	< 1.51	U
Thallium	µg/L	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	< 0.674	U	< 0.264	U
Anions					
Chloride	mg/L	5.10		4.89	
Fluoride	mg/L	0.0790	J	< 0.0525	U*
Sulfate	mg/L	237		227	
General Chemistry					
Total Dissolved Solids	mg/L	782		730	
Field Parameters					
Temperature, Water	DEG_C	16.8		15.6	
Turbidity (field)	NTU	1.83		1.07	
ORP	mV	-15.5		82.0	
Specific Conductivity (field)	mS/cm	1.33		0.94	
Dissolved Oxygen	mg/L	0.56		0.67	
pH (field)	SU	6.86		6.78	

Notes:

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J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Table 2 - Assessment Monitoring Groundwater Sampling Results

Monitoring Well		47			
Sample Date		06-Feb-20		20-Mar-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.378	U	< 0.378	U
Arsenic	µg/L	7.48		7.49	
Barium	µg/L	56.7		36.2	
Beryllium	µg/L	< 0.182	U	< 0.182	U
Boron	µg/L	1290		1330	
Cadmium	µg/L	< 0.217	U	< 0.217	U
Calcium	µg/L	288000		300000	
Chromium	µg/L	< 1.53	U	< 1.53	U
Cobalt	µg/L	5.74		5.26	
Lead	µg/L	0.338	J	0.333	J
Lithium	µg/L	419		440	
Mercury	µg/L	< 0.101	U	< 0.101	U
Molybdenum	µg/L	86.5		93.6	
Selenium	µg/L	< 1.51	U	< 1.51	U
Thallium	µg/L	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	< 0.564	U	2.36	J
Anions					
Chloride	mg/L	5.71		5.71	
Fluoride	mg/L	0.286		0.207	
Sulfate	mg/L	746		797	
General Chemistry					
Total Dissolved Solids	mg/L	1310		1330	
Field Parameters					
Temperature, Water	DEG_C	16.2		17.3	
Turbidity (field)	NTU	18.3		15.1	
ORP	mV	-38.8		-36.1	
Specific Conductivity (field)	mS/cm	1.85		1.47	
Dissolved Oxygen	mg/L	0.18		0.62	
pH (field)	SU	6.54		6.59	

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U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Monitoring Well		48			
Sample Date		06-Feb-20		19-Mar-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.378	U	< 0.378	U
Arsenic	µg/L	< 0.313	U	0.669	J
Barium	µg/L	35.6		35.7	
Beryllium	µg/L	< 0.182	U	< 0.182	U
Boron	µg/L	1020		1280	
Cadmium	µg/L	< 0.217	U	0.254	J
Calcium	µg/L	324000		372000	
Chromium	µg/L	< 1.53	U	< 1.53	U
Cobalt	µg/L	9.26		14.5	
Lead	µg/L	0.128	J	1.07	
Lithium	µg/L	28.5		36.8	
Mercury	µg/L	< 0.101	U	< 0.101	U
Molybdenum	µg/L	< 0.610	U	< 0.610	U
Selenium	µg/L	< 1.51	U	< 1.51	U
Thallium	µg/L	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	< 0.207	U	1.78	J
Anions					
Chloride	mg/L	2.10		2.05	
Fluoride	mg/L	0.147		< 0.0498	U*
Sulfate	mg/L	776		985	
General Chemistry					
Total Dissolved Solids	mg/L	1360		1610	
Field Parameters					
Temperature, Water	DEG_C	16.5		17.9	
Turbidity (field)	NTU	4.08		50.3	
ORP	mV	-27.5		-12.8	
Specific Conductivity (field)	mS/cm	1.88		1.45	
Dissolved Oxygen	mg/L	0.81		0.33	
pH (field)	SU	6.42		6.38	

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µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Monitoring Well		49			
Sample Date		04-Feb-20		19-Mar-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.378	U	< 0.378	U
Arsenic	µg/L	22.6		72.0	
Barium	µg/L	47.1		40.9	
Beryllium	µg/L	< 0.182	U	< 0.182	U
Boron	µg/L	20000		18200	
Cadmium	µg/L	0.221	J	< 0.217	U
Calcium	µg/L	624000		652000	
Chromium	µg/L	< 1.53	U	< 1.53	U
Cobalt	µg/L	12.5		13.8	
Lead	µg/L	0.150	J	0.149	J
Lithium	µg/L	444		425	
Mercury	µg/L	< 0.101	UR	< 0.101	U
Molybdenum	µg/L	218		222	
Selenium	µg/L	< 1.51	U	< 1.51	U
Thallium	µg/L	0.208	J	< 0.148	U
Radium 226 + Radium 228	pCi/L	< 1.16	U	1.22	J
Anions					
Chloride	mg/L	439		391	
Fluoride	mg/L	0.985		0.818	
Sulfate	mg/L	1250		1220	
General Chemistry					
Total Dissolved Solids	mg/L	3140		3030	
Field Parameters					
Temperature, Water	DEG_C	15.8		17.0	
Turbidity (field)	NTU	5.73		50.4	
ORP	mV	-8.5		12.2	
Specific Conductivity (field)	mS/cm	3.99		2.63	
Dissolved Oxygen	mg/L	0.12		0.32	
pH (field)	SU	6.62		6.66	

Notes:

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J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Table 2 - Assessment Monitoring Groundwater Sampling Results

Monitoring Well		50			
Sample Date		05-Feb-20		19-Mar-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.378	U	< 0.378	U
Arsenic	µg/L	1.12		1.14	
Barium	µg/L	154		146	
Beryllium	µg/L	< 0.182	U	< 0.182	U
Boron	µg/L	226		181	
Cadmium	µg/L	< 0.217	U	< 0.217	U
Calcium	µg/L	194000		198000	
Chromium	µg/L	< 1.53	U	< 1.53	U
Cobalt	µg/L	3.44		3.10	
Lead	µg/L	0.608	J	0.428	J
Lithium	µg/L	< 3.39	U	< 3.39	U
Mercury	µg/L	< 0.101	UR	< 0.101	U
Molybdenum	µg/L	< 0.610	U	< 0.610	U
Selenium	µg/L	< 1.51	U	< 1.51	U
Thallium	µg/L	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	< 1.12	U	< 0.435	U
Anions					
Chloride	mg/L	40.1		39.1	
Fluoride	mg/L	0.136		< 0.132	U
Sulfate	mg/L	52.1		54.3	
General Chemistry					
Total Dissolved Solids	mg/L	679		727	
Field Parameters					
Temperature, Water	DEG_C	16.3		16.2	
Turbidity (field)	NTU	15.0		10.8	
ORP	mV	-53.8		10.8	
Specific Conductivity (field)	mS/cm	1.29		0.95	
Dissolved Oxygen	mg/L	0.06		0.31	
pH (field)	SU	6.73		6.74	

Notes:

NA - Not Available

Q - Data Qualifier

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J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Table 2 - Assessment Monitoring Groundwater Sampling Results

Monitoring Well		BRF-104			
Sample Date		03-Feb-20		17-Mar-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Upgradient		Upgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.378	U	< 0.378	U
Arsenic	µg/L	< 0.313	U	< 0.313	U
Barium	µg/L	73.3		75.7	
Beryllium	µg/L	< 0.182	U	< 0.182	U
Boron	µg/L	1520		1380	
Cadmium	µg/L	< 0.217	U	< 0.217	U
Calcium	µg/L	130000		108000	
Chromium	µg/L	< 1.53	U	< 1.53	U
Cobalt	µg/L	< 0.134	U	< 0.134	U
Lead	µg/L	< 0.128	U	< 0.128	U
Lithium	µg/L	5.41		4.71	J
Mercury	µg/L	< 0.101	U	< 0.101	U
Molybdenum	µg/L	< 0.610	U	< 0.610	U
Selenium	µg/L	< 1.51	U	< 1.51	U
Thallium	µg/L	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	< 0.405	U	< 0.455	U
Anions					
Chloride	mg/L	30.2		23.5	
Fluoride	mg/L	0.167		< 0.114	U*
Sulfate	mg/L	85.5		86.9	
General Chemistry					
Total Dissolved Solids	mg/L	465		431	
Field Parameters					
Temperature, Water	DEG_C	17.7		15.9	
Turbidity (field)	NTU	0.64		0.27	
ORP	mV	90.7		107.5	
Specific Conductivity (field)	mS/cm	0.81		0.518	
Dissolved Oxygen	mg/L	1.07		1.58	
pH (field)	SU	6.69		6.66	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Table 2 - Assessment Monitoring Groundwater Sampling Results

Monitoring Well		S			
Sample Date		04-Feb-20		18-Mar-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.378	U	< 0.378	U
Arsenic	µg/L	0.495	J	0.333	J
Barium	µg/L	90.6		93.4	
Beryllium	µg/L	0.182	J	< 0.216	U*
Boron	µg/L	< 103	U*	< 83.4	U*
Cadmium	µg/L	0.593	J	0.505	J
Calcium	µg/L	44300		46300	
Chromium	µg/L	1.88	J	< 1.53	U
Cobalt	µg/L	3.22		3.25	
Lead	µg/L	0.992	J	0.838	J
Lithium	µg/L	3.98	J	< 3.39	U
Mercury	µg/L	< 0.101	UR	< 0.101	U
Molybdenum	µg/L	< 0.610	U	< 0.610	U
Selenium	µg/L	< 1.51	U	< 1.51	U
Thallium	µg/L	0.447	J	< 0.148	U
Radium 226 + Radium 228	pCi/L	< 0.904	U	< 0.284	U
Anions					
Chloride	mg/L	9.68		9.03	
Fluoride	mg/L	0.0594	J	< 0.0263	UJ
Sulfate	mg/L	25.2		25.8	
General Chemistry					
Total Dissolved Solids	mg/L	197		216	
Field Parameters					
Temperature, Water	DEG_C	16.7		17.5	
Turbidity (field)	NTU	24.8		15.8	
ORP	mV	161.9		-15.6	
Specific Conductivity (field)	mS/cm	0.367		0.290	
Dissolved Oxygen	mg/L	0.13		0.31	
pH (field)	SU	5.98		6.07	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

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mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Table 3
Groundwater Sampling Summary

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA Bull Run Fossil Plant

Monitoring Well ID	Monitoring Well Designation	Number of Samples Collected	August 3-8, 2019	November 12-15, 2019	February 3-6, 2020	March 17-20, 2020	Monitoring Program
10-51	Downgradient	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
10-52	Downgradient	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
2	Background	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
47	Downgradient	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
48	Downgradient	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents

Table 3
Groundwater Sampling Summary

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA Bull Run Fossil Plant

Monitoring Well ID	Monitoring Well Designation	Number of Samples Collected	August 3-8, 2019	November 12-15, 2019	February 3-6, 2020	March 17-20, 2020	Monitoring Program
49	Downgradient	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
50	Downgradient	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
BRF-104	Upgradient	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
S	Downgradient	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents

Notes:

Appendix III Constituents - boron, calcium, chloride, fluoride, pH, sulfate, total dissolved solids (TDS)

Appendix IV Constituents - antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, fluoride, lead, lithium, mercury, molybdenum, selenium, thallium, radium 226 and radium 228

Table 4
Groundwater and Surface Water Elevation Summary

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA Bull Run Fossil Plant

Groundwater Elevation Collection Date		05-Aug-19	12-Nov-19	27-Jan-20	11-Mar-20
Monitoring Well	**Units**				
10-51	ft-MSL	794.35	794.16	794.36	792.79
10-52	ft-MSL	794.10	793.91	794.14	792.75
2	ft-MSL	801.89	801.95	802.24	802.19
47	ft-MSL	796.38	796.11	796.60	795.60
48	ft-MSL	798.27	801.41	798.12	800.91
49	ft-MSL	795.07	794.79	794.86	793.43
50	ft-MSL	794.42	794.32	794.40	792.73
BRF-104	ft-MSL	800.76	800.69	801.17	801.15
S	ft-MSL	793.40	793.37	793.68	792.08
Surface Water					
Clinch River	ft-MSL	794.45	794.14	794.29	792.67

Notes:

ft-MSL - feet above mean sea level

Table 5
Hydraulic Conductivity Data Summary

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA Bull Run Fossil Plant

Monitoring Well ID	Formation	Monitoring Well Position	Slug Test Hydraulic Conductivity (cm/sec)
S	Alluvium	Downgradient	2.78E-04
47	Alluvium	Downgradient	1.31E-06
48	Alluvium	Downgradient	NA
49	Alluvium	Downgradient	2.07E-03
50	Alluvium	Downgradient	3.40E-04
10-51	Alluvium	Downgradient	5.46E-04
10-52	Alluvium	Downgradient	4.91E-03
BRF-104	Overburden	Upgradient	4.09E-02
2	Overburden	Background	1.39E-04
		Geometric Mean of Hydraulic Conductivity (cm/sec)	**5.00E-04**

Notes:
cm/sec - centimeters per second
NA - not available

Table 6
Rate and Direction of Groundwater Flow Summary

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA Bull Run Fossil Plant

Groundwater Elevation Collection Date	5-Aug-19	12-Nov-19	27-Jan-20	11-Mar-20
Horizontal Gradient	0.0044	0.0047	0.0047	0.0056
Hydraulic Conductivity (cm/sec)	5.00E-04	5.00E-04	5.00E-04	5.00E-04
Effective Porosity	10%	10%	10%	10%
Flow Direction (cardinal)	South-Southwest	South-Southwest	South-Southwest	South-Southwest
Linear Velocity (ft/yr)	22.9	24.1	24.5	28.9

Notes:

cm/sec - centimeters per second

ft/yr - feet per year

Table 7
Groundwater Protection Standards

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA Bull Run Fossil Plant

Chemical Name	Unit	GWPS
Antimony	mg/L	0.006
Arsenic	mg/L	0.01
Barium	mg/L	2
Beryllium	mg/L	0.004
Boron	mg/L	0.08*
Cadmium	mg/L	0.005
Calcium	mg/L	186*
Chloride	mg/L	5.2*
Chromium	mg/L	0.1
Cobalt	mg/L	0.006
Fluoride	mg/L	4
Lead	mg/L	0.015
Lithium	mg/L	0.04
Mercury	mg/L	0.002
Molybdenum	mg/L	0.1
pH (field)	SU	6.41 - 7.06*
Radium 226 + Radium 228	pCi/L	5
Selenium	mg/L	0.05
Sulfate	mg/L	248.2*
Thallium	mg/L	0.002
Total Dissolved Solids	mg/L	778.8*

Notes:

GWPS - groundwater protection standard

* - Background Threshold Values for Appendix III Constituents (2019)

mg/L - milligrams per liter

SU - standard units

pCi/L - picocuries per liter

N/A - not applicable

APPENDIX A – STATISTICAL ANALYSIS REPORT FOR BULL RUN FOSSIL PLANT, 2020 CCR PROGRAM - VACATUR UNIT

Statistical Analysis Report for BullRun Fossil Plant

2020 CCR Program, Vacatur Unit

Kirk Cameron, Ph.D., MacStat Consulting, Ltd.

2020-06-03

Contents

1 Introduction

This report summarizes the statistical analysis performed on groundwater quality constituents monitored during 2020 under the Coal Combustion Residuals (CCR) Rule's Ground Water Quality Monitoring (GWQM) Program for the Vacatur Unit at the Tennessee Valley Authority (TVA) Bullrun Fossil Plant (BRF). Since this unit was established in 2019, CCR sampling and monitoring for the required Appendix III and Appendix IV constituents (COI) were conducted to develop baseline conditions at this site and to identify any statistically significant exceedances of background levels.

The United States Environmental Protection Agency (USEPA) requires all Owners and/or Operators of fossil plants to establish baseline groundwater quality conditions using a minimum of eight sampling events, collected roughly over a period of one year. As a follow-up to the establishment of baseline groundwater quality conditions, USEPA also requires subsequent performance of at least a single sampling event, under a monitoring phase known as Detection Monitoring, to collect samples for chemical-laboratory analysis of Appendix III constituents. Although most Appendix III constituents are naturally occurring chemicals in groundwater, USEPA requires analysis of these constituents to determine if the CCR Unit shows signs of contributing contamination to a 'usable aquifer.'

During the first year of Detection Monitoring for the Vacatur Unit, monitoring and statistical evaluation of the Appendix III constituents listed in the left-hand column of **Table 1** identified selected values with statistically significant increases (SSI) over background levels. Subsequently, the site moved into Assessment Monitoring, requiring chemical-laboratory analysis of Appendix IV constituents and comparison of those levels against Groundwater Protection Standards (GWPS).

Table 1: CCR Rule Constituents

Appendix III	Appendix IV
Boron	Antimony
Calcium	Arsenic
Chloride	Barium
Fluoride	Beryllium
Sulfate	Cadmium
pH	Chromium
TDS	Cobalt
	Fluoride
	Lead
	Lithium
	Mercury
	Molybdenum
	Rad226+228
	Selenium
	Thallium

For this year's efforts, the baseline datasets of the CCR-Rule GWQM Program were augmented with routine monitoring samples in order to update the backgrond data set. The background data were then utilized to develop statistically-derived GWPS in those cases where site-specific background levels naturally exceed published regulatory limits. Finally, data from the compliance wells were statistically compared to the GWPS to determine whether any standards were exceeded.

As discussed in USEPA's Unified Guidance document on the statistical analysis of groundwater

monitoring data (USEPA 2009), confidence-interval (CI) bands are a recommended technique for performing statistical comparisons against GWPS. In particular, trends at downgradient wells in analytical concentrations of Constituents of Interest (COI) can be plotted and used to estimate CI bands, which in turn can be compared against relevant GWPS. A statistically significant increase (SSI) is found if and only if the lower limit of the CI band exceeds the GWPS for the most recent Assessment Monitoring sampling event.

As required by the United States Environmental Protection Agency's (USEPA's) Coal Combustion Residuals (CCR) Rule section describing the Assessment Monitoring Program (§257.95), test results for the 2020 Assessment Monitoring events were compared to the GWPS for determination of any exceedances. Additional description of how the GWPS for each COI and each CCR Unit were established is provided in subsequent sections of this report.

At the BRF CCR Vacatur Unit, the sampling results used to identify SSIs above the GWPS were obtained from distinct monitoring events collected between January of 2019 and March of 2020 by the firm of Terracon, with Laboratory Analysis performed by Test America Laboratories (located at Pittsburgh, PA, and GEL Laboratories, Charleston, S.C.), and Quality Assurance Controls by Environmental Standards, Inc., all under direct contracts to TVA.

TVA requested the construction of 'Traffic Light' matrices to facilitate an at-a-glance identification of any exceedances of GWPS and to promote intra-company follow-up assessments to explain the outcomes (e.g., other identifiable chemicals used on site or in the vicinity of the plant) and to plan for mitigation actions, whenever warranted. Sample analytical results of CCR-Rule Appendix III and IV constituents obtained from each of the monitoring wells and events were used to perform the statistical analysis and generate the graphs shown in this report. The current CCR Rule groundwater monitoring network for the Vacatur unit, as Certified by a Professional Engineer, are presented in **Table 2**.

The 'R' Statistical Analysis package (www.r-project.org) in conjunction with R-Studio (www.rstudio.com) (both popular public domain software products) and other analytical tools were used in the production of the statistical values and graphs. ProUCL data dumps from TVA's EQuIS Professional and Enterprise Database were used to populate the R-based statistical analyses.

Table 2: CCR Monitoring Network

Background	Downgradient
2	47
	48
	49
	50
	10-51
	10-52
	S

2 Statistical Analysis

At the BRF Vacatur network (see **Table 2**), the sampling results used to compute the background statistics were obtained only from designated background wells using historical data that were first

screened for possible trends or shifts in concentration levels over time. Any early data exhibiting a substantially different pattern or average concentration level than more recent data were excluded from the calculations. The cutoff date used for selecting background data was determined on a constituent by constituent basis, but was designed to include as much data as possible reflecting current groundwater conditions.

Groundwater samples were analyzed for 21 distinct constituents as required for the CCR monitoring program by TDEQ (see **Table 1**). Fluoride is monitored under both Appendices. Only non-filtered sample results were utilized for the statistical analysis. As high turbidity measurements during the purging of wells (e.g., values above 5 NTUs) have the propensity to increase the concentrations of Appendix III and IV constituents, filtered samples were also collected to better understand and/or dispel the potential source(s) of falsely-identified SSIs.

The basic steps in the Assessment Monitoring analysis included the following:

1. Developing groundwater protection standards (GWPS) for each Appendix IV constituent, using published MCLs and/or water quality limits, along with baseline data from upgradient and background well locations at each CCR site;
2. Computing trends and associated confidence interval (CI) bands for each well location and Appendix IV constituent (i.e., each well-constituent pair); and
3. Comparing each CI band against its respective GWPS to assess whether an exceedance occurred.

To accomplish these steps, the data were first summarized and modeled. The background data were initially examined and summarized with descriptive statistics, as shown in **Table 3**. To handle any non-detects in these calculations, non-detect values were treated as statistically 'left-censored,' with the censoring limit equal to the reporting limit (RL). Then the Kaplan-Meier adjustment method (USEPA 2009) was employed to derive estimated summary statistics that account for the presence of non-detects.

2.1 Developing Groundwater Protection Standards (GWPS)

USEPA has published maximum contaminant limits (MCL) or alternate regulatory limits for each of the Appendix IV constituents. Consequently, in most cases the groundwater protection standard (GWPS) is equal to the MCL. However, there may be cases where background levels of a constituent exceed the MCL. In these instances, an alternate GWPS must be derived from on-site background levels.

According to the promulgated CCR Rule (80 Federal Register 21302, 21405, April 17, 2015):

> For each appendix IV constituent that is detected, a groundwater protection standard must be set. The groundwater protection standards must be the MCL or the background concentration level for the detected constituent, whichever is higher. If there is no MCL promulgated for a detected constituent, then the groundwater protection standard must be set at background.

The CCR Rule is also consistent with EPA's Unified Guidance for the statistical analysis of groundwater monitoring data, which states:

Table 3: Background Data Summary Statistics

COI	Units	N	No. NDs	Minimum	Maximum	Mean	Median
Antimony	mg/L	16	16	0.002	0.002	0.001	0.002
Arsenic	mg/L	16	7	0.000426	0.00254	0.0006	0.000548
Barium	mg/L	16	1	0.038	0.0915	0.0456	0.0463
Beryllium	mg/L	16	15	0.000199	0.001	0.0002	0.000599
Cadmium	mg/L	16	16	0.001	0.001	0.0005	0.001
Chromium	mg/L	16	16	0.002	0.00232	0.001	0.002
Cobalt	mg/L	16	0	0.000604	0.00246	0.0013	0.00111
Fluoride	mg/L	16	3	0.0383	1	0.077	0.079
Lead	mg/L	16	16	0.001	0.001	0.0005	0.001
Lithium	mg/L	16	2	0.011	0.0203	0.0154	0.0154
Mercury	mg/L	16	16	0.0002	0.0002	0.0001	0.0002
Molybdenum	mg/L	16	16	0.005	0.005	0.0025	0.005
Rad226+228	pCi/L	15	0	0	1.15	0.351	0.251
Selenium	mg/L	16	16	0.005	0.005	0.0025	0.005
Thallium	mg/L	16	15	0.000631	0.001	0.0006	0.000816

> But a number of situations arise where a GWPS must be based on a background limit. The Part 264 regulations presume such a standard as one of the options under §264.94(a); an ACL may also be determined from background under §264.94(b). More recent Part 258 rules specify a background GWPS where a promulgated or risk-based standard is not available or if the historical background is greater than an MCL [§258.55(h)(2) & (3)]." ((USEPA 2009), p. 7-20).

Based on these rules and guidance, TVA has established GWPS across its CCR program using the following decision logic:

- For each Appendix IV parameter where a GWPS must be established, a comparison is made between the promulgated regulatory limit and a site-specific limit computed from background data.
- If the background-based limit is larger than the promulgated limit, the GWPS is set to the background limit. But if the promulgated limit is larger, the GWPS is set to the published value.

In cases where a background limit must be computed, USEPA's Unified Guidance recommends different strategies for computing a background-based GWPS ((USEPA 2009), Section 7.5). One of these strategies — a 95% confidence, 95% coverage upper tolerance limit (UTL) on background — was selected and used to compute the UTL on site-specific background data for each Appendix IV parameter. Then these UTLs were compared against the promulgated regulatory limits to determine the site-specific GWPS.

To compute each tolerance limit (UTL), the following steps were taken:

All baseline data from designated upgradient or background wells collected through March 2020 were grouped and checked for possible outliers. Outlier screening was performed visually on time series plots of the data, as well as systematically via a modified version of Tukey's boxplot rule. In a boxplot, the length of the box is the range of the central 50% of the sorted measurements. Tukey's original outlier rule states that any observation more than 1.5 box lengths above or below the edges

of the boxplot classifies as a possible outlier. For stable, symmetric data distributions, Tukey's rule often works well.

Groundwater data is often skewed instead of symmetric, and may exhibit shorter (i.e., localized) or longer-term (non-linear) trends. Because of this reality, a modified version of Tukey's rule is generally needed to avoid classifying too many possible outliers. The modification consists of two parts: a) a possible outlier is only flagged if flagged both on the nominal scale of measurement as well as on the log-scale (i.e., when each observation is first mathematically transformed by taking a logarithm); and b) an outlier is only flagged if more than 3 box lengths above the edges of the boxplot. Together, these modifications better account for data skewness and localized trends in the background observations.

If any possible outliers are flagged, they are visually compared against observations at other well locations. If similar patterns or measurement ranges are common, the suspect values are kept in the data. If not, the suspected outliers are formally assessed using Rosner's outlier test. Any confirmed outliers are excluded from the UTL computations.

At the BRF Vacatur unit, 4 possible outliers were flagged in the grouped background data. These values were formally tested as outliers using Rosner's test and further reviewed to determine to what extent confirmed outliers were inconsistent with other site data and/or locational patterns.

Any final and excluded background outliers are listed in **Table 4** below.

Table 4: Confirmed and Excluded Background Outliers

COI	Well	Date	Result	Outlier
Arsenic	2	2019-01-29	0.00254	TRUE
Fluoride	2	2019-11-12	1	TRUE
pH	2	2019-01-29	7.51	TRUE
TDS	2	2019-03-18	1540	TRUE

The grouped baseline data — excluding any confirmed outliers — were analyzed to determine whether they could be fit to a known statistical model. If so, a parametric UTL was computed; if not, a nonparametric UTL was constructed.

To fit potential statistical models, a series of normalizing mathematical transformations was applied to each baseline dataset. These transformations are known as power transformations, since they raise each observation to a mathematical power. The goal is to find, if possible, a transformation that normalizes the data on the transformed scale. Models tested ranged from the tenth root to the tenth power, and included the null transformation (power = 1), which assumes the data are normally distributed without transformation, the logarithm, which models the lognormal distribution, and the cube root, which closely mimics the gamma distribution.

The transformation which most nearly normalized the data was then formally tested using Filliben's probability plot correlation coefficient test. Filliben's test checks for normality of the transformed measurements by computing the correlation between the data and matched quantiles (i.e., z-scores) from a standard normal distribution. The process parallels fitting a line on a normal probability plot of the (transformed) data. The closer to a linear fit, the higher the correlation; the further from a linear fit, the smaller the correlation. Filliben's test formally assesses the strength of the correlation to determine whether it is high enough to declare that the data are consistent with a normal distributional model.

Filliben's test yields a p-value measuring the statistical significance of the result. A p-value no less

than 0.01 was judged as sufficient to assume normality of the (transformed) observations, while data with a Filliben's test p-value less than 0.01 were judged significantly non-normal. Datasets passing Filliben's test were assumed to have a parametric model corresponding to the transformation employed, e.g., data tested on the log-scale were assumed consistent with the lognormal distribution; data tested on the square root scale were assumed consistent with the square-root normal distribution, and so on.

Datasets which could not be sufficiently normalized, thus failing Filliben's test, were analyzed by nonparametric means. In many instances, this may occur when the data includes a large fraction of non-detects. Table 4 lists a shorthand for the statistical model utilized for each Constituent of Interest (COI) under the Model column. (E.g., NP stands for nonparametric, Log stands for the logarithm, implying a lognormal model, and Normal represents the null transformation, implying a normal model.)

The final statistical model for each COI was used to compute an upper tolerance limit (UTL) with 95% coverage and 95% confidence.

When a parametric model is appropriate, on the normalized scale, a UTL is computed using the standard normal theory equation:

$$UTL = \bar{x} + \kappa s$$

where $\bar{x}$ and s represent the mean and standard deviation of the (transformed) observations, and κ is a multiplier which depends on the number of baseline measurements, as well as the desired coverage and confidence levels. If the data have been transformed, the final UTL is derived by back-transforming the scaled UTL, e.g, for a log transformation, the result is exponentiated; for a square-root transformation, the result is squared, etc.

Note that the above formula for an upper tolerance limit looks identical to the general formula for a parametric upper prediction limit. The important difference is in how the κ multiplier is computed, which in turn depends on type and purpose of the statistical limit. In general, parametric prediction and tolerance limits will not be the same, even when using the same background data.

For nonparametric models, the normal theory equation does not apply. Instead, the UTL is selected as one of the largest of the sample values, often the maximum. Because there is no multiplier as in the parametric case, the confidence level associated with a nonparametric UTL is computed 'after the fact,' based on the sample size and desired coverage level: the smaller the sample size, the lower the confidence; the bigger the sample size, the higher the confidence level.

Since nonparametric UTLs do not assume a known statistical model, unless the sample size is fairly large, the achieved confidence level can be much lower than the target of 95%. When this happens, the computed UTL may not be very accurate. A more accurate UTL would likely be larger than the one computed from the available sample data. Unfortunately, without a statistical model, and especially with a large percentage of non-detects, little improvement is possible in the UTL estimates unless a larger sample size is employed.

For the BRF Vacatur unit, **Table 5** lists the calculated GWPS limits established for this monitoring network. **Appendix A** includes time series plots of the data overlain with the estimated GWPS.

2.2 Computing Trend Lines and Confidence Interval Bands

USEPA's Unified Guidance recommends comparing some type of confidence interval (CI) against a groundwater protection standard (GWPS) in order to assess whether or not the limit has been

Table 5: BRF GWPS Limits

COI	Model	N	Coverage	Confidence	UTL	RegLimit	GWPS
Antimony	NP	16	0.95	0.56	0.002	0.006	0.006
Arsenic	Seventh Power	15	0.95	0.95	0.000607	0.01	0.01
Barium	Normal	16	0.95	0.95	0.0548	2	2
Beryllium	NP	16	0.95	0.56	0.001	0.004	0.004
Cadmium	NP	16	0.95	0.56	0.001	0.005	0.005
Chromium	NP	16	0.95	0.56	0.00232	0.1	0.1
Cobalt	Log	16	0.95	0.95	0.0035	0.006	0.006
Fluoride	Square	15	0.95	0.95	0.115	4	4
Lead	NP	16	0.95	0.56	0.001	0.015	0.015
Lithium	Normal	16	0.95	0.95	0.0216	0.04	0.04
Mercury	NP	16	0.95	0.56	0.0002	0.002	0.002
Molybdenum	NP	16	0.95	0.56	0.005	0.1	0.1
Rad226+228	Cube Root	15	0.95	0.95	2.27	5	5
Selenium	NP	16	0.95	0.56	0.005	0.05	0.05
Thallium	NP	16	0.95	0.56	0.001	0.002	0.002

exceeded with statistical significance. If the entire interval exceeds the GWPS, a statistically significant increase (SSI) is identified. If none of the interval, or only part, exceeds the GWPS, no SSI is recorded.

The rationale behind this procedure is predicated on the following:

1. A confidence interval is typically designed to 'contain' or 'capture' a specific target or feature of the underlying groundwater population, usually the mean or median measurement value. An interval rather than a point estimate is utilized because that is the only way to ensure the target is captured with a high degree of statistical confidence.
2. When a confidence interval is entirely on one side or the other of a fixed numerical limit, the confidence is high that the desired population target is also to that side of the limit.
3. Because the target may exist anywhere in the range represented by the confidence interval, an interval that 'straddles' the fixed limit is not guaranteed to be either above or below the GWPS, and certainly not with high or known statistical confidence.

USEPA's logic ensures that a correct decision about the occurrence of an SSI can be made with high statistical assurance.

Since groundwater data are collected over time, and not all at once, some or most of the variation in the measurements may be due to a trend. To better account for this possibility, USEPA also recommends a variation on the confidence interval method known as a confidence interval band around a trend line. In this case, a (linear) trend line is first fit to the data, then a confidence band is constructed around the trend line. The confidence interval band can be compared against a GWPS in much the same fashion as a confidence interval, only now a comparison can be made at different points in time by comparing the 'cross-section' of the band for a given sampling date. If the interval represented by the confidence band cross-section fully exceeds the GWPS, an SSI is identified for that sampling event.

At TVA's CCR sites, CI bands were constructed (as described below) for each well-constituent pair using all available sample data. Cross-sections of each band were then compared to the GWPS for

the most recent Assessment Monitoring event in each case for the purpose of identifying any SSIs. Note that in cases where the data are obviously trending, the CI band technique provides a much more powerful and accurate means of judging exceedances above GWPS. Ignoring a trend typically makes a standard confidence interval much too wide and uncertain to be of much use, due to the extra variation imparted by the trend. For data that are more stable, both methods will tend to give similar results.

2.2.1 Trend Lines Using Linear Regression

Unless there are extreme outliers and/or curvature in the data, linear regression provides a standard and well-tested method for estimating the linear portion of a trend. The slope of the regression line points to the magnitude and direction of the trend. There is also a standard method for computing a confidence band around a linear regression trend line. For instance, equations [21.24] and [21.25] of Section 21.3 in the Unified Guidance can be compactly written as

$$CB_{1-\alpha} = \hat{x}_0 \pm \sqrt{2 s_e^2 F_{1-\alpha,n-2} \left[\frac{1}{n} + \frac{(t_0 - \bar{t})^2}{(n-1)s_t^2} \right]}$$

where CB = confidence band, $\hat{x}_0$ is the regression line estimate at time t_0, s_e^2 is the mean squared error of the regression line, F is a quantile from the F-distribution with 2 and $n\breve{}2$ degrees of freedom, and $\bar{t}$ and s_t^2 represent the mean and standard deviation of the sampling dates.

For well-constituent pairs with no non-detects, linear regression and the formula above were used to construct each confidence band with 98% overall confidence, corresponding to a lower confidence limit with 99% confidence. When non-detects are present, the same formulas apply but an adjustment must be made for the censored measurements. The strategy adopted for TVA's CCR sites involves the following steps:

1. Each non-detect is assumed to follow a triangle distribution centered at half the (sample-specific) reporting limit, and with limits extending from zero to the reporting limit. Then an imputation for each non-detect is randomly drawn from this distribution;
2. The combined set of detected values and imputed non-detects are used to estimate a linear regression trend line and associated confidence band with 98% statistical confidence;
3. Steps (1) and (2) are repeated 500 times, each time with a different set of random imputations, leading to 500 potentially different trend lines and confidence bands;
4. The 500 sets of trends lines and bands are averaged point-wise (i.e., at each time along a sequence of dates spanning the time range of the data) to compute the final trend and confidence band estimates.
5. By repeating this sequence of steps a large number of times (500), the uncertainty associated with the non-detects can be reasonably captured within the final CI band estimate.

2.2.2 Outliers

Prior to constructing any of the confidence interval (CI) bands, the data at each well-constituent pair were examined for possible outliers. As with the grouped background data, visual examination was done with time series plots and the modified Tukey's boxplot rule was utilized for initial screening. Any observations that were flagged and confirmed as pairwise outliers were excluded from calculation of the CI bands.

5 pairwise outliers were confirmed. These outliers are listed in **Table 6** below.

Table 6: Confirmed and Excluded Pairwise Outliers

COI	Well	Date	Result	Outlier
Arsenic	2	2019-01-29	0.00254	TRUE
Barium	S	2019-03-26	0.224	TRUE
Fluoride	2	2019-11-12	1	TRUE
Mercury	10-52	2019-02-19	0.001	TRUE
Molybdenum	10-52	2019-01-30	0.005	TRUE

2.3 Comparing Confidence Interval Bands Against GWPS

To assess whether any SSIs occurred during the 2019 Assessment Monitoring at TVA's CCR sites, the confidence interval (CI) bands described in **Section 2.2** were compared against the constituent-specific groundwater protection standards (GWPS) described in **Section 2.1**. Of note, an SSI was identified if and only if the CI band fully exceeded the GWPS at the most recent sampling event.

To clarify the importance of this last statement, consider the difference in statistical approach between Detection Monitoring and Assessment Monitoring. When utilizing prediction limits in Detection Monitoring, at least two sampling events per year must be collected and evaluated to identify any SSIs above background levels. Each prediction limit is derived from the baseline or background data, then each new compliance point value is compared against its respective prediction limit. If the newest compliance value exceeds the limit, a potential SSI is flagged, to be confirmed or disconfirmed via additional resampling and retesting.

The statistical approach in Assessment Monitoring is different. Comparisons are made against a fixed GWPS via a confidence interval or confidence interval band. No retesting is conducted and none of the individual compliance point measurements are directly compared against the GWPS. Instead, multiple compliance observations must be used to construct each confidence interval or CI band, necessarily at least four and preferably 8 to 10 or more. Consequently, all the Assessment Monitoring data collected from 2019 to 2020 were used to construct the CI bands. Furthermore, a well-constituent pair is considered out of compliance only if its constituent levels currently exceed the GWPS. This is best assessed by considering the cross-section of the CI band associated with the most recent sampling event.

3 Summary of Statistical Analysis

To facilitate an 'at-a-glance' summary of the statistical comparison results, **Table 7** is a 'traffic light' matrix, showing a compact representation of each well location matched against each constituent in Appendix IV. This summary is useful in planning for mitigation actions. Green cells indicate that no SSI was observed. Red cells indicate the opposite: an SSI was flagged at the most recent sampling event. Yellow cells are warnings which indicate that a well-constituent pair should be closely watched. These cases have increasing trends and a CI band whose lower limit is at least 65% of the GWPS. Often, the CI band cross-section straddles the GWPS in yellow cells.

At the BRF Vacatur unit, a total of 7 SSIs and 4 warnings were identified.

Table 7: Traffic Light Matrix for BRF CCR Vacatur Unit

	Well Locations							
COI	**2**	**47**	**48**	**49**	**50**	**10-51**	**10-52**	**S**
Antimony	GRN	GRN	GRN	GRN	GRN	GRN	GRN	GRN
Arsenic	GRN	YLW	GRN	RED	GRN	GRN	RED	GRN
Barium	GRN	GRN	GRN	GRN	GRN	GRN	GRN	GRN
Beryllium	GRN	GRN	GRN	GRN	GRN	GRN	GRN	GRN
Cadmium	GRN	GRN	GRN	GRN	GRN	GRN	GRN	GRN
Chromium	GRN	GRN	GRN	GRN	GRN	GRN	GRN	GRN
Cobalt	GRN	YLW	RED	RED	GRN	GRN	GRN	GRN
Fluoride	GRN	GRN	GRN	GRN	GRN	GRN	GRN	GRN
Lead	GRN	GRN	GRN	GRN	GRN	GRN	GRN	GRN
Lithium	GRN	RED	YLW	RED	GRN	GRN	GRN	GRN
Mercury	GRN	GRN	GRN	GRN	GRN	GRN	GRN	GRN
Molybdenum	GRN	YLW	GRN	RED	GRN	GRN	GRN	GRN
Rad226+228	GRN	GRN	GRN	GRN	GRN	GRN	GRN	GRN
Selenium	GRN	GRN	GRN	GRN	GRN	GRN	GRN	GRN
Thallium	GRN	GRN	GRN	GRN	GRN	GRN	GRN	GRN

Color-Coding Key:
RED = CI Band above GWPS;
GRN = CI Band below GWPS;
YLW = CI Lower Bound at least 65% of GWPS)

4 References

USEPA. 2009. "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance." USEPA: Office of Resource Conservation & Recovery, EPA 530-R-09-007.