

**2019 Annual Groundwater  
Monitoring and Corrective Action  
Report**



Tennessee Valley Authority  
Johnsonville Fossil Plant Active Ash  
Pond 2 CCR Unit

Prepared for:  
Tennessee Valley Authority  
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January 31, 2020

January 31, 2020

**Reference: 2019 Annual Groundwater Monitoring and Corrective Action Report**  
TVA Johnsonville Fossil Plant Active Ash Pond 2 CCR Unit

In accordance with 40 § CFR 257.90(e) of the Disposal of Coal Combustion Residuals from Electric Utilities final rule (CCR Rule), this 2019 Annual Groundwater Monitoring and Corrective Action Report (2019 Annual Report) documents 2019 groundwater monitoring activities at the Active Ash Pond 2 CCR Unit at the Tennessee Valley Authority (TVA) Johnsonville Fossil Plant (JOF).

An overview of the current status of the groundwater monitoring and corrective action program for Active Ash Pond 2 is provided below.

- At the start and end of the current 2019 annual reporting period, Active Ash Pond 2 was operating under an assessment monitoring program in accordance with 40 CFR § 257.95. The assessment monitoring program for Active Ash Pond 2 was initiated on August 15, 2018.
- In the 2018 assessment monitoring sampling, statistically significant levels (SSLs) above the groundwater protection standard for cobalt were observed at monitoring wells 10-AP3 and JOF-103. As a result, an assessment of corrective measures was initiated for Active Ash Pond 2 on April 15, 2019 and was completed on July 15, 2019.
- For the 2019 assessment monitoring events, no new SSLs were identified, and the SSLs for cobalt are at the same monitoring wells identified for the 2018 assessment monitoring.
- As a final groundwater remedy has not been selected for Active Ash Pond 2 pursuant to 40 CFR § 257.97, a Semiannual Report on the Progress of Remedy Selection was prepared and placed in the operating record on January 15, 2020 in accordance with 40 CFR § 257.97(a) and § 257.105(h)(12) to document the progress made toward selection and design of the remedy.
- Since a remedy has not been selected pursuant to 40 CFR § 257.97, remedial activities have not been initiated for Active Ash Pond 2 pursuant to 40 CFR § 257.98 during the current 2019 annual reporting period discussed herein.

In 2017, TVA established a groundwater monitoring network and program at the JOF Active Ash Pond 2 CCR Unit in accordance with 40 CFR § 257.90. The groundwater monitoring network was certified by a qualified Professional Engineer as required by 40 CFR § 257.91(f). During 2019, TVA performed the following groundwater monitoring activities:

- Completed the statistical evaluation of the 2018 assessment monitoring data for Appendix IV constituents in accordance with 40 CFR § 257.95(g) in January 2019 and determined that there were statistically significant levels over the groundwater protection standard for cobalt at monitoring wells 10-AP3 and JOF-103.
- Placed notification of the statistical exceedances of the groundwater protection standard for cobalt at monitoring wells 10-AP3 and JOF-103 in the facility operating record on February 13, 2019 in accordance with 40 CFR § 257.95(g) and § 257.105(h)(8); provided notification to the State of Tennessee in accordance with 40 CFR § 257.106(h)(6); and placed notification on the CCR Compliance Data and Information website (<https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>) in accordance with 40 CFR § 257.107(h)(6).

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- Installed two monitoring wells (JOF-118 and JOF-119) at Active Ash Pond 2. These wells were used in the characterization of the nature and extent of cobalt at monitoring wells 10-AP3 and JOF-103.
- As there has been no indication of offsite migration of cobalt-impacted groundwater onto adjacent parcels of land, there is no current obligation to notify persons who own or reside on adjacent land pursuant to 40 CFR § 257.95(g)(2).
- An Appendix IV alternate source demonstration was performed under 40 CFR § 257.95(g)(3)(ii) but was not completed within the 90-day period of time specified under 40 CFR § 257.95(g)(4).
- Initiated Assessment of Corrective Measures in accordance with 40 CFR § 257.95(g)(3)(i) and 40 CFR § 257.96.
- Completed the Assessment of Corrective Measures in accordance with 40 CFR § 257.96(d) , which was placed on the CCR Rule Compliance Data and Information website (<https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>) in accordance with 40 CFR § 257.107(h)(8).
- Sampled and analyzed wells in the certified monitoring network for CCR constituents (Appendix III and Appendix IV constituents) for the 2019 semiannual assessment monitoring events in accordance with 40 CFR § 257.95(d)(1). The sampling results were placed 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 1 of this 2019 Annual Report in accordance with 40 CFR § 257.95(d)(3).
- Placed notification of exceedances of groundwater protection standards in the facility operating record in accordance with 40 CFR § 257.95(g) and 257.105(h)(8); provided notification to the State of Tennessee in accordance with 40 CFR § 257.106(h)(6); and placed the notification on the CCR Rule Compliance Data and Information website (<https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>) in accordance with 40 CFR § 257.107(h)(6).<sup>1</sup>
- 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).

No problems were encountered during the third year of the Groundwater Quality Monitoring Program; therefore, no further action has been recommended, except for the planned key activities for 2020 that are outlined below.

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<sup>1</sup> Table 6 in this 2019 Annual Groundwater Monitoring and Corrective Action Report meets this notification requirement for the second semiannual assessment monitoring sampling event conducted in 2019.

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The projected key activities for 2020 are:

- Continue semiannual assessment monitoring at the certified groundwater monitoring network consistent with 40 CFR § 257.95 and place the sampling results in the operating record as required by 40 CFR § 257.95(d)(1) and 257.105(h)(6).
- Complete 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).
- Perform further site characterization to improve the JOF Conceptual Site Model (CSM).
- Prepare and place in the operating record a Semiannual Report on the Progress of Remedy Selection on July 15, 2020 in accordance with 40 CFR § 257.97(a) to document the progress made toward selection and design of the remedy.
- Place notification of exceedances of 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 the notification on the CCR Rule Compliance Data and Information website (<https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>) in accordance with 40 CFR § 257.107(h)(6).
- 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 WELL NETWORK

Active Ash Pond 2 is centered approximately 2,000 feet west from the plant's powerhouse. It was created by placing fill and then building an approximate two-mile-long perimeter dike, on an area within the former Tennessee River floodplain (now inundated by Kentucky Lake), to enclose approximately 90 acres. The perimeter dike varies from 25 to 35 feet in height. The unit has been in operation since 1970. It formerly received sluiced fly ash and bottom ash and plant process water. It also received stormwater runoff pumped from the Coal Yard Drainage Basin. The last coal fired generating units were shut down in December 2017; therefore, the Unit no longer receives sluiced production fly ash or bottom ash. The Unit will continue to receive non-CCR waste streams until alternative capacity for these flows are completed in accordance with the requirements and deadlines in the CCR Rule.

The monitoring well network for the JOF Active Ash Pond 2 CCR Unit consists of two background wells (B-9 and JOF-101) and four downgradient wells (10-AP1, 10-AP3, JOF-103 and JOF-104). The downgradient wells are installed at the waste boundary. Figure 1 is an aerial photograph that shows Active Ash Pond 2 and the groundwater monitoring well locations. The monitoring well network was designed for a single CCR Unit (Active Ash Pond 2).

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No monitoring wells in the CCR network were installed or decommissioned during the 2019 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 CCR Compliance Data and Information website (<https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>).

### GROUNDWATER SAMPLING AND LABORATORY ANALYTICAL TESTING

A groundwater sampling and analysis program was developed in 2016-2017 and includes, as required by 40 CFR § 257.93(a), procedures and techniques for: sample collection; sample preservation and shipment; analytical procedures; chain-of-custody control; and quality assurance and quality control (QA/QC). 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 2019 assessment monitoring groundwater sampling was conducted between April and October 2019 and the results are summarized in Table 1. Two semiannual assessment monitoring groundwater sampling events were each followed by retesting groundwater sampling events. A summary of groundwater sample locations, well designations, analytes sampled, sampling dates and monitoring program status is provided in Table 2.

Groundwater elevations were measured in each monitoring well immediately prior to purging during each sampling event as required by 40 CFR § 257.93(c). Groundwater elevations and Tennessee River surface water elevations are summarized in Table 3. Groundwater flow directions were determined for each sampling event, and a generalized depiction of groundwater flow direction is illustrated on Figure 2. In general, groundwater flowed consistently from east to west toward the Tennessee River (Kentucky Lake) on the landward portion of the plant. The uppermost aquifer at the JOF Active Ash Pond 2 CCR Unit consists of a sand and gravel formation (i.e., alluvial deposits).

Testing for hydraulic conductivity at the background or downgradient groundwater monitoring wells, as summarized in Table 4, was determined by a 2018 hydrogeologic evaluation (Terracon, 2018). Testing data indicates the uppermost saturated zone has a geometric mean hydraulic conductivity of  $3.7 \times 10^{-3}$  centimeters per second (cm/sec). Linear groundwater flow velocity was calculated for the uppermost aquifer using:

- the geometric mean hydraulic conductivity calculated from hydraulic slug testing ( $3.7 \times 10^{-3}$  cm/sec);
- horizontal hydraulic gradients measured during the implementation of the groundwater sampling and analysis program, ranging from 0.0065 to 0.0078 feet per foot (ft/ft); and,
- an effective porosity of 20% (TVA, 1995).

The average linear flow velocity in the uppermost aquifer ranges from approximately 125 to 150 feet per year. The rate and direction of groundwater flow for each groundwater sampling event is summarized in Table 5 in accordance with 40 CFR § 257.93(c).

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### STATISTICAL ANALYSIS OF GROUNDWATER DATA

The groundwater monitoring data for the 2019 assessment monitoring events 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 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<sup>2</sup> constituent.<sup>3</sup> The 2019 Statistical Analysis Report is included in Appendix A.

The sampling results used to identify potential groundwater protection standards exceedances were obtained during four monitoring events that were performed between April and October of 2019.<sup>4</sup> Comparisons were made against a fixed groundwater protection standard via a confidence interval band. Retesting was conducted after each semiannual sampling event and none of the individual compliance point measurements were directly compared against the groundwater protection standard. The Appendix IV monitoring data collected in Year-One (2017), Year-Two (2018), and Year-Three (2019)<sup>5</sup> 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 in each case 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 2019 Assessment Monitoring, two cobalt-related SSLs were recorded at monitoring wells JOF-103 and 10-AP3 (as in 2018 Assessment Monitoring) and are summarized in Table 6. These are the same SSLs at the same wells as were previously identified.

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<sup>2</sup> Appendix IV CCR Constituents: antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, fluoride, lead, lithium, mercury, molybdenum, selenium, thallium, radium 226 and radium 228 combined

<sup>3</sup> 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., that could be used as 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. If site-specific background levels are lower, then these 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 levels: 1.) Cobalt - 6 µg/L; 2.) Lithium - 40 µg/L; 3.) Molybdenum – 100 µg/L; and, 4.) Lead - 15 µg/L.

<sup>4</sup> The CCR rule requires a minimum of two semiannual sampling events per well once the required background data has been obtained. In 2019, two semiannual assessment monitoring groundwater sampling events were each followed by retesting groundwater sampling events.

<sup>5</sup> The October 2019 retest groundwater sampling event that followed the second semi-annual sampling event was not included in the statistical evaluation. This information will be included in the 2020 Annual Groundwater Monitoring and Corrective Action Report.

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## NARRATIVE DISCUSSION OF ANY TRANSITION BETWEEN MONITORING PROGRAMS

An Assessment Monitoring Program was established on August 15, 2018 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 CCR Rule Compliance Data and Information website (<https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>) on September 14, 2018 in accordance with 40 CFR § 257.106(h)(4) and 40 CFR § 257.107(h)(4), respectively.

In accordance with assessment monitoring program requirements, subsequent sampling and analysis of all wells in the certified monitoring network for Appendix III and IV constituents occurred in accordance with 40 CFR § 257.95(d)(1). Appendix III and IV constituent concentrations from 2019 assessment monitoring are summarized in Table 1. Groundwater protection standards were established in accordance with 40 CFR § 257.95(d)(2) and are summarized along with Appendix IV SSLs in Table 6. During 2019 Assessment Monitoring, two cobalt-related SSLs were recorded at monitoring wells JOF-103 and 10-AP3. These are the same SSLs at the same wells as were previously identified during the 2018 assessment monitoring. 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 2019 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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TVA Johnsonville Fossil Plant Active Ash Pond 2 CCR Unit

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## References:

TVA, 1995. Johnsonville Groundwater Assessment. Report No. WR28-1-30-111. Tennessee Valley Authority. September 1995.

Terracon, 2018. Aquifer Testing and Equipment Blank Results. TVA CCR Rule – Johnsonville Fossil Plant (JOF). Terracon Consultants, Inc. December 12, 2018.

## Attachments:

Figure 1 – Map with CCR Unit Background and Downgradient Wells

Figure 2 – Generalized Groundwater Flow Direction Map

Table 1 – Assessment Monitoring Groundwater Sampling Results

Table 2 – Groundwater Sampling Summary

Table 3 – Groundwater and Surface Water Elevation Summary

Table 4 – Hydraulic Conductivity Data Summary

Table 5 – Rate and Direction of Groundwater Flow Summary

Table 6 – Statistically Significant Levels (SSLs) Above GWPSs

Appendix A – 2019 Statistical Analysis Report

## **FIGURES**



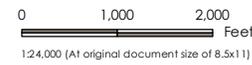
Tennessee River  
(Kentucky Lake)

JOF-118  
JOF-104  
JOF-103  
10-AP1  
10-AP3  
JOF-119

B-9  
JOF-101



- Background Well
- Downgradient Well
- Investigation Well (TDEC Order)
- ➔ Surface Water Flow Direction
- CCR Unit Subject to CCR Rule
- TVA Property Boundary



**Notes**  
 1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet  
 2. Basemap Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Imagery also provided by TVA in 2019

Project Location: New Johnsonville, Humphreys County, Tennessee  
 Prepared by LMB on 2020-01-27  
 Technical Review by MD on 2020-01-27  
 Independent Review by TR on 2020-01-27  
 182603527

Client/Project: Tennessee Valley Authority  
 Johnsonville Fossil Plant  
 CCR Rule

Figure No. 1



**Map with CCR Unit Background and Downgradient Wells**

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Tennessee River  
(Kentucky Lake)

JOF-104

JOF-103

10-AP1

10-AP3

GS-1

B-9

JOF-101



- ▲ Staff Gauge
- Background Well
- Downgradient Well
- ➔ Groundwater Flow Direction
- ➔ Surface Water Flow Direction
- CCR Unit Subject to CCR Rule
- TVA Property Boundary



**Notes**  
 1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet  
 2. BaseMap Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Imagery also provided by TVA in 2019

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 CCR Rule

Figure No. **2**

Title: **Generalized Groundwater Flow Direction Map**



Groundwater flow directions are based on groundwater elevations from CCR monitoring wells.

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## **TABLES**

**Table 1  
Assessment Monitoring  
Groundwater Sampling  
Results**

**CCR Annual Groundwater  
Monitoring and Corrective Action  
Report - TVA Johnsonville Fossil  
Plant**

Monitoring Well		10-AP1							
Sample Date		03-Apr-19		10-Jul-19		18-Sep-19		09-Oct-19	
Sample Round		1		1 - Retest		2		2 - Retest	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q
<b>Total Metals</b>									
Antimony	ug/L	< 0.378	U	< 0.378	U	< 0.378	U	< 0.378	U
Arsenic	ug/L	0.708	J	< 0.773	U*	0.686	J	0.613	J
Barium	ug/L	31.3		28.3		25		32.8	
Beryllium	ug/L	< 0.155	U	< 0.384	U*	< 0.182	U	< 0.182	U
Boron	ug/L	8490		6710		7640		6840	
Cadmium	ug/L	2.18		< 1.07	U*	0.868	J	1.06	
Calcium	ug/L	98500		92400		82600		94400	
Chromium	ug/L	< 1.65	U*	< 1.53	U	< 1.53	U	< 1.69	U*
Cobalt	ug/L	4.02		4.78		3.68		3.89	
Lead	ug/L	< 0.128	U	< 0.168	U*	< 0.128	U	< 0.128	U
Lithium	ug/L	5.58		< 7.92	U*	3.58	J	5.58	
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	< 0.61	U	< 0.61	U	< 0.61	U	< 0.61	U
Selenium	ug/L	< 2.62	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.128	U	< 0.128	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	< 0.221	UJ	< 0.114	U	< 0.226	U	< 0.776	U
<b>Anions</b>									
Chloride	mg/L	22.5		22.6		22.8		21.6	
Fluoride	mg/L	0.131		0.138		0.0969	J	< 0.0921	U*
Sulfate	mg/L	247	J	254		283		273	
<b>General Chemistry</b>									
Total Dissolved Solids	mg/L	490		490		525		509	
<b>Field Parameters</b>									
Temperature, Water	DEG_C	19.1		22.3		21.8		22.2	
Turbidity (field)	NTU	4.38		4.10		4.21		4.67	
ORP	mV	208.9		-101.4		150.2		150.4	
Specific Conductivity (field)	mS/cm	0.620		0.610		0.610		0.570	
Dissolved Oxygen	mg/L	0.25		0.12		0.15		0.47	
pH (field)	SU	5.29		5.3		5.27		5.27	

Notes:

Q - Data Qualifier

U\* - Result should be considered "not-detected" because it was detected in a rinsate blank or laboratory blank at similar level

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

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

U - Analyte not detected

ug/L - micrograms per liter

mg/L - milligrams 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  
Assessment Monitoring  
Groundwater Sampling  
Results**

**CCR Annual Groundwater  
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Report - TVA Johnsonville Fossil  
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Monitoring Well		10-AP3							
Sample Date		03-Apr-19		10-Jul-19		18-Sep-19		09-Oct-19	
Sample Round		1		1 - Retest		2		2 - Retest	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q
<b>Total Metals</b>									
Antimony	ug/L	< 0.378	U	< 0.378	U	< 0.378	U	< 0.378	U
Arsenic	ug/L	0.686	J	< 0.563	U*	0.388	J	0.513	J
Barium	ug/L	17.7		14.6		14.2		< 18	U*
Beryllium	ug/L	< 0.155	U	< 0.246	U*	0.192	J	< 0.182	U
Boron	ug/L	5890		4990		5300		4740	
Cadmium	ug/L	4.74		4.23		3.92		4.22	
Calcium	ug/L	168000		173000		151000		166000	
Chromium	ug/L	< 1.53	U	< 1.53	U	< 1.53	U	< 1.65	U*
Cobalt	ug/L	36.4		34.5		28.8		32.3	
Lead	ug/L	0.19	J	< 0.188	U*	0.146	J	0.249	J
Lithium	ug/L	3.34	J	3.98	J	< 3.39	U	4.14	J
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	< 0.61	U	< 0.61	U	< 0.61	U	< 0.61	U
Selenium	ug/L	< 2.62	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.128	U	< 0.176	U*	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	0.422	J	< 0.0897	U	< 0.739	U	< 1.05	U
<b>Anions</b>									
Chloride	mg/L	25.4		27.9		27		26.7	
Fluoride	mg/L	0.0424	J	0.0449	J	0.0527	J	< 0.0592	U*
Sulfate	mg/L	489	J	512		518		485	
<b>General Chemistry</b>									
Total Dissolved Solids	mg/L	855		852		894		820	
<b>Field Parameters</b>									
Temperature, Water	DEG_C	17.4		18.4		19		18.6	
Turbidity (field)	NTU	4.35		4.72		4.07		3.25	
ORP	mV	255.1		-74.8		222.1		184.3	
Specific Conductivity (field)	mS/cm	1		1.01		0.99		0.93	
Dissolved Oxygen	mg/L	0.22		0.07		0.22		0.58	
pH (field)	SU	4.92		4.97		4.88		4.94	

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DEG\_C - degrees Celsius

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**Table 1  
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Monitoring and Corrective Action  
Report - TVA Johnsonville Fossil  
Plant**

Monitoring Well		B-9							
Sample Date		02-Apr-19		08-Jul-19		17-Sep-19		09-Oct-19	
Sample Round		1		1 - Retest		2		2 - Retest	
Well Designation		Background		Background		Background		Background	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q
<b>Total Metals</b>									
Antimony	ug/L	< 0.378	U	< 0.378	U	< 0.378	U	< 0.378	U
Arsenic	ug/L	< 0.323	U	< 0.323	U	< 0.323	U	< 0.323	U
Barium	ug/L	8.05	J	7.39	J	7.9	J	8.72	J
Beryllium	ug/L	< 0.155	U	< 0.155	U	< 0.182	U	< 0.182	U
Boron	ug/L	< 30.3	U	< 30.3	U	< 38.6	U	< 38.6	U
Cadmium	ug/L	< 0.125	U	< 0.125	U	< 0.125	U	< 0.125	U
Calcium	ug/L	5810		6100		5170		6000	
Chromium	ug/L	< 1.53	U	< 1.53	U	< 1.53	U	< 1.53	U*
Cobalt	ug/L	< 0.075	U	< 0.075	U	< 0.075	U	< 0.075	U
Lead	ug/L	< 0.128	U	< 0.128	U	< 0.128	U	< 0.128	U
Lithium	ug/L	< 3.14	U	< 3.14	U	< 3.39	U	6.84	
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	< 0.61	U	< 0.61	U	< 0.61	U	< 0.61	U
Selenium	ug/L	< 2.62	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.128	U	< 0.128	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	0.135	J	< 0.000	U	< 0.236	U	< 0.369	U
<b>Anions</b>									
Chloride	mg/L	3.7		4.16		4.48		4.49	
Fluoride	mg/L	0.0458	J	0.0514	J	0.0398	J	< 0.0459	U*
Sulfate	mg/L	< 0.589	U*	0.674	J	< 0.98	U*	0.668	J
<b>General Chemistry</b>									
Total Dissolved Solids	mg/L	43	J	< 10	U	36	J	30	
<b>Field Parameters</b>									
Temperature, Water	DEG_C	16.5		17.3		17.5		16.3	
Turbidity (field)	NTU	3.93		4.63		3.85		2.81	
ORP	mV	227.6		22		230.8		159.1	
Specific Conductivity (field)	mS/cm	0.062		0.064		0.06		0.06	
Dissolved Oxygen	mg/L	5.76		6.05		5.9		5.64	
pH (field)	SU	5.21		5.46		5.02		5.8	

Notes:

Q - Data Qualifier

U\* - Result should be considered "not-detected" because it was detected in a rinsate blank or laboratory blank at similar level

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

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

U - Analyte not detected

ug/L - micrograms per liter

mg/L - milligrams 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  
Assessment Monitoring  
Groundwater Sampling  
Results**

**CCR Annual Groundwater  
Monitoring and Corrective Action  
Report - TVA Johnsonville Fossil  
Plant**

Monitoring Well		JOF-101							
Sample Date		02-Apr-19		08-Jul-19		17-Sep-19		09-Oct-19	
Sample Round		1		1 - Retest		2		2 - Retest	
Well Designation		Background		Background		Background		Background	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q
<b>Total Metals</b>									
Antimony	ug/L	< 0.378	U						
Arsenic	ug/L	< 0.323	U						
Barium	ug/L	7.05	J	4.4	J	4.57	J	< 5.24	U*
Beryllium	ug/L	< 0.155	U	< 0.155	U	< 0.182	U	< 0.182	U
Boron	ug/L	< 30.3	U	< 30.3	U	< 38.6	U	< 38.6	U
Cadmium	ug/L	< 0.125	U						
Calcium	ug/L	3500		3590		3110		3730	
Chromium	ug/L	< 1.53	U	< 1.53	U	< 1.53	U	< 1.72	U*
Cobalt	ug/L	0.612		< 0.609	U*	0.56		0.236	J
Lead	ug/L	0.171	J	< 0.128	U	< 0.128	U	< 0.128	U
Lithium	ug/L	< 3.14	U	< 3.14	U	< 3.39	U	6.52	
Mercury	ug/L	< 0.101	U						
Molybdenum	ug/L	< 0.61	U						
Selenium	ug/L	< 2.62	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.128	U	< 0.128	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	0.180	J	< 0.311	U	< 0.351	U	< 0.121	U
<b>Anions</b>									
Chloride	mg/L	3.6		3.98		4.29		4.46	
Fluoride	mg/L	0.0317	J	0.0319	J	0.0348	J	< 0.0451	U*
Sulfate	mg/L	< 0.79	U*	0.879	J	< 1.44	U*	0.826	J
<b>General Chemistry</b>									
Total Dissolved Solids	mg/L	27	J	33	J	37	J	29	
<b>Field Parameters</b>									
Temperature, Water	DEG_C	16.5		18.8		20.2		16.9	
Turbidity (field)	NTU	4.67		3.66		1.66		1.7	
ORP	mV	221.5		74.8		225.4		147.1	
Specific Conductivity (field)	mS/cm	0.046		0.045		0.044		0.042	
Dissolved Oxygen	mg/L	6.39		6.76		6.63		6.29	
pH (field)	SU	5.13		5.2		4.69		5.6	

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NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

**Table 1  
Assessment Monitoring  
Groundwater Sampling  
Results**

**CCR Annual Groundwater  
Monitoring and Corrective Action  
Report - TVA Johnsonville Fossil  
Plant**

Monitoring Well		JOF-103							
Sample Date		03-Apr-19		09-Jul-19		18-Sep-19		10-Oct-19	
Sample Round		1		1 - Retest		2		2 - Retest	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q
<b>Total Metals</b>									
Antimony	ug/L	< 0.378	U	0.58	J	0.435	J	< 0.378	U
Arsenic	ug/L	0.573	J	2.78		0.606	J	0.526	J
Barium	ug/L	32.4		< 30.4	U*	28.3		33.9	
Beryllium	ug/L	0.16	J	< 1.36	U*	0.627	J	0.22	J
Boron	ug/L	7000		6370		6860		6650	
Cadmium	ug/L	2.8		3.71		2.3		2.76	
Calcium	ug/L	61600		65600		56400		63100	
Chromium	ug/L	< 1.95	U*	< 1.53	U	< 1.53	U	< 1.53	U
Cobalt	ug/L	61.9		59.8		51.5		52.7	
Lead	ug/L	< 0.128	U	< 1.2	U*	< 0.128	U	< 0.128	U
Lithium	ug/L	10.6		11.5		12.4		10.7	
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	< 0.61	U	< 1.33	U*	< 0.61	U	< 0.61	U
Selenium	ug/L	< 2.62	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.128	U	< 2.29	U*	1.08		< 0.148	U
Radium 226 + Radium 228	pCi/L	0.115	J	< 0.130	U	< 1.05	U	< 0.511	U
<b>Anions</b>									
Chloride	mg/L	30.1		32.1		31.5		29.1	
Fluoride	mg/L	0.529		0.607		0.569		0.508	
Sulfate	mg/L	195	J	198		219		192	
<b>General Chemistry</b>									
Total Dissolved Solids	mg/L	397		392		455		436	
<b>Field Parameters</b>									
Temperature, Water	DEG_C	18.8		19.5		19.9		19.1	
Turbidity (field)	NTU	3.11		4.6		2.87		0.85	
ORP	mV	235.2		-113.7		210.6		144.6	
Specific Conductivity (field)	mS/cm	0.53		0.533		0.527		0.499	
Dissolved Oxygen	mg/L	0.39		0.15		0.04		0.18	
pH (field)	SU	4.84		4.93		4.68		5	

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mg/L - milligrams 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  
Assessment Monitoring  
Groundwater Sampling  
Results**

**CCR Annual Groundwater  
Monitoring and Corrective Action  
Report - TVA Johnsonville Fossil  
Plant**

Monitoring Well		JOF-104							
Sample Date		03-Apr-19		09-Jul-19		18-Sep-19		10-Oct-19	
Sample Round		1		1 - Retest		2		2 - Retest	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q
<b>Total Metals</b>									
Antimony	ug/L	< 0.378	U	< 0.378	U	0.893	J	< 0.378	U
Arsenic	ug/L	0.746	J	< 0.631	U*	0.602	J	0.617	J
Barium	ug/L	34.6		< 28.6	U*	26.9		30.1	
Beryllium	ug/L	< 0.155	U	< 0.155	U	< 0.182	U	< 0.182	U
Boron	ug/L	3730		3330		3160		3230	
Cadmium	ug/L	0.802	J	< 0.357	U*	0.321	J	0.361	J
Calcium	ug/L	71700		78300		60200		71800	
Chromium	ug/L	< 1.53	U	< 1.53	U	< 1.53	U	< 1.53	U
Cobalt	ug/L	1.73		1.46		1.19		0.62	
Lead	ug/L	< 0.128	U	< 0.128	U	< 0.128	U	< 0.128	U
Lithium	ug/L	3.54	J	3.52	J	3.42	J	4.08	J
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	< 0.61	U	< 0.61	U	< 0.61	U	< 0.61	U
Selenium	ug/L	< 2.62	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.128	U	< 0.128	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	0.250	J	< 0.198	U	< 0.856	U	< 0.400	U
<b>Anions</b>									
Chloride	mg/L	18		18.9		19.4		18.2	
Fluoride	mg/L	0.256		0.246		0.283		0.2	
Sulfate	mg/L	271	J	284		283		294	
<b>General Chemistry</b>									
Total Dissolved Solids	mg/L	466		462		500		490	
<b>Field Parameters</b>									
Temperature, Water	DEG_C	18.1		19		19		18.2	
Turbidity (field)	NTU	2.01		2.58		0.42		3.26	
ORP	mV	215.3		-100.4		176.2		148.7	
Specific Conductivity (field)	mS/cm	0.62		0.66		0.62		0.6	
Dissolved Oxygen	mg/L	0.29		0.25		-0.6		0.21	
pH (field)	SU	5.29		5.43		5.28		5.33	

Notes:

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

U - Analyte not detected

ug/L - micrograms per liter

mg/L - milligrams 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  
Groundwater Sampling Summary**

**CCR Annual Groundwater Monitoring and Corrective  
Action Report - TVA Johnsonville Fossil Plant**

Well ID	Well Designation	Number of Samples Collected	April 2-3, 2019	July 8-10, 2019	September 17-18, 2019	October 9-10, 2019	Monitoring Program
			Sample Round 1	1 - Retest	2	2 - Retest	
10-AP1	Downgradient	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
10-AP3	Downgradient	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
B-9	Background	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
JOF-101	Background	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
JOF-103	Downgradient	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
JOF-104	Downgradient	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents

Notes:

Assessment Monitoring groundwater samples analyzed for Appendix III and Appendix IV constituents

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 combined

**Table 3  
Groundwater and Surface Water  
Elevation Summary**

**CCR Annual Groundwater  
Monitoring and Corrective Action  
Report - TVA Johnsonville Fossil  
Plant**

Groundwater Elevation Collection Date		02-Apr-19	08-Jul-19	17-Sep-19	08-Oct-19
<b>Monitoring Well</b>	<b>Units</b>				
10-AP1	ft-MSL	354.64	359.18	354.77	354.09
10-AP3	ft-MSL	354.78	359.33	354.94	354.21
B-9	ft-MSL	398.92	395.53	393.41	393.00
JOF-101	ft-MSL	400.64	397.62	395.59	395.15
JOF-103	ft-MSL	355.08	359.69	355.25	354.54
JOF-104	ft-MSL	354.90	359.52	355.07	354.35
		<b>Surface Water</b>			
<b>Tennessee River</b>	ft-MSL	354.94	359.55	355.06	354.23

Notes:

ft-MSL - feet above mean sea level

**Table 4  
Hydraulic Conductivity Data  
Summary**

**CCR Annual Groundwater Monitoring and  
Corrective Action Report - TVA  
Johnsonville Fossil Plant**

<b>Well ID</b>	<b>Well Designation</b>	<b>Slug Test Hydraulic Conductivity (cm/sec)</b>
<b>B-9</b>	Background	9.2E-05
<b>10-AP1</b>	Downgradient	1.11E-02
<b>10-AP3</b>	Downgradient	7.48E-03
<b>JOF-101</b>	Background	1.83E-04
<b>JOF-103</b>	Downgradient	1.89E-02
<b>JOF-104</b>	Downgradient	9.83E-02
<b>Geometric Mean of Hydraulic Conductivity (cm/sec)</b>		<b>3.7E-03</b>

Notes:

cm/sec - centimeters per second

**Table 5  
Rate and Direction of Groundwater  
Flow Summary**

**CCR Annual Groundwater Monitoring and  
Corrective Action Report  
TVA - Johnsonville Fossil Plant**

Groundwater Elevation Collection Date	2-Apr-19	8-Jul-19	17-Sep-19	8-Oct-19
Sample Round	1	1 - Retest	2	2 - Retest
Horizontal Gradient	0.0078	0.0065	0.0069	0.0070
Hydraulic Conductivity (cm/sec)	3.7E-03	3.7E-03	3.7E-03	3.7E-03
Effective Porosity	20%	20%	20%	20%
Flow Direction (cardinal)	West	West	West	West
Linear Velocity (ft/yr)	150	125	133	134

Notes:

cm/sec - centimeters per second

ft/yr - feet per year

**Table 6**  
**Statistically Significant Levels (SSLs) Above GWPSs**

**CCR Annual Groundwater Monitoring and Corrective Action**  
**Report - TVA Johnsonville Fossil Plant**

Appendix IV Parameter*	GWPS (a)	Updated GWPS (b)	Downgradient wells with analytical results above GWPS (c)	Updated LCBs (d)	SSL LCB > GWPS (e)
Antimony (mg/l)	0.006	0.006	None	NA	NA
Arsenic (mg/l)	0.01	0.01	None	NA	NA
Barium (mg/l)	2	2	None	NA	NA
Beryllium (mg/l)	0.004	0.004	None	NA	NA
Cadmium (mg/l)	0.005	0.005	10-AP3	0.004	NO
			JOF-103	0.001	NO
Chromium (mg/l)	0.1	0.1	None	NA	NA
Cobalt (mg/l)	0.006	0.006	10-AP3	0.028	<b>YES</b>
			JOF-103	0.0455	<b>YES</b>
Fluoride (mg/l)	4	4	None	NA	NA
Lead (mg/l)	0.015	0.015	None	NA	NA
Lithium (mg/l)	0.04	0.04	JOF-103	0.0078	NO
Mercury (mg/l)	0.002	0.002	None	NA	NA
Molybdenum (mg/l)	0.1	0.1	None	NA	NA
Radium-226+228 (pCi/l)	5	5	None	NA	NA
Selenium (mg/l)	0.05	0.05	None	NA	NA
Thallium (mg/l)	0.002	0.002	None	NA	NA

Notes:

NA – Not applicable

\* - Total Metals concentrations presented in Table 1 are reported in micrograms per liter (µg/L)

(a) Groundwater Protection Standards (GWPSs) documented in notice dated 10/15/2018 [reported in milligrams per liter (mg/L)]

(b) GWPSs updated as of 11/13/2019 with 3 additional sample results collected on April 2-3, 2019, July 8-10, 2019 and September 17-18, 2019 [reported in mg/L]

(c) Downgradient wells with analytical results above GWPS November 2016 through September 17-18, 2019 (per 40 CFR 257.95(b) and (d))

(d) Most recent value of 99% lower confidence band (LCB) on the mean of Appendix IV groundwater sampling events between November 2016 and September 17-18, 2019 - Upper confidence band (UCB) not shown as it is greater than LCB [reported in mg/L]

(e) SSL: "statistically significant level over GWPS" occurs when the updated LCB value at the last sampling event exceeds the updated GWPS

**APPENDIX A**  
**STATISTICAL ANALYSIS REPORT**

**STATISTICAL ANALYSIS REPORT  
FOR JOHNSONVILLE FOSSIL PLANT**

**2019**

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# 1 Introduction

This report summarizes the statistical analysis performed on groundwater quality constituents monitored during the Coal Combustion Residuals (CCR) Rule’s 2019 Annual Groundwater Monitoring (GWM) Program for the Tennessee Valley Authority (TVA) Johnsonville Fossil Plant Active Ash Pond 2. The 2019 Annual GWM Program is the third year of the program. Statistically significant increases (SSIs) were identified for one or more parameters based on the 2017 annual groundwater sampling results; therefore, the Active Ash Pond 2 transitioned to the Assessment Monitoring phase of the monitoring program.

Baseline datasets collected during the first year of monitoring were combined with data collected in 2018 and 2019 and were used to establish statistically-derived Groundwater Protection Standards (GWPS) for the Active Ash Pond 2 CCR Unit located at JOF. Consistent with methods presented in USEPA’s Unified Guidance document on the statistical analysis of groundwater monitoring data (2009), confidence-interval (CI) bands were compared against relevant GWPS. A statistically significant level (SSL) is found if and only if the lower limit of the CI band exceeds the GWPS for the most recent Assessment Monitoring sampling event.

At the JOF plant’s CCR Unit, the sampling results used to identify potential GWPS exceedances were obtained during a minimum of three distinct monitoring events that were performed between April and September of 2019 by Terracon, with laboratory analysis performed by Test America Laboratories (located at Pittsburg, PA, and St Louis, MO), and Quality Assurance Controls by Environmental Standards, Inc., all under direct contracts to TVA.

The current CCR Rule groundwater monitoring network, as Certified by a Professional Engineer at the firm of AECOM or other, is presented in **Table 1**.

**Table 1. CCR Rule Monitoring Well Network**

Background		Downgradient	
B-9	JOF-103	10-AP1	
JOF-101	JOF-104	10-AP3	

The ‘R’ Statistical Analysis package ([www.r-project.org](http://www.r-project.org)) in conjunction with R-Studio ([www.rstudio.com](http://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.

Groundwater samples collected as part of the CCR Rule monitoring program were analyzed for constituents listed in Appendix IV of the CCR Rule. Only non-filtered sample results were utilized for the statistical analysis of Appendix IV constituents. As high turbidity measurements during the purging of wells (e.g., values above 5 NTUs) have the propensity to increase the concentrations of Appendix IV constituents, filtered samples were also collected to better understand and/or dispel the potential source(s) of falsely-named GWPS exceedances.

**Table 2. CCR Rule Monitored Constituents**

Appendix III Constituents (Detection Monitoring)	Appendix IV Constituents (Assessment Monitoring)
Boron Calcium Chloride Fluoride pH (field) Sulfate Total Dissolved Solids (TDS)	Antimony Arsenic Barium Beryllium Cadmium Chromium Cobalt Fluoride Lead Lithium Mercury Molybdenum Radium 226 + 228 Selenium Thallium

## 2 Statistical Analysis

The Assessment Monitoring analysis includes the following steps:

- 1) Developing GWPS for each Appendix IV constituent. The GWPS is the published MCL/water quality limit or the background concentration (95% UTL with 95% coverage), whichever is larger;
- 2) Computing trends and associated CI bands for each downgradient 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.

### 2.1 Developing Groundwater Protection Standards (GWPS)

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.”

On July 17, 2018, EPA unofficially promulgated alternate regulatory limits (i.e., potential GWPS) 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 GWPS, those may be used in place of background levels under 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
4. Lead - 15 µg/L.

An Upper Tolerance Limit (UTL) with 95% confidence and 95% coverage was calculated using pooled 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 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.

For JOF, **Table 3, included below**, lists the calculated UTLs and final GWPS established for CCR Unit.

**Table 3. JOF Groundwater Protection Standards (GWPS)**

COI	N	ND.PCT	MODEL	COV	CONF	UTL	UNITS	MCL	GWPS
Antimony	38	100	NP	0.95	0.858	0.0020	mg/L	0.006	0.006
Arsenic	38	73.7	Square	0.95	0.950	0.0004	mg/L	0.01	0.01
Barium	38	5.3	NP	0.95	0.858	0.0184	mg/L	2	2
Beryllium	38	100	NP	0.95	0.858	0.0010	mg/L	0.004	0.004
Cadmium	38	100	NP	0.95	0.858	0.0010	mg/L	0.005	0.005
Chromium	38	86.8	NP	0.95	0.858	0.0022	mg/L	0.1	0.1
Cobalt*	38	42.1	Log	0.95	0.950	0.0035	mg/L	0.006	0.006
Fluoride	40	25	Log	0.95	0.950	0.0630	mg/L	4	4
Lead	38	89.5	Tenth Root	0.95	0.950	0.0018	mg/L	0.015	0.015
Lithium*	38	100	NP	0.95	0.858	0.0064	mg/L	0.04	0.04
Mercury	38	100	NP	0.95	0.858	0.0002	mg/L	0.002	0.002
Molybdenum*	38	97.4	NP	0.95	0.858	0.0050	mg/L	0.1	0.1
Rad226+228	38	0	NP	0.95	0.858	1.4600	pCi/L	5	5
Selenium	38	97.4	NP	0.95	0.858	0.0050	mg/L	0.05	0.05
Thallium	38	100	NP	0.95	0.858	0.0010	mg/L	0.002	0.002

\* No potential Health Effects provided for these Constituents of Interests (COI)

To compute each UTL, the following steps were taken:

- 1) All baseline data - those from designated up-gradient or background wells collected from the Program's first sampling event through September of 2019 were grouped and checked for possible outliers.

At JOF, no background outliers among the Appendix IV parameters were flagged.

- 2) The grouped baseline data were also 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.

Datasets which could not be sufficiently normalized were analyzed using nonparametric methods. Nonparametric UTLs do not assume a known statistical model and require larger sample sizes to achieve the target confidence level of 95%

- 3) The final statistical model for each COI was used to compute an 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  $\kappa$  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.

For nonparametric models, the normal theory equation does not apply. Instead, the UTL is selected as one of the largest of the sample values, typically 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.

**Table 4. Descriptive Summary Statistics of Background Data**

Constituent	Unit	N	No. of NDs	Minimum	Maximum	Mean	Median
Antimony	mg/L	38	38	0.0020	0.0020	0.0010	0.0020
Arsenic	mg/L	38	28	0.0002	0.0010	0.0003	0.0003
Barium	mg/L	38	2	0.0044	0.0184	0.0074	0.0074
Beryllium	mg/L	38	38	0.0010	0.0010	0.0005	0.0010
Cadmium	mg/L	38	38	0.0010	0.0010	0.0005	0.0010
Chromium	mg/L	38	33	0.0005	0.0022	0.0008	0.0009
Cobalt	mg/L	38	16	0.0001	0.0023	0.0006	0.0004
Fluoride	mg/L	40	10	0.0263	0.1000	0.0401	0.0397
Lead	mg/L	38	34	0.0001	0.0010	0.0003	0.0002
Lithium	mg/L	38	38	0.0050	0.0064	0.0025	0.0050
Mercury	mg/L	38	38	0.0002	0.0002	0.0001	0.0002
Molybdenum	mg/L	38	37	0.0009	0.0050	0.0009	0.0030
Rad226+228	pCi/L	38	0	0.0000	1.4600	0.3972	0.3820
Selenium	mg/L	38	37	0.0013	0.0050	0.0013	0.0031
Thallium	mg/L	38	38	0.0010	0.0010	0.0005	0.0010

Notes:

1. ND = not detected above the laboratory reporting limit.
2. All computations involving non-detects handled using the Kaplan-Meier adjustment. In the case of 100% NDs, mean is computed by substituting half the reporting limit for each ND.

## 2.2 Computing Trend Lines and Confidence Interval Bands

The USEPA's Unified Guidance recommends comparing some type of CI against a GWPS in order to assess whether or not the limit has been exceeded with statistical significance. If the entire interval exceeds the GWPS, an SSL is identified. If none of the interval, or only part, exceeds the GWPS, no SSL is recorded.

Since groundwater data are collected over time, variation in the measurements may be due to a trend. To 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 SSL is identified for that sampling event.

At JOF CI bands were constructed using equations [21.24] and [21.25] of Section 21.3 in the Unified Guidance for each well-constituent pair using all data collected through August of 2018. 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 SSLs.

For well-constituent pairs with no non-detects, linear regression and the formulas referenced 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.

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.

As with the grouped background data, the data was initially screened for evidence of outliers. Six outliers were flagged and excluded from subsequent statistical calculations, including one

observation each of antimony at JOF-104, arsenic at JOF-103, cadmium at JOF-103 and 10-AP3, lithium at JOF-103, and radium at 10-AP3.

## **2.3 Comparing Confidence Interval Bands Against GWPS**

To assess whether any SSLs occurred during the 2018 Assessment Monitoring at JOF, the CI bands were compared against the constituent-specific GWPS. An SSL was identified if and only if the CI band fully exceeded the GWPS at the *most recent* sampling event.

### 3 Summary of Statistical Analysis

To facilitate an ‘at-a-glance’ summary of the statistical comparison results, **Table 5** 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 SSL was observed in 2018. Red cells indicate that an SSL was flagged during the most recent sampling events. 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 JOF site, two cobalt-related SSLs were recorded at wells JOF-103 and 10-AP3. Additionally, one warning flag (yellow) was raised for cadmium at well 10-AP3. In summary, a total of two SSLs and one warning were identified at Program network wells that are located near the JOF plant’s CCR Unit during the Assessment Monitoring.

**Table 5. JOF Traffic Light Matrix Based on Comparative Analysis of Statistical Analysis Results versus Groundwater Protection Standards (GWPS)**

ITEM No.	Constituent of Interest	TRAFFIC LIGHT MATRIX					
		GROUNDWATER QUALITY MONITORING WELL LOCATIONS					
		B-9	JOF-101	JOF-103	JOF-104	10-AP1	10-AP3
1.	Antimony	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
2.	Arsenic	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
3.	Barium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
4.	Beryllium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
5.	Cadmium	GREEN	GREEN	GREEN	GREEN	GREEN	YELLOW
6.	Chromium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
7.	Cobalt	GREEN	GREEN	RED	GREEN	GREEN	RED
8.	Fluoride	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
9.	Lead	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
10.	Lithium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
11.	Mercury	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
12.	Molybdenum	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
13.	Rad226+228	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
14.	Selenium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
15.	Thallium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN

COLOR-CODING KEY:	
	Monitored data for the specific COI are deemed to fall below GWPS
	Monitored data are deemed to fall below GWPS, but an internal warning is issued to TVA staff that CI band lower limit is at least 65% of the GWPS.
	Monitored data for the specific COI are deemed to exceed GWPS

## 4 References

1) US Environmental Protection Agency (2009) *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance* - Office of Resource Conservation and Recovery EPA 530/R-09-007

2) US Environmental Protection Agency (2007) *Framework for Metals Risk Assessment* EPA 120/R-07/001 Office of the Science Advisor Risk Assessment Forum, Washington, DC 20460