

**2018 Annual Groundwater  
Monitoring and Corrective  
Action Report**



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



Prepared for:  
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January 31, 2019



January 31, 2019

**Reference: 2018 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 Federal Coal Combustion Residuals (CCR) Rule (CCR Rule), this 2018 Annual Groundwater Monitoring and Corrective Action Report (2018 Annual Report) documents 2018 groundwater monitoring activities at the Active Ash Pond 2 CCR Unit at the Tennessee Valley Authority (TVA) Johnsonville Fossil Plant (JOF). 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 2018, TVA performed the following groundwater monitoring activities:

- Conducted a statistical analysis of the 2017 detection monitoring groundwater sampling data in accordance with 40 CFR 257.93(h), and it was 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 2017 Annual Groundwater Monitoring and Corrective Action Report, which was placed on the CCR Compliance Data and Information website (<https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>).
- 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)(1) 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 CCR Compliance Data and Information website <https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals> in accordance with 40 CFR 257.107(h)(4).
- Sampled and analyzed groundwater in the certified monitoring network for Appendix IV constituents in accordance with 40 CFR 257.95(b).
- Sampled wells in the certified monitoring network and analyzed samples for CCR constituents (Appendix III and Appendix IV constituents) 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 2018 Annual Report in accordance with 257.95(d)(3).
- Established groundwater protection standards in accordance with 40 CFR 257.95(d)(2) and included the standards in this 2018 Annual Report in accordance with 257.95(d)(3).

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- Performed field and desktop site characterization investigations to improve the JOF 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).

No problems were encountered during the second year of the TVA Groundwater Quality Monitoring Program and therefore, no further action has been recommended, except for the planned key activities for 2019 that are outlined below.

The projected key activities for 2019 are:

- Complete an evaluation of whether one or more Appendix IV constituents are detected at statistically significant levels (SSLs) above the established groundwater protection standards in accordance with 40 CFR 257.95(g).
- 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 of the release 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.
- Notification of the exceedances of established groundwater protection standards will be placed in the facility operating record in accordance with 40 CFR 257.95(g) and 257.105(h)(8); will be provided to the State of Tennessee in accordance with 40 CFR 257.106(h)(6); and will be placed 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).
- All persons who own the land or reside on the land that directly overlies any part of the plume of contamination if contaminants have migrated off-site will be notified 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 in accordance with 40 CFR 257.95(g)(3)(i) and 40 CFR 257.96.
- Perform further field and desktop site characterization investigations to improve the JOF CSM.
- Continue semi-annual assessment monitoring at the certified groundwater monitoring network consistent with 40 CFR 257.95.
- 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.

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- 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 fly ash or bottom ash.

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).

No monitoring wells in the CCR network were installed or decommissioned during the 2018 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 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.

Assessment monitoring groundwater sampling was conducted between May and August 2018 and the results are summarized in Table 1. 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).

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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 0.0071 to 0.0075 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 136 to 144 feet per year.

### STATISTICAL ANALYSIS OF GROUNDWATER DATA

The groundwater monitoring data for the 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 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>1</sup> constituent<sup>2</sup>. The 2018 Statistical Analysis Report is included in Appendix A.

The sampling results used to identify potential groundwater protection standards exceedances were obtained during five distinct monitoring events that were performed between May and August of 2018<sup>3</sup>. Comparisons were made against a fixed groundwater protection standard via a confidence interval or confidence interval band. No retesting was conducted and none of the individual compliance point measurements were directly compared against the groundwater protection standard. All of the Appendix IV monitoring data collected both in Year-One and Year-Two were used to construct the confidence interval bands. Cross-sections of each

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<sup>1</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>2</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, these 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; and, 4.) Lead - 15 µg/L.

<sup>3</sup> The CCR rule requires a minimum of two semi-annual sampling events per well once the required background data has been obtained. Groundwater aquifers can be quite complex, with significant changes and heterogeneity over both time and space. Two events per well per year is sometimes inadequate to reasonably characterize groundwater quality. Much greater flexibility in statistical approach, as well critical information about groundwater variability, can be gained from more frequent sampling.

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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 Assessment Monitoring, two cobalt-related SSLs were recorded at wells JOF-103 and 10-AP3.

### NARRATIVE DISCUSSION OF ANY TRANSITION BETWEEN MONITORING PROGRAMS

In January 2018, TVA evaluated the groundwater monitoring data for SSLs over background levels for the constituents listed in Appendix III<sup>4</sup> as required by 40 CFR 257.93(h). The groundwater analytical results from the initial round of detection monitoring indicated SSLs of Appendix III CCR constituents at the downgradient monitoring wells. TVA performed error checking and investigated whether the SSL 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 determine whether a source other than the CCR materials contained within the JOF Active Ash Pond 2 Area was the cause of the SSL. The alternate source demonstration study did not demonstrate that the SSL was 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 CCR Compliance Data and Information website(<https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>) in accordance with 40 CFR 257.106(h)(4) and 40 CFR 257.107(h)(4), respectively.

In accordance with assessment monitoring program requirements, groundwater in wells in the certified monitoring network was sampled and analyzed 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 monitoring network 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 1. Groundwater protection standards were established in accordance with 40 CFR 257.95(d)(2) and are summarized in Table 5. In January 2019, 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 2018 Annual Report, during Assessment Monitoring, two cobalt-related SSLs were recorded at monitoring wells JOF-103 and 10-AP3. 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.

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<sup>4</sup> Appendix III CCR Constituents: boron, calcium, chloride, fluoride, pH, sulfate and total dissolved solids (TDS).

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## LIMITATIONS

This document entitled 2018 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 – Groundwater Protection Standards

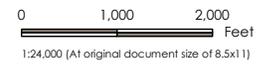
Appendix A – 2018 Statistical Analysis Report

## FIGURES





- ▲ Staff Gauge
- Background Well
- Downgradient Well
- ➔ Groundwater 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

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



Project Location: New Johnsonville, Humphreys County, Tennessee  
 Prepared by: CMB on 2019-01-14  
 Technical Review by: WSW on 2019-01-14  
 Independent Review by: JK on 2019-01-14

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

Figure No. **2**

Title: **Generalized Groundwater Flow Direction Map**

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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		24-May-18		13-Jun-18		27-Jun-18		25-Jul-18		15-Aug-18	
Sample Round		1		2		3		4		5	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q								
<b>Total Metals</b>											
Antimony	mg/L	< 0.00112	U								
Arsenic	mg/L	0.000867	J	0.000830	J	0.000772	J	0.000430	J	< 0.000451	U*
Barium	mg/L	0.0276		0.0292		0.0313		0.0278		0.0235	
Beryllium	mg/L	0.0000880	J	0.0000790	J	0.0000570	J	< 0.0000780	U*	< 0.0000570	U
Boron	mg/L	9.00		8.31		6.82		6.85		5.17	
Cadmium	mg/L	0.00205		0.00144		0.00114		0.000856	J	< 0.000570	U*
Calcium	mg/L	94.3		96.2		101		88.7		77.1	
Chromium	mg/L	< 0.00143	U*	< 0.00202	U*	< 0.00203	U*	< 0.000631	U	< 0.000631	U
Cobalt	mg/L	0.00371		0.00395		0.00360		0.00301		0.00246	
Lead	mg/L	< 0.0000940	U	0.000101	J	0.000106	J	0.000122	J	< 0.000187	U*
Lithium	mg/L	0.00735		< 0.00642	U*	0.00453	J	0.00490	J	< 0.00584	U*
Mercury	mg/L	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000662	U*	< 0.0000653	U
Molybdenum	mg/L	< 0.000474	U								
Selenium	mg/L	< 0.000813	U								
Thallium	mg/L	< 0.0000630	U								
Radium 226 + Radium 228	pCi/L	0.350	U	0.249	U	0.322	UJ	0.297	U*	0.332	U*
<b>Anions</b>											
Chloride	mg/L	22.2		20.9		21.7		22.4		23.4	
Fluoride	mg/L	0.127		0.146		0.172		0.151		0.138	
Sulfate	mg/L	279		261		264		294		302	
<b>General Chemistry</b>											
Total Dissolved Solids	mg/L	552		546		498		531		522	
<b>Field pH</b>											
pH (field)	SU	5.27		5.29		5.24		5.39		5.25	

Notes:

NA - Not Available

Q - Data Qualifier

U\* - This result should be considered not detected because it was 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

pCi/L - picoCurie per liter

SU - Standard Unit

**ASSESSMENT  
MONITORING**

**Table 1 - Assessment  
Monitoring Groundwater  
Sampling Results**

**CCR Annual Groundwater Monitoring and Corrective  
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Monitoring Well		10-AP3									
Sample Date		23-May-18		13-Jun-18		26-Jun-18		24-Jul-18		14-Aug-18	
Sample Round		1		2		3		4		5	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q								
<b>Total Metals</b>											
Antimony	mg/L	< 0.00112	U								
Arsenic	mg/L	0.000876	J	0.000772	J	< 0.000668	U*	0.000487	J	< 0.000696	U*
Barium	mg/L	0.0149		0.0156		0.0179		0.0158		0.0156	
Beryllium	mg/L	0.000100	J	0.000122	J	0.0000600	J	< 0.000104	U*	0.0000570	J
Boron	mg/L	5.65		5.79		4.98		5.11		5.70	
Cadmium	mg/L	0.00450		0.00487		0.00522		0.00535		0.00459	
Calcium	mg/L	166		178		192		205		167	
Chromium	mg/L	< 0.00154	U*	< 0.00201	U*	< 0.00182	U*	< 0.000631	U	< 0.00182	U*
Cobalt	mg/L	0.0331		0.0371		0.0368		0.0342		0.0364	
Lead	mg/L	0.0000980	J	< 0.0000940	U	< 0.0000940	U	0.000111	J	< 0.0000940	U
Lithium	mg/L	0.00483	J	< 0.00460	U*	< 0.00256	U	0.00316	J	0.00411	J
Mercury	mg/L	< 0.0000653	U								
Molybdenum	mg/L	< 0.000474	U								
Selenium	mg/L	< 0.000813	U								
Thallium	mg/L	0.0000910	J	0.000106	J	0.000110	J	< 0.0000630	U	0.000103	J
Radium 226 + Radium 228	pCi/L	0.378	U	0.144	J	0.384	UJ	0.693	U*	0.489	U*
<b>Anions</b>											
Chloride	mg/L	26.1		26.3		27.5		29.7		28.8	
Fluoride	mg/L	0.0548	J	0.0484	J	0.0865	J	< 0.0263	U	0.0621	J
Sulfate	mg/L	514		540		548		610		614	
<b>General Chemistry</b>											
Total Dissolved Solids	mg/L	954		948		869		908		941	
<b>Field pH</b>											
pH (field)	SU	4.83		4.91		4.85		5.02		4.86	

Notes:

NA - Not Available

Q - Data Qualifier

U\* - This result should be considered not detected because it was 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

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mg/L - milligrams per liter

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**ASSESSMENT  
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**Table 1 - Assessment  
Monitoring Groundwater  
Sampling Results**

**CCR Annual Groundwater Monitoring and Corrective  
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Monitoring Well		B-9									
Sample Date		23-May-18		12-Jun-18		26-Jun-18		24-Jul-18		14-Aug-18	
Sample Round		1		2		3		4		5	
Well Designation		Background		Background		Background		Background		Background	
Analyte	Units	Result	Q								
<b>Total Metals</b>											
Antimony	mg/L	< 0.00112	U								
Arsenic	mg/L	0.000329	J	0.000337	J	< 0.000371	U*	< 0.000323	U	< 0.000377	U*
Barium	mg/L	0.00779	J	0.00750	J	0.00815	J	0.00813	J	0.00799	J
Beryllium	mg/L	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000980	U*	< 0.0000570	U
Boron	mg/L	< 0.0303	U								
Cadmium	mg/L	< 0.000125	U								
Calcium	mg/L	5.38		5.44		5.90		5.94		5.59	
Chromium	mg/L	< 0.00168	U*	< 0.00197	U*	< 0.00208	U*	< 0.000631	U	< 0.00216	U*
Cobalt	mg/L	< 0.0000750	U	0.0000940	J	< 0.0000750	U	< 0.0000750	U	< 0.0000750	U
Lead	mg/L	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	0.000112	J	< 0.0000990	U*
Lithium	mg/L	< 0.00256	U								
Mercury	mg/L	< 0.0000653	U								
Molybdenum	mg/L	< 0.000474	U								
Selenium	mg/L	< 0.000813	U								
Thallium	mg/L	< 0.0000630	U								
Radium 226 + Radium 228	pCi/L	0.235	U	0.0868	U	0.646	J	0.465	U*	0.505	U*
<b>Anions</b>											
Chloride	mg/L	3.35		3.42		4.23		4.77		4.45	
Fluoride	mg/L	0.0399	J	0.0487	J	0.0596	J	0.0308	J	0.0282	J
Sulfate	mg/L	0.498	J	0.528	J	0.699	J	< 0.380	U	< 0.646	U*
<b>General Chemistry</b>											
Total Dissolved Solids	mg/L	57.0		39.0		36.0		40.0		43.0	
<b>Field pH</b>											
pH (field)	SU	5.33		5.14		5.61		5.78		5.41	

Notes:

NA - Not Available

Q - Data Qualifier

U\* - This result should be considered not detected because it was 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

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**ASSESSMENT  
MONITORING**

**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		23-May-18		12-Jun-18		26-Jun-18		24-Jul-18		14-Aug-18	
Sample Round		1		2		3		4		5	
Well Designation		Background		Background		Background		Background		Background	
Analyte	Units	Result	Q								
<b>Total Metals</b>											
Antimony	mg/L	< 0.00112	U								
Arsenic	mg/L	0.000371	J	0.000387	J	< 0.000360	U*	< 0.000323	U	< 0.000370	U*
Barium	mg/L	0.00538	J	0.00563	J	0.00583	J	0.00563	J	0.00528	J
Beryllium	mg/L	< 0.0000570	U								
Boron	mg/L	< 0.0303	U								
Cadmium	mg/L	< 0.000125	U								
Calcium	mg/L	3.13		3.32		3.49		3.24		3.24	
Chromium	mg/L	< 0.00148	U*	< 0.00196	U*	< 0.00181	U*	< 0.000631	U	< 0.00201	U*
Cobalt	mg/L	0.000659		0.000368	J	0.000435	J	0.000273	J	< 0.000366	U*
Lead	mg/L	< 0.0000940	U								
Lithium	mg/L	< 0.00256	U								
Mercury	mg/L	< 0.0000653	U								
Molybdenum	mg/L	< 0.000474	U								
Selenium	mg/L	< 0.000813	U								
Thallium	mg/L	< 0.0000630	U								
Radium 226 + Radium 228	pCi/L	0.382	J	0.309	U	0.305	J	0.410	U*	0.612	U*
<b>Anions</b>											
Chloride	mg/L	3.52		4.19		3.90		4.45		4.81	
Fluoride	mg/L	0.0263	J	0.0284	J	0.0531	J	< 0.0263	U	< 0.0263	U
Sulfate	mg/L	0.863	J	1.95		1.22		0.829	J	< 1.10	U*
<b>General Chemistry</b>											
Total Dissolved Solids	mg/L	44.0	J	40.0		30.0		33.0		32.0	
<b>Field pH</b>											
pH (field)	SU	5.07		5.19		5.41		5.46		5.08	

Notes:

NA - Not Available

Q - Data Qualifier

U\* - This result should be considered not detected because it was 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

pCi/L - picoCurie per liter

SU - Standard Unit

**ASSESSMENT  
MONITORING**

**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		24-May-18		13-Jun-18		26-Jun-18		25-Jul-18		14-Aug-18	
Sample Round		1		2		3		4		5	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q								
<b>Total Metals</b>											
Antimony	mg/L	< 0.00112	U								
Arsenic	mg/L	0.000655	J	0.000675	J	< 0.000656	U*	< 0.000323	U	< 0.000541	U*
Barium	mg/L	0.0287		0.0299		0.0304		0.0278		0.0303	
Beryllium	mg/L	0.000259	J	0.000257	J	0.000162	J	< 0.000247	U*	0.000184	J
Boron	mg/L	7.07		7.34		6.12		6.64		7.41	
Cadmium	mg/L	0.00337		0.00292		0.00313		0.00250		0.00282	
Calcium	mg/L	57.8		60.4		64.5		57.4		59.1	
Chromium	mg/L	< 0.00152	U*	< 0.00184	U*	< 0.00184	U*	< 0.000631	U	< 0.00130	U*
Cobalt	mg/L	0.0525		0.0580		0.0536		0.0457		0.0575	
Lead	mg/L	0.0000980	J	< 0.0000940	U						
Lithium	mg/L	0.0113		< 0.0114	U*	0.00888		0.00961		0.0104	
Mercury	mg/L	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000969	U*	< 0.0000653	U
Molybdenum	mg/L	< 0.000474	U								
Selenium	mg/L	< 0.000813	U								
Thallium	mg/L	< 0.0000630	U								
Radium 226 + Radium 228	pCi/L	0.308	U	0.325	J	0.215	UJ	0.532	U*	0.416	U*
<b>Anions</b>											
Chloride	mg/L	28.1		29.7		30.9		31.7		31.3	
Fluoride	mg/L	0.589		0.843		0.551		0.510		0.497	
Sulfate	mg/L	202		196		195		210		228	
<b>General Chemistry</b>											
Total Dissolved Solids	mg/L	437		460		427		444		432	
<b>Field pH</b>											
pH (field)	SU	4.94		4.99		4.93		5.06		4.81	

Notes:

NA - Not Available

Q - Data Qualifier

U\* - This result should be considered not detected because it was 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

pCi/L - picoCurie per liter

SU - Standard Unit

**ASSESSMENT  
MONITORING**

**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		24-May-18		13-Jun-18		27-Jun-18		25-Jul-18		15-Aug-18	
Sample Round		1		2		3		4		5	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q								
<b>Total Metals</b>											
Antimony	mg/L	< 0.00112	U	0.00796	J						
Arsenic	mg/L	0.000959	J	0.000770	J	0.000685	J	0.000506	J	< 0.000627	U*
Barium	mg/L	0.0363		0.0357		0.0359		0.0312		0.0273	
Beryllium	mg/L	0.0000710	J	0.0000670	J	< 0.0000570	U	< 0.0000670	U*	< 0.0000570	U
Boron	mg/L	3.37		3.65		3.09		3.33		2.51	
Cadmium	mg/L	0.000199	J	0.000266	J	0.000263	J	0.000251	J	< 0.000351	U*
Calcium	mg/L	62.6		68.6		73.0		66.1		60.5	
Chromium	mg/L	< 0.00141	U*	< 0.00199	U*	< 0.00195	U*	< 0.000631	U	< 0.000631	U
Cobalt	mg/L	0.00255		0.00171		0.00150		0.00109		0.000782	
Lead	mg/L	< 0.0000940	U	< 0.000282	U*						
Lithium	mg/L	0.00539		< 0.00459	U*	0.00257	J	0.00388	J	< 0.00431	U*
Mercury	mg/L	< 0.0000653	U								
Molybdenum	mg/L	< 0.000474	U								
Selenium	mg/L	< 0.000813	U								
Thallium	mg/L	< 0.0000630	U								
Radium 226 + Radium 228	pCi/L	0.363	J	0.272	U	0.183	UJ	0.345	U*	0.605	U*
<b>Anions</b>											
Chloride	mg/L	15.0		15.5		18.1		19.1		19.0	
Fluoride	mg/L	0.246		0.267		0.316		0.244		0.221	
Sulfate	mg/L	271		272		275		306		297	
<b>General Chemistry</b>											
Total Dissolved Solids	mg/L	473		521		485		493		499	
<b>Field pH</b>											
pH (field)	SU	5.32		5.32		5.23		5.36		5.21	

Notes:

NA - Not Available

Q - Data Qualifier

U\* - This result should be considered not detected because it was 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

pCi/L - picoCurie per liter

SU - Standard Unit

**ASSESSMENT  
MONITORING**

**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	May 23-24, 2018	June 12-13, 2018	June 26-27, 2018	July 24-25, 2018	August 14-15, 2018	Assessment Monitoring Program
10-AP1	Downgradient	5	X	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	5	X	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	5	X	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	5	X	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	5	X	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	5	X	X	X	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 3  
Groundwater and Surface Water Elevation  
Summary**

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

Groundwater Elevation Collection Date		23-May-18	12-Jun-18	26-Jun-18	24-Jul-18	14-Aug-18
Monitoring Well	Units					
10-AP1	ft-MSL	358.27	358.25	358.37	357.03	355.98
10-AP3	ft-MSL	358.52	358.51	358.67	357.29	356.25
B-9	ft-MSL	399.26	398.37	398.54	396.54	394.57
JOF-101	ft-MSL	400.72	400.03	400.08	398.40	396.76
JOF-103	ft-MSL	358.98	359.00	359.15	357.75	356.73
JOF-104	ft-MSL	358.76	358.74	358.86	357.47	356.42
Tennessee River	ft-MSL	358.91	359.01	359.16	357.81	356.68

**Table 4 - Hydraulic Conductivity  
Data Summary**

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

Well ID	Well Designation	Slug Test Hydraulic Conductivity (cm/sec)
<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

NA - Not available

**Table 5 - Groundwater Protection Standards**

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

Chemical Name	Unit	GWPS / BTV*
Antimony	mg/L	0.006
Arsenic	mg/L	0.01
Barium	mg/L	2
Beryllium	mg/L	0.004
Boron	mg/L	0.0279*
Cadmium	mg/L	0.005
Calcium	mg/L	6.54*
Chloride	mg/L	7.75*
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	4.18 – 6.75*
Radium 226 + Radium 228	pCi/L	5
Selenium	mg/L	0.05
Sulfate	mg/L	8.57*
Thallium	mg/L	0.002
Total Dissolved Solids	mg/L	130*

Notes:

GWPS - groundwater protection standard

\* - BTV - Background Threshold Values for Appendix III Constituents (2017)

mg/L - milligrams per liter

SU - standard units

pCi/L - picocuries per liter

N/A - not applicable

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

**STATISTICAL ANALYSIS REPORT  
FOR JOHNSONVILLE FOSSIL PLANT**

**2018**



1/14/2019

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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 2018 Annual Groundwater Monitoring (GWM) Program for the Tennessee Valley Authority (TVA) Johnsonville Fossil Plant Active Ash Pond 2. The 2018 Annual GWM Program is the second 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 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 five distinct monitoring events that were performed between May of 2018 and August of 2018 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 groundwater protection standards (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 confidence interval (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	32	100	NP	0.95	0.8063	0.0020	mg/L	0.006	0.006
Arsenic	32	68.8	Square	0.95	0.9500	0.0004	mg/L	0.01	0.01
Barium	32	6.2	NP	0.95	0.8063	0.0184	mg/L	2	2
Beryllium	32	100	NP	0.95	0.8063	0.0010	mg/L	0.004	0.004
Cadmium	32	100	NP	0.95	0.8063	0.0010	mg/L	0.005	0.005
Chromium	32	84.4	NP	0.95	0.8063	0.0022	mg/L	0.1	0.1
Cobalt*	32	37.5	Log	0.95	0.9500	0.0043	mg/L	0.006	0.006
Fluoride	34	29.4	Log	0.95	0.9500	0.0654	mg/L	4	4
Lead	32	90.6	NP	0.95	0.8063	0.0010	mg/L	0.015	0.015
Lithium*	32	100	NP	0.95	0.8063	0.0064	mg/L	0.04	0.04
Mercury	32	100	NP	0.95	0.8063	0.0002	mg/L	0.002	0.002
Molybdenum*	32	96.9	NP	0.95	0.8063	0.0050	mg/L	0.1	0.1053
Rad226+228	32	0	NP	0.95	0.8063	1.4600	pCi/L	5	5
Selenium	32	96.9	NP	0.95	0.8063	0.0050	mg/L	0.05	0.05
Thallium	32	100	NP	0.95	0.8063	0.0010	mg/L	0.002	0.002

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

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

- 1) All baseline data - those from designated up-gradient or background wells collected up through from the Program's first sampling event through August of 2018 were grouped and checked for possible outliers.

At (list plant name), no likely outliers among the background data were flagged. (If outlier's are identified a brief description of outlier, potential causes and whether or not the outlier was retained in the data set.

- 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 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  $\kappa$  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	Units	N	No. of NDs	Minimum	Maximum	Mean	Median
Antimony	mg/L	32	31	0.0006	0.0020	0.0006	0.0013
Arsenic	mg/L	32	14	0.0003	0.0031	0.0012	0.0010
Barium	mg/L	32	0	0.0206	0.0852	0.0471	0.0422
Beryllium	mg/L	32	32	0.0010	0.0010	0.0005	0.0010
Cadmium	mg/L	32	16	0.0001	0.0010	0.0003	0.0003
Chromium	mg/L	32	19	0.0005	0.0025	0.0007	0.0006
Cobalt	mg/L	32	13	0.0001	0.0011	0.0003	0.0003
Lead	mg/L	32	4	0.0306	0.2880	0.1295	0.0880
Lithium	mg/L	32	25	0.0001	0.0010	0.0002	0.0002
Mercury	mg/L	32	20	0.0022	0.0099	0.0040	0.0038
Molybdenum	mg/L	32	32	0.0002	0.0002	0.0001	0.0002
Radium 226 + 228	pCi/L	32	3	0.0006	0.0955	0.0413	0.0379
Selenium	mg/L	30	0	0.0190	2.5300	0.8943	0.8175
Thallium	mg/L	32	31	0.0024	0.0050	0.0024	0.0037

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 confidence interval (CI) against a groundwater protection standard (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 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.

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. Discuss outliers and whether they were retained in data set.

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

To assess whether any SSLs occurred during the 2018 Assessment Monitoring at JOF, the confidence interval (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