2018 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
1101 Market Street
Chattanooga, TN 37402

Prepared by:
Stantec Consulting Services Inc.
8770 Guion Road, Suite B
Indianapolis, IN 46268

January 31, 2019

Stantec

January 31, 2019

Reference: **2018 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 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 Ash Pond 2 and Consolidated Waste Dry Stack Multiunit CCR Unit at the Tennessee Valley Authority (TVA) Shawnee Fossil Plant (SHF). In 2017, TVA established a groundwater monitoring network and program at the SHF Ash Pond 2 and Consolidated Waste Dry Stack Multiunit 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 Kentucky 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).

- Performed field and desktop site characterization investigations to improve the SHF 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 Kentucky 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 SHF 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.

- 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 are covered 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 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 sluice and plant waters and stormwater runoff from the plant, Consolidated Waste Dry Stack (Special Waste Landfill), and Coal Yard Drainage Basin.

The monitoring well network for the SHF Ash Pond 2 (Main Ash Pond/Stilling Pond) and Consolidated Dry Stack Multi-Unit CCR unit 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 Dry Stack).

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 June 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 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 northern 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 (Main Ash Pond/Stilling Pond) and Consolidated Dry Stack Multi-Unit CCR unit 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 0.002 to 0.006 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 129 to 388 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[1] constituent[2]. 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

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

[2] 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.

August of 2018[3]. 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 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 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, one molybdenum-related SSL was recorded at well D-74B.

NARRATIVE DISCUSSION OF ANY TRANSITION BETWEEN MONITORING PROGRAMS

In January 2018, TVA evaluated the groundwater monitoring data for SSIs over background levels for the constituents listed in Appendix III[4] as required by 40 CFR 257.93(h). The groundwater analytical results from the initial round of detection monitoring indicated SSIs of Appendix III CCR constituents at the downgradient monitoring wells. TVA performed error checking and investigated whether the SSI over background resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality as specified in 40 CFR 257.94(e)(2). TVA also performed investigations to determine whether a source other than the CCR materials contained within the SHF Ash Pond 2 and Consolidated Waste Dry Stack Multiunit was the cause of the SSI. The alternate source demonstration study did not demonstrate that the SSI 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 Kentucky 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, one molybdenum-related SSL was recorded at monitoring well D-74B. 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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[3] 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.

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

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.

Prepared by Benjamin D. Schutt
(signature)

Benjamin D. Schutt, PE
Environmental Engineer

Reviewed by
(signature)

Jeremiah H. Armitage, LPG
Senior Geologist

Reviewed by
(signature)

John E. Griggs, LPG
Principal Geologist

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.

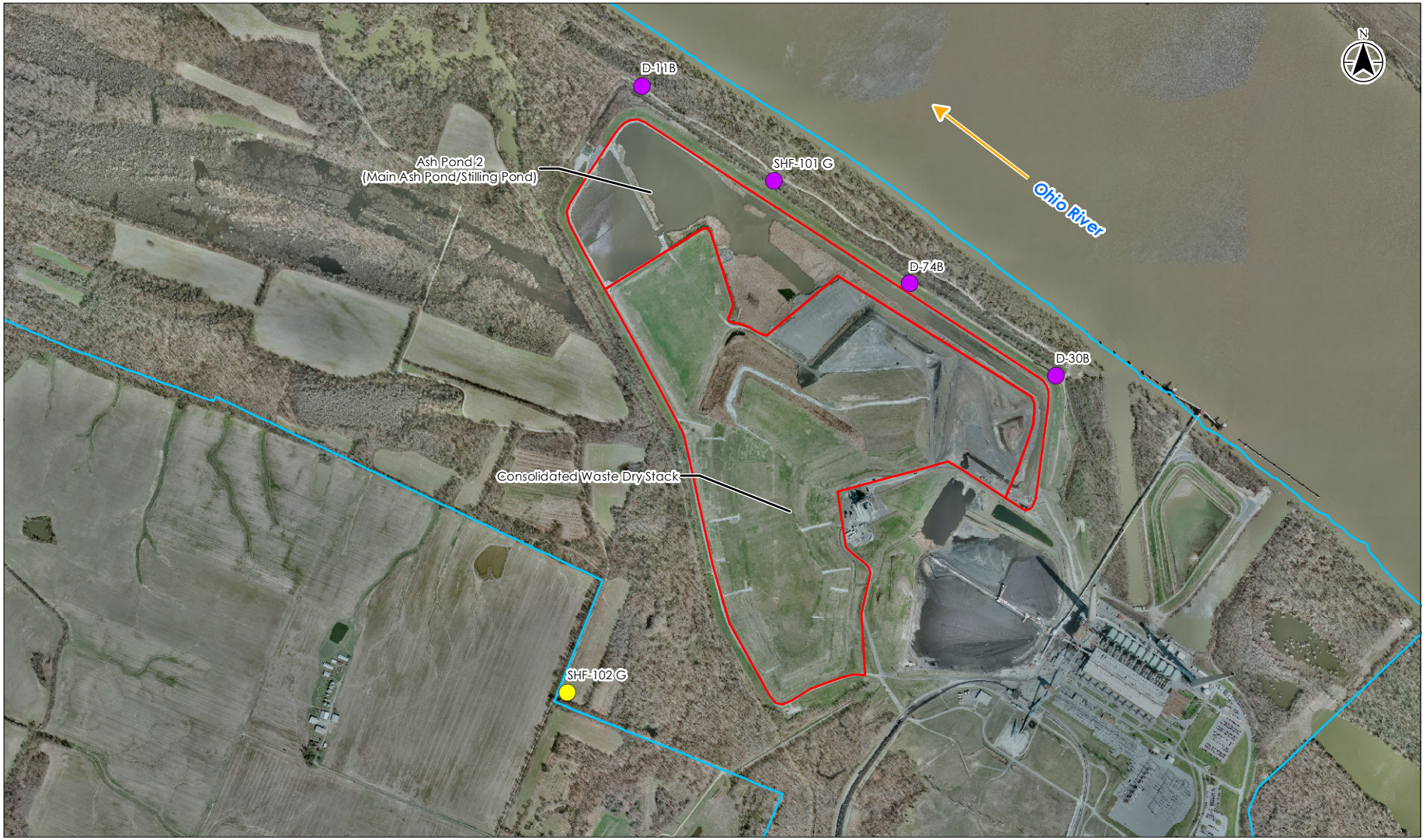
Attachments:

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 – Groundwater Protection Standards

Appendix A – 2018 Statistical Analysis Report

FIGURES



- Background Well
- Downgradient Well
- CCR Unit Subject to CCR Rule
- TVA Property Boundary

0 750 1,500 Feet

1:18,000 (At original document size of 8.5x11)

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

Stantec

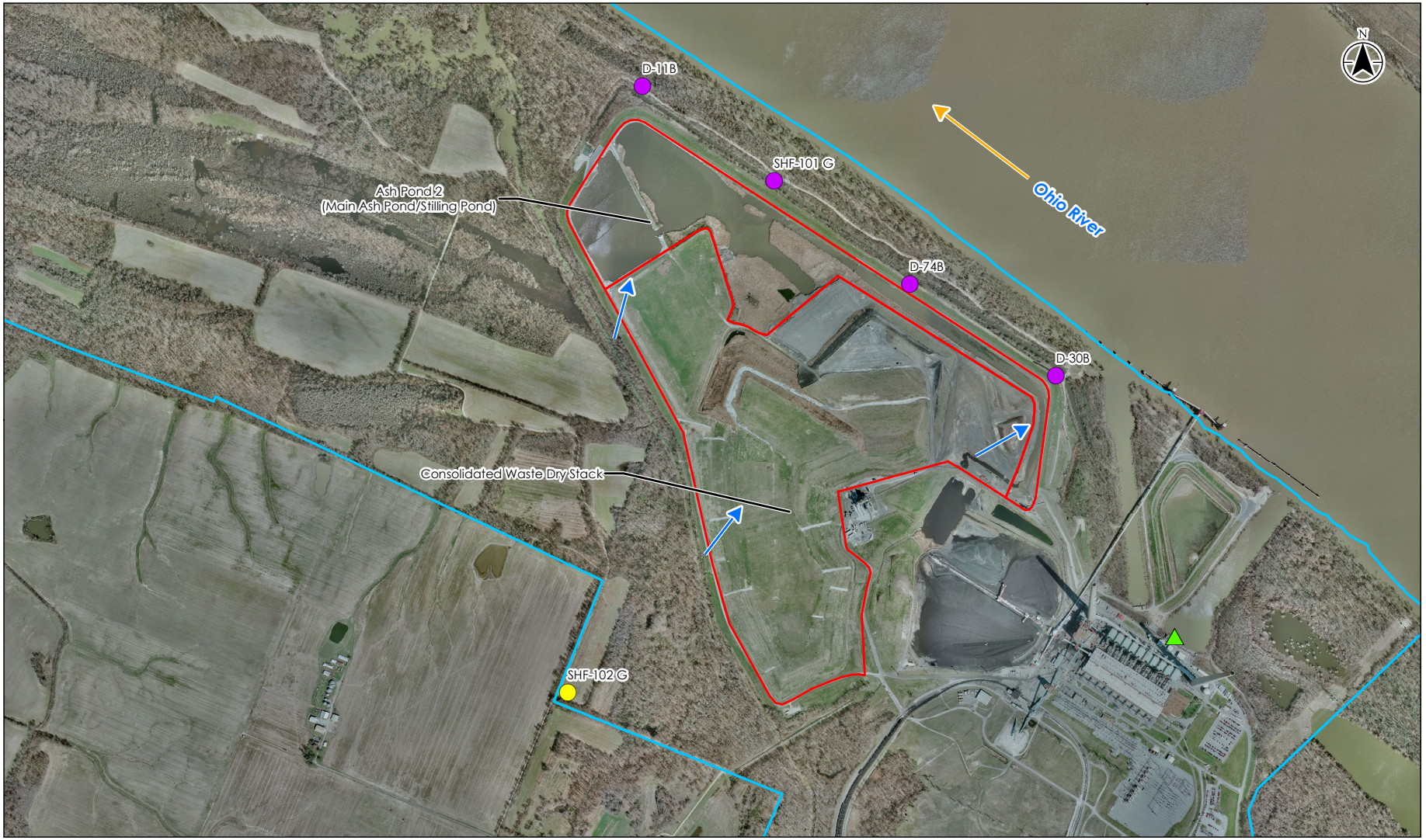
TVA

Project Location	182603174
West Paducah McCracken County, Kentucky	Prepared by WSW on 2018-01-30 Technical Review by MD on 2018-01-30 Independent Review by JK on 2018-01-30

Client/Project
Tennessee Valley Authority
Shawnee Fossil Plant
CCR Rule

Figure No.
1

Title
Map with CCR Unit Background and Downgradient Wells



Staff Gauge
Background Well
Downgradient Well
Groundwater Flow Direction
CCR Unit Subject to CCR Rule
TVA Property Boundary

0 750 1,500 Feet

1:18,000 (At original document size of 8.5x11)

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

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

Stantec

TVA

Project Location
West Paducah
McCracken County, Kentucky

182603174
Prepared by CMB on 2018-12-17
Technical Review by WSW on 2018-12-17
Independent Review by MD on 2018-12-17

Client/Project
Tennessee Valley Authority
Shawnee Fossil Plant
CCR Rule

Figure No.
2

Title
Generalized Groundwater Flow Direction Map

TABLES

Table 1
Assessment Monitoring
Groundwater Sampling Results

Monitoring Well		D-11B									
Sample Date		05-Jun-18		26-Jun-18		17-Jul-18		07-Aug-18		27-Aug-18	
Sample Round		1		2		3		4		5	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals											
Antimony	mg/L	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U
Arsenic	mg/L	< 0.000687	U*	0.000623	J	< 0.000740	U*	0.000447	J	0.000505	J
Barium	mg/L	0.0578		0.0388		0.0436		0.0324		0.0358	
Beryllium	mg/L	< 0.000104	U*	< 0.0000570	U	0.0000930	J	< 0.0000570	U	< 0.0000570	U
Boron	mg/L	1.89		1.71		1.08		1.09		1.41	
Cadmium	mg/L	0.000488	J	0.000476	J	0.000314	J	0.000252	J	0.000431	J
Calcium	mg/L	45.0		48.9		34.7		29.6		42.5	
Chromium	mg/L	< 0.00166	U*	< 0.00122	U*	< 0.00206	U*	< 0.00170	U*	< 0.00161	U*
Cobalt	mg/L	0.00162		0.000963		0.00129		0.00106		0.000843	
Lead	mg/L	0.000193	J	0.000182	J	0.000288	J	< 0.0000940	U	0.000113	J
Lithium	mg/L	0.0120	J	0.00860		0.00952		0.00919		0.00963	
Mercury	mg/L	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U
Molybdenum	mg/L	< 0.000474	U	< 0.000474	U	< 0.000474	U	< 0.000474	U	< 0.000474	U
Selenium	mg/L	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U
Thallium	mg/L	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U
Radium 226 + Radium 228	pCi/L	0.587	J	0.766	J	0.626	U*	0.700	U*	0.434	U*
Anions											
Chloride	mg/L	20.0		20.0		19.4		15.1		20.0	
Fluoride	mg/L	0.0395	J	0.135	J	0.0890	J	< 0.0645	U*	0.0905	J
Sulfate	mg/L	164		168		128		97.1		146	
General Chemistry											
Total Dissolved Solids	mg/L	317		356		281		242		303	
Field pH											
pH (field)	SU	5.18		5.18		5.27		5.26		5.22	

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

Table 1
Assessment Monitoring
Groundwater Sampling Results

Monitoring Well		D-30B									
Sample Date		06-Jun-18		26-Jun-18		18-Jul-18		08-Aug-18		28-Aug-18	
Sample Round		1		2		3		4		5	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals											
Antimony	mg/L	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U
Arsenic	mg/L	< 0.000595	U*	0.000511	J	< 0.000559	U*	< 0.000323	U	0.000502	J
Barium	mg/L	0.0595		0.0706		0.0586		0.0402		0.0470	
Beryllium	mg/L	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U
Boron	mg/L	3.55		3.97		2.95		0.746		0.405	
Cadmium	mg/L	0.000141	J	0.000155	J	0.000125	J	< 0.000125	U	< 0.000125	U
Calcium	mg/L	60.9		64.6		51.8		30.1		25.3	
Chromium	mg/L	< 0.00127	U*	< 0.00105	U*	< 0.00177	U*	< 0.000631	U	< 0.00222	U*
Cobalt	mg/L	0.00194		0.00212		0.00156		0.000852		0.000895	
Lead	mg/L	< 0.000156	U*	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U
Lithium	mg/L	0.00448	J	0.00310	J	< 0.00362	U*	< 0.00256	U	0.00267	J
Mercury	mg/L	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U
Molybdenum	mg/L	< 0.000474	U	< 0.000474	U	< 0.000474	U	< 0.000474	U	< 0.000474	U
Selenium	mg/L	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U
Thallium	mg/L	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U
Radium 226 + Radium 228	pCi/L	0.315	J	0.490	J	0.758	U*	0.308	U*	0.448	U*
Anions											
Chloride	mg/L	23.2		23.3		24.5		15.6		17.7	
Fluoride	mg/L	0.171		0.137	J	0.166		0.159		0.190	
Sulfate	mg/L	97.3		113		92.2		37.1		27.5	
General Chemistry											
Total Dissolved Solids	mg/L	308		349		284		215		174	
Field pH											
pH (field)	SU	6.27		6.26		6.31		6.38		6.30	

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

Table 1
Assessment Monitoring
Groundwater Sampling Results

Monitoring Well		D-74B									
Sample Date		06-Jun-18		26-Jun-18		18-Jul-18		08-Aug-18		28-Aug-18	
Sample Round		1		2		3		4		5	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals											
Antimony	mg/L	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U
Arsenic	mg/L	0.00690		0.00251		< 0.00174	U*	0.000976	J	0.00106	
Barium	mg/L	0.0490		0.0517		0.0476		0.0465		0.0459	
Beryllium	mg/L	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U
Boron	mg/L	3.48		2.81		2.84		2.92		2.93	
Cadmium	mg/L	0.000174	J	0.000243	J	0.000250	J	0.000267	J	0.000219	J
Calcium	mg/L	26.5		24.5		23.3		21.5		22.0	
Chromium	mg/L	< 0.00132	U*	< 0.00101	U*	< 0.00110	U*	< 0.000631	U	< 0.00208	U*
Cobalt	mg/L	0.00695		0.00402		0.00275		0.00172		0.00162	
Lead	mg/L	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U
Lithium	mg/L	0.00365	J	< 0.00256	U	< 0.00293	U*	< 0.00256	U	< 0.00256	U
Mercury	mg/L	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U
Molybdenum	mg/L	0.174		0.184		0.158		0.215		0.232	
Selenium	mg/L	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U
Thallium	mg/L	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U
Radium 226 + Radium 228	pCi/L	0.221	U	0.0635	UJ	0.650	U*	0.357	U*	0.428	U*
Anions											
Chloride	mg/L	20.8		20.2		22.5		17.9		21.2	
Fluoride	mg/L	0.249		0.232		0.188		0.198		0.212	
Sulfate	mg/L	61.6		52.6		61.9		57.1		56.3	
General Chemistry											
Total Dissolved Solids	mg/L	163		159		161		174		153	
Field pH											
pH (field)	SU	6.19		6.07		5.94		6.05		5.98	

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

Table 1
Assessment Monitoring
Groundwater Sampling Results

Monitoring Well		SHF-101G									
Sample Date		06-Jun-18		26-Jun-18		17-Jul-18		08-Aug-18		28-Aug-18	
Sample Round		1		2		3		4		5	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals											
Antimony	mg/L	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U
Arsenic	mg/L	0.00201		0.00107		< 0.00113	U*	0.000718	J	0.00139	
Barium	mg/L	0.0315		0.0322		0.0327		0.0254		0.0307	
Beryllium	mg/L	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U
Boron	mg/L	3.31		2.96		2.42		2.71		2.90	
Cadmium	mg/L	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U
Calcium	mg/L	23.9		23.2		20.8		18.0		20.8	
Chromium	mg/L	< 0.00149	U*	< 0.00105	U*	< 0.00184	U*	< 0.000631	U	< 0.00201	U*
Cobalt	mg/L	0.00182		0.00184		0.00154		0.00123		0.00171	
Lead	mg/L	< 0.000114	U*	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U
Lithium	mg/L	0.00922		0.00795		0.00804		0.00676		0.00702	
Mercury	mg/L	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U
Molybdenum	mg/L	< 0.000474	U	< 0.000474	U	< 0.000474	U	< 0.000474	U	< 0.000474	U
Selenium	mg/L	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U
Thallium	mg/L	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	0.0000640	J
Radium 226 + Radium 228	pCi/L	0.270	J	1.01		0.873	J	0.394	U*	0.599	U*
Anions											
Chloride	mg/L	19.1		18.5		20.5		16.9		20.6	
Fluoride	mg/L	0.133		0.102	J	0.103		0.0954	J	0.114	
Sulfate	mg/L	71.2		69.7		74.3		73.5		72.8	
General Chemistry											
Total Dissolved Solids	mg/L	163		193		185		200		178	
Field pH											
pH (field)	SU	5.92		5.83		5.74		5.82		5.92	

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

Table 1
Assessment Monitoring
Groundwater Sampling Results

Monitoring Well		SHF-102G									
Sample Date		05-Jun-18		25-Jun-18		17-Jul-18		07-Aug-18		27-Aug-18	
Sample Round		1		2		3		4		5	
Well Designation		Upgradient		Upgradient		Upgradient		Upgradient		Upgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals											
Antimony	mg/L	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U
Arsenic	mg/L	< 0.000413	U*	< 0.000403	U*	< 0.000492	U*	0.000349	J	0.000403	J
Barium	mg/L	0.183		0.186		0.185		0.164		0.168	
Beryllium	mg/L	< 0.0000570	UJ	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U
Boron	mg/L	< 0.0303	U	< 0.0303	U	< 0.0303	U	< 0.0303	U	< 0.0303	U
Cadmium	mg/L	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U
Calcium	mg/L	25.8		26.1		25.8		23.7		24.1	
Chromium	mg/L	< 0.00124	U*	< 0.00122	U*	< 0.00184	U*	< 0.00186	U*	< 0.00216	U*
Cobalt	mg/L	< 0.0000750	U	< 0.0000750	U	< 0.0000750	U	< 0.0000750	U	0.000174	J
Lead	mg/L	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U
Lithium	mg/L	0.00818	J	0.00721		0.00669		0.00688		0.00637	
Mercury	mg/L	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U
Molybdenum	mg/L	< 0.000474	U	< 0.000474	U	< 0.000474	U	< 0.000474	U	0.000479	J
Selenium	mg/L	0.00102	J	0.00159	J	0.00148	J	< 0.000813	U	< 0.000813	U
Thallium	mg/L	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	0.0000690	J
Radium 226 + Radium 228	pCi/L	0.178	U	0.689	U*	0.521	U*	0.898	U*	0.415	U*
Anions											
Chloride	mg/L	34.6		36.5		37.3		32.3		34.5	
Fluoride	mg/L	0.255		0.482	J	0.210		0.176		0.204	
Sulfate	mg/L	11.9		12.6		12.4		9.75		9.73	
General Chemistry											
Total Dissolved Solids	mg/L	214		212		230		230		196	
Field pH											
pH (field)	SU	6.20		6.23		6.15		6.28		6.19	

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

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	June 5-6, 2018	June 25-26, 2018	July 16-17, 2018	August 7-8, 2018	August 27-28, 2018	Assessment Monitoring Program
D-11B	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
D-30B	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
D-74B	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
SHF-101G	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
SHF-102G	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

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		05-Jun-18	25-Jun-18	16-Jul-18	07-Aug-18	27-Aug-18
Monitoring Well	**Units**					
D-11B	ft-MSL	309.72	309.77	307.17	304.36	303.79
D-30B	ft-MSL	308.08	305.17	300.03	299.37	299.37
D-74B	ft-MSL	312.74	311.21	309.22	308.62	308.58
SHF-101G	ft-MSL	310.51	309.64	309.07	307.00	306.65
SHF-102G	ft-MSL	323.25	322.38	322.27	321.06	320.22
Ohio River	ft-MSL	306.79	302.18	295.84	295.53	295.54

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

Kellberg, J.M., 1951. *Geology of the Shawnee Steam Plant Site* . Central Planning. 29-3.

Lindquist, Kathrine F., Bohac, Charles E., and Young, Steve, 1992. *Shawnee Groundwater Assessment, Phase II. Report No. WR28-1-35-112. Norris, Tennessee.*

Table 5 - Groundwater Protection Standards

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA Shawnee 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	0.0328*
Cadmium	mg/L	0.005
Calcium	mg/L	27*
Chloride	mg/L	35.6*
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	5.83 - 6.57*
Radium 226 + Radium 228	pCi/L	5
Selenium	mg/L	0.05
Sulfate	mg/L	14.4*
Thallium	mg/L	0.002
Total Dissolved Solids	mg/L	257*

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 SHAWNEE FOSSIL PLANT

2018

1/15/2019

Contents

Tables

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) Shawnee Fossil Plant (SHF) Ash Pond 2 and Consolidated Waste Dry Stack Multiunit CCR Unit. 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 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 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 five distinct monitoring events that were performed between June 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	
SHF-102G	D-11B	D-74B
	SHF-101G	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 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 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	15	100	NP	0.95	0.5367	0.0020	mg/L	0.006	0.006
Arsenic	15	53.3	Log	0.95	0.9500	0.0005	mg/L	0.01	0.01
Barium	15	0	Log	0.95	0.9500	0.1934	mg/L	2	2
Beryllium	15	100	NP	0.95	0.5367	0.0010	mg/L	0.004	0.004
Cadmium	15	100	NP	0.95	0.5367	0.0010	mg/L	0.005	0.005
Chromium	15	100	NP	0.95	0.5367	0.0031	mg/L	0.1	0.1
Cobalt*	15	80	NP	0.95	0.5367	0.0005	mg/L	0.006	0.006
Fluoride	15	0	Square	0.95	0.9500	0.2845	mg/L	4	4
Lead	15	100	NP	0.95	0.5367	0.0010	mg/L	0.015	0.015
Lithium*	15	46.7	Log	0.95	0.9500	0.0081	mg/L	0.04	0.04
Mercury	15	100	NP	0.95	0.5367	0.0002	mg/L	0.002	0.002
Molybdenum*	15	93.3	NP	0.95	0.5367	0.0050	mg/L	0.1	0.1053
Rad226+228	14	0	Square Root	0.95	0.9500	1.6748	pCi/L	5	5
Selenium	15	53.3	Sixth Power	0.95	0.9500	0.0019	mg/L	0.05	0.05
Thallium	15	80	NP	0.95	0.5367	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 up through from the Program’s first sampling event through August of 2018 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:

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

where $\overline{x}$ 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	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, 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 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.

2.3 Comparing Confidence Interval Bands Against GWPS

To assess whether any SSIs occurred during the 2018 Assessment Monitoring at SHF, the confidence interval (CI) bands were compared against the constituent-specific GWPS. A SSI 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 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, one molybdenum-related SSL during the Assessment Monitoring was recorded at well D-74B. No warning flags (yellow) were found. In summary, a total of one SSL 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	RED	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