

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



Tennessee Valley Authority
Shawnee Fossil Plant Ash Pond 2
and Consolidated Waste Dry Stack
Multiunit 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 Shawnee Fossil Plant Ash Pond 2 and Consolidated Waste Dry Stack Multiunit 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 Ash Pond 2 and Consolidated Waste Dry Stack CCR Multiunit at the Tennessee Valley Authority (TVA) Shawnee Fossil Plant (SHF). The Consolidated Waste Dry Stack is also known as the Special Waste Landfill.

An overview of the current status of the groundwater monitoring and corrective action program for Ash Pond 2 and Consolidated Waste Dry Stack CCR Multiunit is provided below.

- At the start and end of the 2019 current annual reporting period, the Ash Pond 2 and Consolidated Waste Dry Stack CCR Multiunit was operating under an assessment monitoring program in accordance with 40 CFR § 257.95. The assessment monitoring program for the Ash Pond 2 and Consolidated Waste Dry Stack CCR Multiunit was initiated on August 15, 2018.
- In the 2018 assessment monitoring sampling, statistically significant levels (SSLs) above the groundwater protection standard for molybdenum was observed at monitoring well D-74B. As a result, an assessment of corrective measures was initiated for the Ash Pond 2 and Consolidated Waste Dry Stack CCR Multiunit on April 15, 2019 and was completed on July 15, 2019.
- For the 2019 assessment monitoring events, the previously observed molybdenum-related SSL was not recorded at well D-74B.
- As a remedy has not been selected for the Ash Pond 2 and Consolidated Waste Dry Stack CCR Multiunit 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.
- Remedial activities have not been initiated for the Ash Pond 2 and Consolidated Waste Dry Stack CCR Multiunit 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 SHF Ash Pond 2 and Consolidated Waste Dry Stack CCR Multiunit 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 molybdenum at monitoring well D-74B.
- Placed notification of the statistical exceedances of the groundwater protection standard for molybdenum at monitoring well D-74B 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 Kentucky in accordance with 40 CFR §257.106(h)(6); and placed 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).

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- As there has been no indication of offsite migration of molybdenum-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 Kentucky 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)¹.
- 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.

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).
- Evaluate 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).
- Continue to refine the characterization of the nature and extent of the release in accordance with 40 CFR § 257.95(g)(1).

¹ 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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- Perform further site characterization to improve the SHF 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 Kentucky in accordance with 40 CFR § 257.106(h)(6); and place 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

The Consolidated Waste Dry Stack (CWDS) is located to the west of the powerhouse. The original portions of the stack have interim cover and are approximately 110 acres in area and about 100 feet in height. The unit is considered an active CCR landfill unit and currently receives dry fly ash and flue gas desulfurization wastes from the plant and dredged bottom ash from Ash Pond 2. Ash Pond 2 is used for: (1) storage of fly ash and bottom ash from coal burning at the Shawnee Fossil Plant, and (2) clarification and treatment of sludge and plant flows.

The monitoring well network for the SHF Ash Pond 2 and Consolidated Waste Dry Stack CCR Multiunit consists of one background well (SHF-102G) and four downgradient wells (D-11B, D-30B, D-74B, and SHF-101G). The downgradient wells are installed at the waste boundary. Figure 1 is an aerial photograph that shows the groundwater monitoring well locations. The monitoring well network was designed for a multi-unit CCR unit (Ash Pond 2 [Main Ash Pond/Stilling Pond] and Consolidated Waste Dry Stack).

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 Rule 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.

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The 2019 assessment monitoring groundwater sampling was conducted between July² 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 Ohio 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. The groundwater flow at SHF is influenced by the Ohio River to the north of the site. The primary groundwater flow direction is in a northeastern direction toward the Ohio River.

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, 2019). The uppermost aquifer at the SHF Ash Pond 2 and Consolidated Waste Dry Stack CCR Multiunit is the Regional Gravel Aquifer (RGA), which is overlain by Upper Continental Sand, and then the Upper Continental Clay, above which is alluvium. The RGA rests unconformably on top of the McNairy Formation, consisting of Cretaceous fluvial deltaic sandstones and clays. The RGA has a geometric mean hydraulic conductivity of 1.00×10^{-2} centimeters per second (cm/sec). Linear groundwater flow velocity was calculated for the uppermost aquifer using:

- the geometric mean hydraulic conductivity calculated from hydraulic testing (1.00×10^{-2} cm/sec);
- horizontal hydraulic gradients measured during the implementation of the groundwater sampling and analysis program, ranging from 0.0038 to 0.0043 feet per foot (ft/ft); and,
- an effective porosity of 16% (Stantec, 2010).

The average linear flow velocity in the uppermost aquifer ranges from approximately 245 to 280 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).

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

² Scheduled groundwater sampling events between January and June 2019 could not be completed due to prolonged elevated Ohio River stage.

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considered the appropriate groundwater protection standard depending on background well concentrations for each Appendix IV³ constituent.⁴ 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 July and October of 2019.⁵ 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)⁶ 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, the previously observed molybdenum-related SSL was not recorded at monitoring well D-74B as summarized in Table 6.

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 Kentucky 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 2018 Assessment Monitoring, one molybdenum-related SSL was recorded at well D-74B; however, during the 2019 Assessment Monitoring, the previously observed molybdenum-related SSL was not recorded at well D-74B. Despite the absence of an SSL in the current data set, TVA is continuing to evaluate potential remedies in accordance with 40 CFR § 257.97 in the event future monitoring data demonstrates the necessity. 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.

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

⁴ USEPA has published MCLs or alternate regulatory limits for each of the Appendix IV constituents. Consequently, in most cases the groundwater protection standard is equal to the MCL. However, there may be cases where background levels of a constituent exceed the MCL. In these instances, an alternate groundwater protection standard must be derived from on-site background levels. On July 30, 2018, EPA provided alternate regulatory limits (i.e., 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.

⁵ 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.

⁶ The October 2019 retest groundwater sampling event that followed the second semiannual sampling event was not included in the statistical evaluation. This information will be included in the statistical evaluation of 2020 assessment monitoring sampling events.

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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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References:

Stantec, 2010. *Report of Geotechnical Exploration and Slope Stability Evaluation. Ash Pond 1 & 2 and Consolidated Waste Dry Stack.* Shawnee Fossil Plant. July 14, 2010.

Terracon, 2019. *Aquifer Testing and Equipment Blank Results. TVA CCR Rule – Shawnee Fossil Plant (SHF).* Terracon Consultants, Inc. January 15, 2019.

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

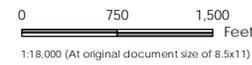
Table 6 – Statistically Significant Levels (SSLs) Above GWPSs

Appendix A – 2019 Statistical Analysis Report

FIGURES



- Background Well
- Downgradient Well
- CCR Unit Boundary (Approximate)
- TVA Property Boundary



Notes
 1. Coordinate System: NAD 1983 StatePlane Kentucky South FIPS 1602 Feet
 2. Imagery Source: Provided by Client (Dated 2016)

Project Location: West Paducah, McCracken County, Kentucky
 Prepared by LMB on 2020-01-03
 Technical Review by MD on 2020-01-03
 Independent Review by TR on 2020-01-03

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

Figure No.: 1

Title: Map with CCR Unit Background and Downgradient Wells



U:\B0025\A\gh\mxd\fig_1\CCRUnit_Background_andDowngradientWells.mxd Revised: 2020/01/03 by: Billmanan

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- ▲ 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 Kentucky South FIPS 1602 Feet
 2. Imagery Source: Provided by Client (Dated 2016)

Project Location: West Paden, McCracken County, Kentucky
 Prepared by LMB on 2020-01-03
 Technical Review by MD on 2020-01-03
 Independent Review by TR on 2020-01-03

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

Figure No.: 2

Title: Generalized Groundwater Flow Direction Map



Groundwater flow directions are based on Ohio River elevations and groundwater elevations from CCR and Non-CCR monitoring wells.

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TABLES

**Table 1
Assessment Monitoring
Groundwater Sampling
Results**

**CCR Annual Groundwater Monitoring
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Shawnee Fossil Plant**

Monitoring Well		D-11B							
Sample Date		31-Jul-19		27-Aug-19		24-Sep-19		16-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
Total Metals									
Antimony	ug/L	< 0.378	U	< 0.378	U	< 0.378	U	0.492	J
Arsenic	ug/L	0.328	J	< 0.507	U*	0.366	J	< 0.545	U*
Barium	ug/L	58.9		59.3		40.7		43.8	
Beryllium	ug/L	< 0.182	U	< 0.182	U	< 0.182	U	< 0.46	U*
Boron	ug/L	1420	J	1880		1100		1280	
Cadmium	ug/L	0.352	J	0.431	J	0.225	J	0.311	J
Calcium	ug/L	36100		40400		28800		33700	
Chromium	ug/L	< 1.53	U	< 2.37	U*	< 1.53	U	< 1.53	U
Cobalt	ug/L	1.15		1.58		1.42		1.61	
Lead	ug/L	0.15	J	< 0.128	U	< 0.128	U	< 0.128	U
Lithium	ug/L	9.03		11.1		9.63		8.76	
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	< 1.51	U	< 1.51	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.148	U	< 0.148	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	< 0.0981	U	< 0.646	U	< 0.790	U	< 0.786	U
Anions									
Chloride	mg/L	16.5		17.4		16.4		16.9	
Fluoride	mg/L	0.0999	J	0.0721	J	< 0.0545	U*	0.0603	J
Sulfate	mg/L	125	J	137		109		121	
General Chemistry									
Total Dissolved Solids	mg/L	254		303		252		289	
Field Parameters									
Temperature, Water	DEG_C	19.1		18.8		19.4		18.3	
Turbidity (field)	NTU	11.3		4.7		2.13		2.69	
ORP	mV	-211.1		175.5		179.1		182.3	
Specific Conductivity (field)	mS/cm	0.361		0.414		0.29		0.355	
Dissolved Oxygen	mg/L	0.21		0.25		0.07		0.41	
pH (field)	SU	5.28		5.09		4.92		5.25	

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
Shawnee Fossil Plant**

Monitoring Well		D-30B							
Sample Date		31-Jul-19		27-Aug-19		24-Sep-19		16-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
Total Metals									
Antimony	ug/L	0.799	J	< 0.378	U	< 0.378	U	< 0.378	U
Arsenic	ug/L	< 0.323	U	< 0.472	U*	0.364	J	< 0.4	U*
Barium	ug/L	92.8		99.5		102		85.2	
Beryllium	ug/L	< 0.24	U*	< 0.182	U	< 0.182	U	< 0.606	U*
Boron	ug/L	10900	J	11500		7870		7690	
Cadmium	ug/L	0.156	J	0.238	J	0.268	J	0.138	J
Calcium	ug/L	84100		83700		96500		94400	
Chromium	ug/L	< 1.53	U	< 2.4	U*	< 1.53	U	< 1.53	U
Cobalt	ug/L	2.18		2.7		3.31		3.83	
Lead	ug/L	< 0.128	U						
Lithium	ug/L	3.97	J	4.34	J	4.5	J	< 3.39	U
Mercury	ug/L	< 0.101	U						
Molybdenum	ug/L	< 0.61	U						
Selenium	ug/L	< 1.51	U						
Thallium	ug/L	< 0.256	U*	< 0.148	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	< 0.161	U	< 0.646	U	< 0.223	U	< 1.15	U
Anions									
Chloride	mg/L	25.4		24		25.5		23.1	
Fluoride	mg/L	0.142		0.127		< 0.0803	U*	0.0813	J
Sulfate	mg/L	202	J	208		245		213	
General Chemistry									
Total Dissolved Solids	mg/L	456		459		533		489	
Field Parameters									
Temperature, Water	DEG_C	19.1		18.7		18.5		18.3	
Turbidity (field)	NTU	3		1.19		0.8		0.69	
ORP	mV	-190.7		53.3		34		28.6	
Specific Conductivity (field)	mS/cm	0.650		0.661		0.67		0.69	
Dissolved Oxygen	mg/L	0.22		0.25		0.06		0.28	
pH (field)	SU	6.29		6.05		6.07		6.17	

Notes:

Q - Data Qualifier

U* - Result should be considered "not-detected" because it was detected in a rinsate blank or laboratory blank at a 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
Shawnee Fossil Plant**

Monitoring Well		D-74B							
Sample Date		31-Jul-19		27-Aug-19		24-Sep-19		16-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
Total Metals									
Antimony	ug/L	< 0.378	U	< 0.378	U	< 0.378	U	< 0.378	U
Arsenic	ug/L	1.14		< 0.776	U*	0.525	J	< 0.499	U*
Barium	ug/L	56		51.5		44.3		41.7	
Beryllium	ug/L	< 0.182	U	< 0.182	U	< 0.182	U	< 0.44	U*
Boron	ug/L	4940	J	4610		3140		3240	
Cadmium	ug/L	0.38	J	0.351	J	0.281	J	0.521	J
Calcium	ug/L	34700		27100		22900		22400	
Chromium	ug/L	13.2	J	< 2.56	U*	< 1.53	U	< 1.53	U
Cobalt	ug/L	3.03		2.78		1.9		1.46	
Lead	ug/L	< 0.128	U	< 0.128	U	< 0.128	U	< 0.128	U
Lithium	ug/L	< 3.39	U	4.77	J	< 3.39	U	< 3.39	U
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	68.6		65.7		79.5		110	
Selenium	ug/L	< 1.51	U	< 1.51	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.148	U	< 0.148	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	< 0.447	U	< 0.596	U	< 1.04	U	< 0.197	U
Anions									
Chloride	mg/L	19.5		19.5		18.2		18	
Fluoride	mg/L	0.145		0.135		< 0.0874	U*	0.0952	J
Sulfate	mg/L	93.5	J	68.1		62.2		57.3	
General Chemistry									
Total Dissolved Solids	mg/L	192		161		186		148	
Field Parameters									
Temperature, Water	DEG_C	21.1		21		21.1		20.6	
Turbidity (field)	NTU	0.32		0.36		0.41		0.3	
ORP	mV	-149.5		148.4		160.6		107.1	
Specific Conductivity (field)	mS/cm	0.31		0.271		0.224		0.234	
Dissolved Oxygen	mg/L	0.23		0.24		0.04		0.26	
pH (field)	SU	5.81		5.52		5.45		5.95	

Notes:

Q - Data Qualifier

U* - Result should be considered "not-detected" because it was detected in a rinsate blank or laboratory blank at a 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
Shawnee Fossil Plant**

Monitoring Well		SHF-101G							
Sample Date		01-Aug-19		27-Aug-19		24-Sep-19		16-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
Total Metals									
Antimony	ug/L	< 0.378	U						
Arsenic	ug/L	1.46		< 1.18	U*	1.48		< 1.2	U*
Barium	ug/L	< 31.1	U*	33		32.1		29.2	
Beryllium	ug/L	< 0.182	U	< 0.182	U	< 0.182	U	< 0.548	U*
Boron	ug/L	3140	J	3380		2660		2940	
Cadmium	ug/L	< 0.125	U						
Calcium	ug/L	22200		21700		21500		22200	
Chromium	ug/L	4.21		< 1.53	U	< 1.53	U	< 1.53	U
Cobalt	ug/L	1.42		1.73		1.66		1.65	
Lead	ug/L	< 0.128	U						
Lithium	ug/L	5.72		8.25		7.37		5.87	
Mercury	ug/L	< 0.101	U						
Molybdenum	ug/L	< 0.679	U*	< 0.61	U	< 0.61	U	< 0.61	U
Selenium	ug/L	< 1.51	U						
Thallium	ug/L	< 0.148	U						
Radium 226 + Radium 228	pCi/L	< 0.139	U	< 0.116	U	< 0.240	U	< 0.688	U
Anions									
Chloride	mg/L	19.1		19.6		18.8		18.6	
Fluoride	mg/L	0.105		0.0991	J	< 0.0735	U*	0.0751	J
Sulfate	mg/L	68.8		73.9		69.1		69	
General Chemistry									
Total Dissolved Solids	mg/L	151		178		208		172	
Field Parameters									
Temperature, Water	DEG_C	18.7		18.8		19.1		17.4	
Turbidity (field)	NTU	3.68		0.83		0.5		0.34	
ORP	mV	48.5		117.6		95.7		59	
Specific Conductivity (field)	mS/cm	0.248		0.251		0.229		0.251	
Dissolved Oxygen	mg/L	0.29		0.45		0.23		0.52	
pH (field)	SU	5.78		5.44		5.46		5.95	

Notes:

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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
Shawnee Fossil Plant**

Monitoring Well		SHF-102G							
Sample Date		30-Jul-19		26-Aug-19		23-Sep-19		15-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
Total Metals									
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	< 0.385	U*
Barium	ug/L	157		147		168		161	
Beryllium	ug/L	< 0.182	U	< 0.182	U	< 0.182	U	< 0.881	U*
Boron	ug/L	< 38.6	UJ	< 38.6	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	26300		26000		25100		24600	
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	< 0.121	U*
Lead	ug/L	< 0.128	U	< 0.128	U	< 0.128	U	< 0.128	U
Lithium	ug/L	5.16		6.49		6.78		< 5.32	U*
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	< 1.51	U	< 1.51	U	1.73	J	< 1.51	U
Thallium	ug/L	< 0.148	U	< 0.148	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	< 0.178	U	0.617	J	1.19	J	< 0.695	U
Anions									
Chloride	mg/L	33.8		35.9		33.9		33.2	
Fluoride	mg/L	0.196		0.201		0.133		0.121	
Sulfate	mg/L	11.8	J	11.2		11.5		11.9	
General Chemistry									
Total Dissolved Solids	mg/L	205		193		230		205	J
Field Parameters									
Temperature, Water	DEG_C	16.1		15.8		16.1		15.5	
Turbidity (field)	NTU	2		3.45		0.54		0.52	
ORP	mV	-100.3		180.5		120.5		215.8	
Specific Conductivity (field)	mS/cm	0.362		0.367		0.333		0.361	
Dissolved Oxygen	mg/L	3.77		4.91		3.64		3.89	
pH (field)	SU	6.07		5.83		5.86		6.27	

Notes:

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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 Shawnee Fossil Plant**

Well ID	Well Designation	Number of Samples Collected	July 30 - August 1, 2019	August 26-27, 2019	September 23-24, 2019	October 15-16, 2019	Monitoring Program
Sample Round			1	1 - Retest	2	2 - Retest	
D-11B	Downgradient	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
D-30B	Downgradient	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
D-74B	Background	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
SHF-101G	Background	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
SHF-102G	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 Shawnee Fossil Plant**

Groundwater Elevation Collection Date		30-Jul-19	26-Aug-19	23-Sep-19	15-Oct-19
Monitoring Well	Units				
D-11B	ft-MSL	312.64	306.60	304.74	304.46
D-30B	ft-MSL	306.69	303.30	303.59	303.32
D-74B	ft-MSL	312.55	310.16	310.02	309.89
SHF-101G	ft-MSL	311.68	308.61	306.83	306.71
SHF-102G	ft-MSL	324.30	322.58	321.18	318.38
		Surface Water			
Ohio River	ft-MSL	305.68	301.98	301.18	301.08

Notes:

ft-MSL - feet above mean sea level

**Table 4
Hydraulic Conductivity Data
Summary**

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

Well ID	Well Designation	Slug Test Hydraulic Conductivity (cm/sec)
D-11B	Downgradient	NA
D-30B	Downgradient	1.00E-02
D-74B	Downgradient	1.09E-02
SHF-101G	Downgradient	NA
SHF-102G	Background	9.24E-03
Geometric Mean of Hydraulic Conductivity (cm/sec)		1.00E-02

Notes:

cm/sec - centimeters per second

NA - Not available

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

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

Groundwater Elevation Collection Date	30-Jul-19	26-Aug-19	23-Sep-19	15-Oct-19
Sample Round	1	1 - Retest	2	2 - Retest
Horizontal Gradient	0.0038	0.0043	0.0040	0.0039
Hydraulic Conductivity (cm/sec)	1.00E-02	1.00E-02	1.00E-02	1.00E-02
Effective Porosity	16%	16%	16%	16%
Flow Direction (cardinal)	Northeast	Northeast	Northeast	Northeast
Linear Velocity (ft/yr)	245	280	260	254

Notes:

cm/sec - centimeters per second

ft/yr - feet per year

TABLE 6: Statistically Significant Levels (SSLs) Above GWPSs

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	None	NA	NA
Chromium (mg/l)	0.1	0.1	None	NA	NA
Cobalt (mg/l)	0.006	0.006	D-74B	0.0016	NO
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	None	NA	NA
Mercury (mg/l)	0.002	0.002	None	NA	NA
Molybdenum (mg/l)	0.1053	0.1	D-74B	0.06	NO
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) GWPSs documented in notice dated 10/15/2018 [reported in milligrams per liter (mg/L)]

(b) GWPSs updated as of 11/14/2019 with 3 additional sample results collected on July 30, 2019 through August 1, 2019, August 26-27, 2019 and September 23-25, 2019 [reported in mg/L]

(c) Downgradient wells with analytical results above GWPS November 2016 through September 23-25, 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 23-25, 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
SHAWNEE 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) Shawnee Fossil Plant (SHF) Ash Pond 2 and Consolidated Waste Dry Stack Multiunit CCR Unit. 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 Ash Pond 2 and Consolidated Waste Dry Stack Multiunit CCR Unit 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 Ash Pond 2 and Consolidated Waste Dry Stack Multiunit CCR Unit located at SHF. 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. An SSI is found if and only if the lower limit of the CI band exceeds the GWPS for the most recent Assessment Monitoring sampling event.

At the SHF 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 July 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	
SHF-102G	D-11B SHF-101G	D-74B D-30B

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

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.

Appendix A summary of constituents included in the data analysis is provided in the second column of **Table 2**.

Table 2. CCR Rule Monitored Constituents

Appendix III Constituents (Detection Monitoring)	Appendix IV Constituents (Assessment Monitoring)
Boron	Antimony
Calcium	Arsenic
Chloride	Barium
Fluoride	Beryllium
pH (field)	Cadmium
Sulfate	Chromium
Total Dissolved Solids (TDS)	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 the SHF, **Table 3, included below**, lists the calculated UTLs and final GWPS established for CCR Unit.

Table 3. SHF Groundwater Protection Standards (GWPS)

COI	N	ND.PCT	MODEL	COV	CONF	UTL	UNITS	MCL	GWPS
Antimony	18	100	NP	0.95	0.603	0.0020	mg/L	0.006	0.006
Arsenic	18	61.1	Log	0.95	0.950	0.0005	mg/L	0.01	0.01
Barium	18	0	NORMAL	0.95	0.950	0.1929	mg/L	2	2
Beryllium	18	100	NP	0.95	0.603	0.0010	mg/L	0.004	0.004
Cadmium	18	100	NP	0.95	0.603	0.0010	mg/L	0.005	0.005
Chromium	18	100	NP	0.95	0.603	0.0031	mg/L	0.1	0.1
Cobalt*	18	83.3	NP	0.95	0.603	0.0005	mg/L	0.006	0.006
Fluoride	18	0	Cube	0.95	0.950	0.2764	mg/L	4	4
Lead	18	100	NP	0.95	0.603	0.0010	mg/L	0.015	0.015
Lithium*	18	38.9	Square	0.95	0.950	0.0081	mg/L	0.04	0.04
Mercury	18	100	NP	0.95	0.603	0.0002	mg/L	0.002	0.002
Molybdenum*	18	94.4	NP	0.95	0.603	0.0050	mg/L	0.1	0.1
Rad226+228	18	0	Cube Root	0.95	0.950	1.7726	pCi/L	5	5
Selenium	18	55.6	Seventh Power	0.95	0.950	0.0019	mg/L	0.05	0.05
Thallium	18	83.3	NP	0.95	0.603	0.0010	mg/L	0.002	0.002

* No potential Health Effects provided for these Constituents of Interests (COI) - See Appendix "C"

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 from the Program's first sampling event through September 2019 were grouped and checked for possible outliers.

At SHF, one statistical outlier among the background data was flagged and confirmed by Rosner's test for fluoride at well SHF-102G (result = 0.482 mg/L). This value was excluded from subsequent calculations.

- 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 κ is a multiplier which depends on the number of baseline measurements, as well as the desired coverage and confidence levels. If the data have been transformed, the final UTL is derived by back-transforming the scaled UTL.

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	18	18	0.0020	0.0020	0.0010	0.0020
Arsenic	mg/L	18	11	0.0002	0.0018	0.0003	0.0003
Barium	mg/L	18	0	0.1470	0.1860	0.1687	0.1680
Beryllium	mg/L	18	18	0.0010	0.0010	0.0005	0.0010
Cadmium	mg/L	18	18	0.0010	0.0010	0.0005	0.0010
Chromium	mg/L	18	18	0.0020	0.0031	0.0010	0.0020
Cobalt	mg/L	18	15	0.0001	0.0005	0.0001	0.0001
Fluoride	mg/L	19	0	0.1330	0.4820	0.2283	0.2150
Lead	mg/L	18	18	0.0010	0.0010	0.0005	0.0010
Lithium	mg/L	18	7	0.0052	0.0093	0.0067	0.0068
Mercury	mg/L	18	18	0.0002	0.0002	0.0001	0.0002
Molybdenum	mg/L	18	17	0.0005	0.0050	0.0005	0.0027
Rad226+228	pCi/L	18	0	0.1780	1.2100	0.6206	0.5770
Selenium	mg/L	18	10	0.0010	0.0050	0.0016	0.0016
Thallium	mg/L	18	15	0.0001	0.0010	0.0001	0.0001

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, a SSI is identified. If none of the interval, or only part, exceeds the GWPS, no SSI 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 SSI is identified for that sampling event.

At SHF, 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 SSIs.

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.

2.3 Comparing Confidence Interval Bands Against GWPS

To assess whether any SSIs occurred during the 2019 Assessment Monitoring at SHF, the confidence interval (CI) bands were compared against the constituent-specific GWPS. An SSI was identified if and only if the CI band fully exceeded the GWPS at the *most recent* sampling event.

As with the grouped background data, the data were initially screened for evidence of outliers. Two outliers were flagged and excluded from subsequent statistical calculations, including one observation each of arsenic (0.0069 mg/L) and chromium (0.0132 mg/L) at D-74B.

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 statistically significant level (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 SHF site, no SSLs were found during the Assessment Monitoring. However, one molybdenum-related warning flag was recorded at well D-74B. In summary, a total of one warning was identified at Program network wells that are located near to the SHF plant’s CCR Unit during the Assessment Monitoring.

Table 5. SHF 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				
		SHF-102G	D-11B	SHF-101G	D-74B	D-30B
1.	Antimony	GREEN	GREEN	GREEN	GREEN	GREEN
2.	Arsenic	GREEN	GREEN	GREEN	GREEN	GREEN
3.	Barium	GREEN	GREEN	GREEN	GREEN	GREEN
4.	Beryllium	GREEN	GREEN	GREEN	GREEN	GREEN
5.	Cadmium	GREEN	GREEN	GREEN	GREEN	GREEN
6.	Chromium	GREEN	GREEN	GREEN	GREEN	GREEN
7.	Cobalt	GREEN	GREEN	GREEN	GREEN	GREEN
8.	Fluoride	GREEN	GREEN	GREEN	GREEN	GREEN
9.	Lead	GREEN	GREEN	GREEN	GREEN	GREEN
10.	Lithium	GREEN	GREEN	GREEN	GREEN	GREEN
11.	Mercury	GREEN	GREEN	GREEN	GREEN	GREEN
12.	Molybdenum	GREEN	GREEN	GREEN	YELLOW	GREEN
13.	Rad226+228	GREEN	GREEN	GREEN	GREEN	GREEN
14.	Selenium	GREEN	GREEN	GREEN	GREEN	GREEN
15.	Thallium	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