2019 Annual Groundwater Monitoring and Corrective Action Report

Tennessee Valley Authority
Paradise Fossil Plant Gypsum
Disposal Area Multi-Unit CCR Unit

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Reference: 2019 Annual Groundwater Monitoring and Corrective Action Report
TVA Paradise Fossil Plant Gypsum Disposal Area Multi-Unit 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 Gypsum Disposal Area Multi-Unit CCR Unit at the Tennessee Valley Authority (TVA) Paradise Fossil Plant (PAF).

An overview of the current status of the groundwater monitoring and corrective action program for the Gypsum Disposal Area Multi-Unit is provided below.

- At the start and end of the current 2019 annual reporting period, the Gypsum Disposal Area Multi-Unit was operating under an assessment monitoring program in accordance with 40 CFR § 257.95. The assessment monitoring program for the Gypsum Disposal Area Multi-Unit was initiated on August 15, 2018.
- In the 2018 assessment monitoring sampling, statistically significant levels (SSLs) above the groundwater protection standards were not observed at the downgradient monitoring wells. As a result, an assessment of corrective measures was neither required nor initiated for the Gypsum Disposal Area Multi-Unit.
- For the 2019 assessment monitoring events, no SSLs above the groundwater protection standards were recorded in the certified monitoring well network for the PAF Gypsum Disposal Area Multi-Unit.
- No Semiannual Report on the Progress of Remedy Selection was required to be placed in the operating record 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 Gypsum Disposal Area Multi-Unit 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 PAF Gypsum Disposal Area Multi-Unit in accordance with 40 CFR § 257.90. The groundwater monitoring network was certified by a qualified Professional Engineer as required by 40 CFR § 257.91(f). During 2019, TVA performed the following groundwater monitoring activities:

- For the 2019 semiannual assessment monitoring events, wells in the certified monitoring network were sampled and analyzed 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 2019 Annual Report in accordance with 40 CFR § 257.95(d)(3). No SSLs over groundwater protection standards were observed.
- Placed notification of no exceedances of groundwater protection standards was placed 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 records 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).
- Perform further site characterization to improve the PAF Conceptual Site Model (CSM).
- 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).

[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.

GROUNDWATER MONITORING WELL NETWORK

The Gypsum Disposal Area is located in the southwest corner of PAF. The Gypsum Disposal Area is bordered by hilly and grassy areas on all sides. Gypsum Disposal Area Stilling Ponds 1 & 2 are located at the southeast end of the Gypsum Disposal Area. The Gypsum Disposal Area is approximately 225 acres in area and partially enclosed by a 1.4-mile-long dike with a maximum height of approximately 62 feet. TVA placed the Gypsum Disposal Area (previously named Gypsum Stack Ash Pond) into service in 1986 as a conventional pond but then converted the pond to a disposal stack for co-mingled gypsum and fly ash in 1996. The Gypsum Disposal Area currently serves as a disposal facility for gypsum and fly ash. Stilling Pond 1 & 2 receive process water and stormwater drainage from the Gypsum Disposal Area and the surrounding drainage area. Stilling Pond 1 is approximately 15 acres in area and Stilling Pond 2 is approximately 6 acres in area. Stilling Pond 1 drains to Stilling Pond 2, which discharges to a surface water channel that eventually leads to the Peabody Ash Pond, which is located on the southeast side of PAF.

The monitoring well network for the PAF Gypsum Disposal Area Multi-Unit consists of one background well (95-48A), two upgradient wells (PAF-101 and PAF-104) and five downgradient wells (94-35A, PAF-103, PAF-114, PAF-115, and PAF-116). The downgradient wells are installed at the waste boundary. Figure 1 is an aerial photograph that shows the Gypsum Disposal Area and the groundwater monitoring well locations. The monitoring well network was designed for a CCR Multi-Unit (Gypsum Disposal Area, Gypsum Disposal Area Stilling Pond 1, and Gypsum Disposal Area Stilling Pond 2).

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, as required by 40 CFR § 257.93(a), 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). The groundwater monitoring program includes sampling and analysis procedures designed to provide monitoring results that are an accurate representation of groundwater quality at background and downgradient wells.

The 2019 assessment monitoring groundwater sampling was conducted between January 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 Green 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 PAF is influenced by the Green River to the northeast and Jacobs Creek to the east and southeast. The groundwater flow direction in the vicinity of the PAF Gypsum Disposal Area Multi-Unit is to the east-southeast. The PAF Gypsum Disposal Area Multi-Unit is underlain by mine spoils that can be locally clay

rich but are mostly silty materials with interspersed sandy zones that include occasional gravels and boulders.

Testing for hydraulic conductivity at the background, upgradient, or downgradient groundwater monitoring wells, as summarized in Table 4, was determined by a 2018 hydrogeologic evaluation (Terracon, 2018). Testing data indicates the uppermost saturated zone within the mine spoils has a geometric mean hydraulic conductivity of 3.6×10^{-3} centimeters per second (cm/sec). Linear groundwater flow velocity was calculated for the uppermost aquifer using:

- the geometric mean hydraulic conductivity calculated from hydraulic testing (3.6×10^{-3} cm/sec);
- horizontal hydraulic gradients measured during the implementation of the groundwater sampling and analysis program, ranging from 0.0097 to 0.0106 feet per foot (ft/ft); and,
- an effective porosity of 30% (assumed effective porosity value [TVA, 1998]).

The average linear flow velocity in the uppermost aquifer ranges from approximately 121 to 133 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 considered the appropriate groundwater protection standard depending on background well concentrations for each Appendix IV[2] constituent.[3] The 2019 Statistical Analysis Report is included in Appendix A and covers the three CCR Units at PAF.

The sampling results used to identify potential groundwater protection standards exceedances were obtained during four monitoring events that were performed between January and October of 2019.[4] Comparisons were made against a fixed groundwater protection standard via a confidence interval band.

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

[3] 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 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.

[4] 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.

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)[5] 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. No SSLs above groundwater protection standards were recorded during 2019 Assessment Monitoring in the certified monitoring well network for the PAF Gypsum Disposal Area Multi-Unit.

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 in Table 6. During 2019 Assessment Monitoring, no SSLs were recorded in the certified monitoring well network for the PAF Gypsum Disposal Area. 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.

[5] The September/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.

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:

TVA, 1998. Paradise Fossil Plant Groundwater Assessment No. WR98-1-64-124. October 1998.

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

Attachments:

Figure 1 – Map with CCR Unit Background and Downgradient Wells
Figure 2 – Generalized Groundwater Flow Direction Map

Table 1 – Assessment Monitoring Groundwater Sampling Results
Table 2 – Groundwater Sampling Summary
Table 3 – Groundwater and Surface Water Elevation Summary
Table 4 – Hydraulic Conductivity Data Summary
Table 5 – Rate and Direction of Groundwater Flow Summary
Table 6 – Statistically Significant Levels (SSLs) Above GWPSs

Appendix A – 2019 Statistical Analysis Report

FIGURES

Background Well

Upgradient Well

Downgradient Well

CCR Unit Subject to CCR Rule

TVA Property Boundary

0 1,500 3,000 Feet

1:36,000 (At original document size of 8.5x11)

Notes
1. Coordinate System: NAD 1983 StatePlane Kentucky South FIPS 1602 Feet
2. Basemap Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Project Location	182603529
Drakesboro	Prepared by LMB on 2020-01-03
Muhlenberg County,	Technical Review by MD on 2020-01-03
Kentucky	Independent Review by TR on 2020-01-03

Client/Project
Tennessee Valley Authority
Paradise Fossil Plant
CCR Rule

Figure No.
1

Title
Map with CCR Unit Background and Downgradient Wells

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

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

0 1,500 3,000 Feet

1:36,000 (At original document size of 8.5x11)

Notes
1. Coordinate System: NAD 1983 StatePlane Kentucky South FIPS 1602 Feet
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Paradise Fossil Plant
CCR Rule

Figure No.
2

Title
Generalized Groundwater Flow Direction Map

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TABLES

Table 1
Assessment Monitoring Groundwater Sampling Results

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

Monitoring Well		94-35A							
Sample Date		09-Jan-19		05-Mar-19		23-Jul-19		02-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	< 1.12	U	< 0.378	U	0.481	J	< 0.378	U
Arsenic	ug/L	3.99		2.59		3.1		3	
Barium	ug/L	14.6		< 13.8	U*	< 16.1	U*	13.2	
Beryllium	ug/L	< 0.057	U	< 0.155	U	< 0.182	U	< 0.376	U*
Boron	ug/L	16100		13200		12600		12100	
Cadmium	ug/L	< 0.125	U	< 0.125	U	< 0.125	U	< 0.125	U
Calcium	ug/L	490000		372000		366000		402000	
Chromium	ug/L	< 0.768	U*	< 1.53	U	< 1.78	U*	< 1.53	U
Cobalt	ug/L	3.74		3.51		4.22		5.14	
Lead	ug/L	< 0.166	U*	< 0.128	U	0.137	J	0.255	J
Lithium	ug/L	112		78.7	J	78.6		82.7	
Mercury	ug/L	< 0.0653	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	3.26	J	2.47	J	2.5	J	2.57	J
Selenium	ug/L	< 0.813	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.063	U	< 0.128	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	0.703	J	< 0.769	U*	< 0.509	U	1.53	J
Anions									
Chloride	mg/L	281		247		234		256	
Fluoride	mg/L	0.36		0.348		0.281		0.213	J
Sulfate	mg/L	1620		1320		1450		1660	
General Chemistry									
Total Dissolved Solids	mg/L	3280		2800		2980		3490	
Field Parameters									
Temperature, Water (C)	DEG_C	15.8		15		17.7		18.3	
Turbidity, field	NTU	4.36*		4.45		4.17		2.11	
ORP	mV	2		-5.9		-195.9		-274.4	
Specific Cond. (Field)	mS/cm	3.85		3.34		3.55		3.18	
Dissolved Oxygen	mg/L	0.17		2.63		0.12		0.31	
pH (field)	SU	6.15		6.7		6.71		6.5	

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

* - Turbidity measurement collected prior to the final turbidity value, final turbidity value not measured

ASSESSMENT MONITORING

Table 1
Assessment Monitoring Groundwater Sampling Results

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

Monitoring Well		95-48A							
Sample Date		08-Jan-19		04-Mar-19		23-Jul-19		01-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	< 1.12	U	< 0.378	U	< 0.378	U	< 0.378	U
Arsenic	ug/L	6.6		5.19		5.72		5.61	
Barium	ug/L	5.65	J	< 5.75	U*	< 5.84	U*	5.44	J
Beryllium	ug/L	0.891	J	1.03		0.928	J	< 1.73	U*
Boron	ug/L	285		291		304		307	
Cadmium	ug/L	< 0.125	U	< 0.125	U	< 0.125	U	< 0.125	U
Calcium	ug/L	469000		435000		384000		425000	
Chromium	ug/L	< 0.631	U	< 1.53	U	< 1.53	U	< 1.53	U
Cobalt	ug/L	82.1		99.5		84.1		71.6	
Lead	ug/L	< 0.094	U	< 0.294	U*	< 0.128	U	< 0.128	U
Lithium	ug/L	166		146		150		167	
Mercury	ug/L	< 0.0653	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	0.982	J	< 0.61	U	< 0.61	U	< 0.61	U
Selenium	ug/L	< 0.813	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	0.192	J	< 0.128	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	1.99	J	1.50	J	1.72		2.79	
Anions									
Chloride	mg/L	36.5		33.4		35.7		36.5	
Fluoride	mg/L	0.513		0.526		0.368		0.292	
Sulfate	mg/L	2960		3000		2920		2960	
General Chemistry									
Total Dissolved Solids	mg/L	4580		4120		4130		4100	
Field Parameters									
Temperature, Water (C)	DEG_C	14.3		8.6		16		17.6	
Turbidity, field	NTU	5.53		12.5		3.48		2.39	
ORP	mV	1.5		66.8		-27.6		-313.1	
Specific Cond. (Field)	mS/cm	4.55		4.06		4.48		3.64	
Dissolved Oxygen	mg/L	0.35		0.36		0.19		0.19	
pH (field)	SU	6.7		6.01		6.03		5.94	

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DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

ASSESSMENT MONITORING

Table 1
Assessment Monitoring Groundwater Sampling Results

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

Monitoring Well		PAF-101							
Sample Date		09-Jan-19		06-Mar-19		23-Jul-19		01-Oct-19	
Sample Round		1		1 - Retest		2		2 - Retest	
Well Designation		Upgradient		Upgradient		Upgradient		Upgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals									
Antimony	ug/L	< 1.12	U	< 0.378	U	0.667	J	< 0.378	U
Arsenic	ug/L	8.79		4.84		3.22		3.14	
Barium	ug/L	19.9		< 251	U*	22.4		21.4	
Beryllium	ug/L	< 0.057	U	< 0.155	U	0.191	J	< 0.458	U*
Boron	ug/L	372		396		420		360	
Cadmium	ug/L	< 0.125	U	< 0.125	U	< 0.125	U	< 0.125	U
Calcium	ug/L	209000		160000		151000		152000	
Chromium	ug/L	< 0.631	U	1.62	J	< 1.6	U*	< 1.53	U
Cobalt	ug/L	0.488	J	0.531		0.54		0.37	J
Lead	ug/L	< 0.094	U	< 0.128	U	< 0.128	U	< 0.128	U
Lithium	ug/L	65.4		70.3		53.6		61.8	
Mercury	ug/L	< 0.0653	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	5.67		6.07		6.48		7	
Selenium	ug/L	< 0.813	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.063	U	< 0.128	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	< 0.227	U	< 0.237	U	< 0.168	U	1.38	J
Anions									
Chloride	mg/L	2.43		2.81		2.61		2.61	
Fluoride	mg/L	0.45		0.376		0.429		0.29	
Sulfate	mg/L	509		440		339		409	
General Chemistry									
Total Dissolved Solids	mg/L	1190		1110		1020		1020	
Field Parameters									
Temperature, Water (C)	DEG_C	15.5		15.5		16.9		17.2	
Turbidity, field	NTU	3		4.26		3.31		1.63	
ORP	mV	-45.6		-41.2		-153.1		-260.8	
Specific Cond. (Field)	mS/cm	1.67		1.5		1.5		1.23	
Dissolved Oxygen	mg/L	0.17		0.66		0.19		0.22	
pH (field)	SU	6.39		6.93		6.96		6.81	

Notes:

Q - Data Qualifier

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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

ASSESSMENT MONITORING

Table 1
Assessment Monitoring Groundwater Sampling Results

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

Monitoring Well		PAF-103							
Sample Date		10-Jan-19		05-Mar-19		24-Jul-19		01-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	< 1.12	U	< 0.378	U	< 0.378	U	0.845	J
Arsenic	ug/L	< 2.15	U*	1.05		1.24		1.48	
Barium	ug/L	21.6		< 19.1	U*	< 18.9	U*	17.1	
Beryllium	ug/L	< 0.057	U	< 0.155	U	< 0.182	U	< 1.15	U*
Boron	ug/L	1020		902		885		926	
Cadmium	ug/L	< 0.125	U	< 0.125	U	< 0.125	U	< 0.125	U
Calcium	ug/L	335000		301000		268000		280000	
Chromium	ug/L	< 0.631	U	< 1.53	U	< 1.53	U	< 1.53	U
Cobalt	ug/L	7.58		6.25		6.68		6.07	
Lead	ug/L	< 0.094	U	< 0.128	U	< 0.128	U	< 0.128	U
Lithium	ug/L	90.2		79.4		72.4		86.1	
Mercury	ug/L	< 0.0653	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	2.46	J	2.37	J	2.09	J	< 3.26	U*
Selenium	ug/L	< 0.813	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.063	U	< 0.128	U	< 0.148	U	< 0.707	U*
Radium 226 + Radium 228	pCi/L	1.06	J	0.660	J	0.636	J	< 0.0648	U
Anions									
Chloride	mg/L	19.4		21.9		17		17.2	
Fluoride	mg/L	0.308		0.321		0.163	J	0.185	J
Sulfate	mg/L	1280		1210		1210		1220	
General Chemistry									
Total Dissolved Solids	mg/L	2500		2330		2420		2510	
Field Parameters									
Temperature, Water (C)	DEG_C	14.6		11.7		19.3		21.4	
Turbidity, field	NTU	1.44		1.79		0.68		0.31	
ORP	mV	10.4		8.7		-156.9		-316.9	
Specific Cond. (Field)	mS/cm	3		2.78		2.97		2.42	
Dissolved Oxygen	mg/L	0.34		0.54		0.34		0.43	
pH (field)	SU	7.78		6.52		6.57		6.49	

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

ASSESSMENT MONITORING

Table 1
Assessment Monitoring Groundwater Sampling Results

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

Monitoring Well		PAF-104							
Sample Date		08-Jan-19		06-Mar-19		23-Jul-19		01-Oct-19	
Sample Round		1		1 - Retest		2		2 - Retest	
Well Designation		Upgradient		Upgradient		Upgradient		Upgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals									
Antimony	ug/L	< 1.12	U	< 0.378	U	< 0.378	U	< 0.378	U
Arsenic	ug/L	6.59		5.29		5.39		4.79	
Barium	ug/L	12.7		< 118	U*	< 12.7	U*	12.4	
Beryllium	ug/L	< 0.057	U	< 0.155	U	< 0.182	U	< 0.456	U*
Boron	ug/L	933		886		931		940	
Cadmium	ug/L	< 0.125	U	< 0.125	U	< 0.125	U	< 0.125	U
Calcium	ug/L	321000		283000		279000		288000	
Chromium	ug/L	< 0.631	U	< 1.53	U	< 1.53	U	< 1.53	U
Cobalt	ug/L	3.86		3.63		4.08		3.91	
Lead	ug/L	< 0.094	U	< 0.128	U	< 0.128	U	< 0.128	U
Lithium	ug/L	58.1		59.6		52.3		60.3	
Mercury	ug/L	< 0.0653	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	1.49	J	1.38	J	1.3	J	< 1.32	U*
Selenium	ug/L	< 0.813	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.063	U	< 0.128	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	0.675	J	0.634		< 0.229	U	1.01	J
Anions									
Chloride	mg/L	69.2		58.3		56.1		56.1	
Fluoride	mg/L	0.227	J	0.21	J	0.207	J	0.165	J
Sulfate	mg/L	1460		1490		1440		1490	
General Chemistry									
Total Dissolved Solids	mg/L	3010		2860		2710		2890	
Field Parameters									
Temperature, Water (C)	DEG_C	16.2		15.5		16.9		17.3	
Turbidity, field	NTU	1.36		0.7		0.44		0.46	
ORP	mV	-24.4		-24.3		-74.9		-260.8	
Specific Cond. (Field)	mS/cm	3.7		3.47		3.66		3.01	
Dissolved Oxygen	mg/L	0.3		0.44		0.35		0.2	
pH (field)	SU	6.72		6.6		6.62		6.55	

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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

ASSESSMENT MONITORING

Table 1
Assessment Monitoring Groundwater Sampling Results

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

Monitoring Well		PAF-114							
Sample Date		10-Jan-19		05-Mar-19		24-Jul-19		02-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	< 1.12	U	< 0.378	U	0.388	J	< 0.378	U
Arsenic	ug/L	< 2.5	U*	0.735	J	0.999	J	0.814	J
Barium	ug/L	21.9		< 20.5	U*	24.1		17.3	
Beryllium	ug/L	0.181		< 0.155	U	0.203	J	< 1	U*
Boron	ug/L	42900		41100		43800		41700	
Cadmium	ug/L	< 0.125	U	< 0.125	U	< 0.125	U	< 0.125	U
Calcium	ug/L	673000		572000		546000		589000	
Chromium	ug/L	< 0.631	U	< 1.53	U	< 1.53	U	< 1.53	U
Cobalt	ug/L	6.22		5.66		6.32		5.93	
Lead	ug/L	1.23		< 0.148	U*	< 0.128	U	< 0.128	U
Lithium	ug/L	98.5		80.2		82.4		88.2	
Mercury	ug/L	< 0.0653	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	37		36.2		36.5		39.9	
Selenium	ug/L	< 0.813	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	1.35		1.35		1.23		1.2	
Radium 226 + Radium 228	pCi/L	1.03	J	0.730	J	0.638	J	< 0.580	U
Anions									
Chloride	mg/L	439		388		383		396	
Fluoride	mg/L	3.09		2.6		2.46		2.78	
Sulfate	mg/L	1750		1430		1610		1750	
General Chemistry									
Total Dissolved Solids	mg/L	3350		3020		3220		3510	
Field Parameters									
Temperature, Water (C)	DEG_C	16.8		17		18.5		19.6	
Turbidity, field	NTU	0.69		1.41		0.3		0.76	
ORP	mV	-7		-16.1		25.9		-262.7	
Specific Cond. (Field)	mS/cm	3.93		3.65		3.85		3.21	
Dissolved Oxygen	mg/L	0.21		0.27		0.37		0.26	
pH (field)	SU	8.95		6.96		6.61		6.68	

Notes:

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mg/L - milligrams per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

ASSESSMENT MONITORING

Table 1
Assessment Monitoring Groundwater Sampling Results

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

Monitoring Well		PAF-115							
Sample Date		10-Jan-19		07-Mar-19		24-Jul-19		02-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	< 1.12	U	< 0.378	U	0.388	J	< 0.378	U
Arsenic	ug/L	4.06		1.33		2.14		2.23	
Barium	ug/L	18.3		515		< 15.7	U*	13.3	
Beryllium	ug/L	< 0.057	U	< 0.155	U	< 0.182	U	< 0.424	U*
Boron	ug/L	1240		715		716		939	
Cadmium	ug/L	< 0.125	U	< 0.125	U	< 0.125	U	< 0.125	U
Calcium	ug/L	249000		225000		227000		231000	
Chromium	ug/L	< 0.631	U	1.58	J	< 1.79	U*	< 1.53	U
Cobalt	ug/L	3.38		3.54		3.95		3.57	
Lead	ug/L	< 0.094	U	< 0.128	U	< 0.128	U	< 0.128	U
Lithium	ug/L	76.6		86.5		64.3		67.6	
Mercury	ug/L	< 0.0653	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	3.03	J	2.07	J	1.95	J	2.15	J
Selenium	ug/L	< 0.813	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.063	U	< 0.128	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	0.348	J	< 0.335	U	< 0.184	U	< 0.895	U
Anions									
Chloride	mg/L	28.9		23.6		24.5		28	
Fluoride	mg/L	0.348		0.291		0.182	J	0.202	J
Sulfate	mg/L	1270		1390		1310		1320	
General Chemistry									
Total Dissolved Solids	mg/L	2410		2620		2560		2570	
Field Parameters									
Temperature, Water (C)	DEG_C	16		15.6		17.5		18.3	
Turbidity, field	NTU	11.1		4.23		3.94		2.46	
ORP	mV	-18.7		38.8		-179.4		-271.5	
Specific Cond. (Field)	mS/cm	3.25		3.35		3.44		2.88	
Dissolved Oxygen	mg/L	0.14		0.24		0.23		0.16	
pH (field)	SU	6.75		6.77		6.75		6.58	

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

ASSESSMENT MONITORING

Table 1
Assessment Monitoring Groundwater Sampling Results

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

Monitoring Well		PAF-116							
Sample Date		09-Jan-19		07-Mar-19		24-Jul-19		02-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	< 1.12	U	< 0.378	U	< 0.378	U	< 0.378	U
Arsenic	ug/L	12.4		10		10		7.88	
Barium	ug/L	16.7		1420		< 16.5	U*	13.7	
Beryllium	ug/L	0.079	J	< 0.155	U	0.199	J	< 0.453	U*
Boron	ug/L	31400		31500		32200		29200	
Cadmium	ug/L	< 0.125	U	< 0.125	U	< 0.125	U	< 0.125	U
Calcium	ug/L	682000		593000		568000		587000	
Chromium	ug/L	< 0.631	U	1.55	J	< 1.53	U	< 1.53	U
Cobalt	ug/L	5.69		6.19		6.75		4.31	
Lead	ug/L	< 0.094	U	< 0.128	U	< 0.128	U	< 0.128	U
Lithium	ug/L	140		194		116		128	
Mercury	ug/L	< 0.0653	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	42.3		47		45.6		36.5	
Selenium	ug/L	< 0.813	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	0.099	J	< 0.128	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	0.833	J	0.517		0.474	J	< 0.448	U
Anions									
Chloride	mg/L	343		327		316		351	
Fluoride	mg/L	1.21		1.18		0.988		0.881	
Sulfate	mg/L	1800		1750		1770		1960	
General Chemistry									
Total Dissolved Solids	mg/L	3520		3860		3460		3700	
Field Parameters									
Temperature, Water (C)	DEG_C	16.6		17.4		19		19.6	
Turbidity, field	NTU	1.99		0.38		0.62		0.39	
ORP	mV	4.9		-1.2		-185.9		-366.9	
Specific Cond. (Field)	mS/cm	4.13		3.93		4.01		3.43	
Dissolved Oxygen	mg/L	0.3		0.31		0.27		0.23	
pH (field)	SU	6.25		6.33		6.54		6.42	

Notes:

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NTU - Nephelometric Turbidity Units

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mS/cm - milliseimens per centimeter

SU - Standard Unit

ASSESSMENT MONITORING

Table 2
Groundwater Sampling Summary

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

Well ID	Well Designation	Number of Samples Collected	January 8-10, 2019	March 4-7, 2019	July 23-24, 2019	October 1-2, 2019	Monitoring Program
Sample Round			1	1 - Retest	2	2 - Retest	
94-35A	Downgradient	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
95-48A	Background	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
PAF-101	Upgradient	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
PAF-103	Downgradient	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
PAF-104	Upgradient	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
PAF-114	Downgradient	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
PAF-115	Downgradient	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
PAF-116	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 Paradise Fossil Plant

Groundwater Elevation Collection Date		07-Jan-19	04-Mar-19	22-Jul-19	30-Sep-19
Monitoring Well	**Units**				
94-35A	ft-MSL	445.43	446.39	445.52	443.84
95-48A	ft-MSL	445.20	444.08	444.23	443.77
PAF-101	ft-MSL	502.42	506.10	503.43	500.48
PAF-103	ft-MSL	449.51	449.14	449.38	448.97
PAF-104	ft-MSL	478.84	482.15	480.72	477.52
PAF-114	ft-MSL	457.42	458.61	457.05	455.54
PAF-115	ft-MSL	448.05	449.06	446.29	445.51
PAF-116	ft-MSL	467.51	467.81	467.59	465.91
		Surface Water			
Green River	ft-MSL	378.72	390.20	365.92	365.23

Notes:

ft-MSL - Feet above mean sea level

Table 4
Hydraulic Conductivity Data Summary

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

Well ID	Well Designation	Slug Test Hydraulic Conductivity (cm/sec)
94-35A	Downgradient	5.6E-03
95-48A	Background	1.2E-03
PAF-101	Upgradient	2.6E-02
PAF-103	Downgradient	3.45E-04
PAF-104	Upgradient	6.84E-03
PAF-114	Downgradient	9.02E-03
PAF-115	Downgradient	6.06E-03
PAF-116	Downgradient	1.26E-03
Geometric Mean of Hydraulic Conductivity (cm/sec)		**3.6E-03**

Notes:

cm/sec - centimeters per second

Table 5
Rate and Direction of Groundwater Flow Summary

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

Groundwater Elevation Collection Date	7-Jan-19	4-Mar-19	22-Jul-19	30-Sep-19
Sample Round	**1**	**1 - Retest**	**2**	**2 - Retest**
Horizontal Gradient	0.0097	0.0100	0.0106	0.0102
Hydraulic Conductivity (cm/sec)	3.6E-03	3.6E-03	3.6E-03	3.6E-03
Effective Porosity	30%	30%	30%	30%
Flow Direction (cardinal)	East- Southeast	East-Southeast	East-Southeast	East-Southeast
Linear Velocity (ft/yr)	121	124	133	127

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)	0.0136	0.0154	None	NA	NA
Barium (mg/l)	2	2	None	NA	NA
Beryllium (mg/l)	0.05	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)	0.0889	0.0995	None	NA	NA
Fluoride (mg/l)	4	4	None	NA	NA
Lead (mg/l)	0.015	0.015	None	NA	NA
Lithium (mg/l)	0.165	0.17	PAF-116	0.112	NO
Mercury (mg/l)	0.002	0.002	None	NA	NA
Molybdenum (mg/l)	0.1	0.1	None	NA	NA
Radium-226+228 (pCi/l)	5	5	None	NA	NA
Selenium (mg/l)	0.05	0.05	None	NA	NA
Thallium (mg/l)	0.002	0.002	None	NA	NA

Notes:

NA – Not applicable

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

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

(b) GWPSs updated as of 10/3/2019 with 3 additional sample results collected on January 7-11, 2019, March 4-7, 2019 and July 23-25, 2019 [reported in mg/L]

(c) Downgradient wells with analytical results above GWPS November 2016 through July 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 July 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

PARADISE FOSSIL PLANT

2019

1/15/2020

Contents

1 Introduction 2
2 Statistical Analysis 4
2.1 Developing Groundwater Protection Standards (GWPS) 4
2.2 Computing Trend Lines and Confidence Interval Bands 8
2.2.1 Outliers 9
2.3 Comparing Confidence Interval Bands Against GWPS 10
3 Summary of Statistical Analysis 11
4 References 15

Tables

Table 1. CCR Rule Monitoring Well Networks 2
Table 2. CCR Rule Monitored Constituents 3
Table 3A. PAF, Gypsum Stack, Groundwater Protection Standards (GWPS) 5
Table 3B. PAF, Peabody, Groundwater Protection Standards (GWPS) 5
Table 3C. PAF, Slag Pond, Groundwater Protection Standards (GWPS) 6
Table 4A. Descriptive Summary Statistics of Background Data, Gypsum Stack 7
Table 4B. Descriptive Summary Statistics of Background Data, Peabody 8
Table 4C. Descriptive Summary Statistics of Background Data, Slag Pond 8

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) Paradise Fossil Plant (PAF). 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 CCR Units 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 each Unit located at PAF. Consistent with methods presented in USEPA's Unified Guidance document on the statistical analysis of groundwater monitoring data (2009), confidence-interval (CI) bands were compared against relevant GWPS. A statistically significant level (SSL) is found if and only if the lower limit of the CI band exceeds the GWPS for the most recent Assessment Monitoring sampling event.

At the PAF plant's CCR Units, the sampling results used to identify potential GWPS exceedances were obtained during a minimum of three distinct monitoring events that were performed between January and July 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 networks — one for the Gypsum Stack area, one for the Peabody area, and one for the Slag Pond area — as Certified by a Professional Engineer at the firm of AECOM or other, are presented in **Table 1**.

Table 1. CCR Rule Monitoring Well Networks

Site	Background		Downgradient	
Gypsum Stack	95-48A PAF-101 PAF-104		94-35A PAF-114 PAF-103	PAF-115 PAF-116
Peabody Ash Pond	95-48A 10-5	PAF-105 PAF-106	PAF-119 10-6 PAF-118	PAF-117 PAF-107 10-4
Slag Ponds Area	95-48A PAF-108	PAF-109	PAF-110 95-47C	PAF-113 PAF-112

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. 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 GWPS for each Appendix IV constituent. The GWPS is the published MCL/water quality limit or the background concentration (95% UTL with 95% coverage), whichever is larger;
2) Computing trends and associated CI bands for each downgradient well location and Appendix IV constituent (i.e., each well-constituent pair); and
3) Comparing each CI band against its respective GWPS to assess whether an exceedance occurred.

2.1 Developing Groundwater Protection Standards (GWPS)

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

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

On July 17, 2018, EPA unofficially promulgated alternate regulatory limits (i.e., potential GWPS) for four of the Appendix IV chemical Constituents of Interest (COIs) for which the agency has not assigned MCLs to date. In the absence of MCLs or site-specific GWPS, those may be used in place of background levels under 257.95(h)(2). Specifically, those alternate COIs include threshold values at the following health-based levels:

1. Cobalt - 6 µg/L
2. Lithium - 40 µg/L
3. Molybdenum – 100 µg/L
4. Lead - 15 µg/L.

An Upper Tolerance Limit (UTL) with 95% confidence and 95% coverage was calculated using pooled site-specific background data for each Appendix IV parameter. Then these UTLs were compared against the promulgated regulatory limits to determine the site-specific GWPS.

To handle any non-detects in these calculations, non-detect values were treated as statistically 'left-censored,' with the censoring limit equal to the reporting limit (RL). Then the Kaplan-Meier adjustment method (USEPA, 2009) was employed to derive estimated summary statistics that account for the presence of non-detects.

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

Table 3A. PAF, Gypsum Stack, Groundwater Protection Standards (GWPS)

COI	N	ND.PCT	MODEL	COV	CONF	UTL	UNITS	MCL	GWPS
Antimony	57	94.7	NP	0.95	0.946	0.0024	mg/L	0.006	0.006
Arsenic	57	0	NP	0.95	0.946	0.0154	mg/L	0.01	0.0154
Barium	57	14	NP	0.95	0.946	0.2510	mg/L	2	2
Beryllium	57	66.7	Square	0.95	0.950	0.0011	mg/L	0.004	0.004
Cadmium	57	100	NP	0.95	0.946	0.0010	mg/L	0.005	0.005
Chromium	57	91.2	Fourth Root	0.95	0.950	0.0034	mg/L	0.1	0.1
Cobalt*	57	3.5	NP	0.95	0.946	0.0995	mg/L	0.006	0.0995
Fluoride	60	5	Square Root	0.95	0.950	0.6192	mg/L	4	4
Lead	57	87.7	Tenth Root	0.95	0.950	0.0014	mg/L	0.015	0.015
Lithium*	57	0	NP	0.95	0.946	0.1700	mg/L	0.04	0.17
Mercury	57	100	NP	0.95	0.946	0.0002	mg/L	0.002	0.002
Molybdenum*	57	35.1	NP	0.95	0.946	0.0092	mg/L	0.1	0.1
Rad226+228	57	0	Cube Root	0.95	0.950	3.8391	pCi/L	5	5
Selenium	57	91.2	Square	0.95	0.950	0.0020	mg/L	0.05	0.05
Thallium	57	94.7	NP	0.95	0.946	0.0010	mg/L	0.002	0.002

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

Table 4B. PAF, Peabody, Groundwater Protection Standards (GWPS)

COI	N	ND.PCT	MODEL	COV	CONF	UTL	UNITS	MCL	GWPS
Antimony	76	98.7	NP	0.95	0.980	0.0049	mg/L	0.006	0.006
Arsenic	76	14.5	NP	0.95	0.980	0.0154	mg/L	0.01	0.0154
Barium	76	18.4	Square	0.95	0.950	0.0157	mg/L	2	2
Beryllium	76	75	Square	0.95	0.950	0.0011	mg/L	0.004	0.004
Cadmium	76	97.4	NP	0.95	0.980	0.0014	mg/L	0.005	0.005
Chromium	76	97.4	NP	0.95	0.980	0.0029	mg/L	0.1	0.1
Cobalt*	76	3.9	NP	0.95	0.980	0.0995	mg/L	0.006	0.0995
Fluoride	80	7.5	Log	0.95	0.950	0.5602	mg/L	4	4
Lead	76	86.8	NP	0.95	0.980	0.0031	mg/L	0.015	0.015
Lithium*	76	0	NP	0.95	0.980	0.1700	mg/L	0.04	0.17
Mercury	76	100	NP	0.95	0.980	0.0002	mg/L	0.002	0.002
Molybdenum*	76	35.5	NP	0.95	0.980	0.0050	mg/L	0.1	0.1
Rad226+228	76	0	Tenth Root	0.95	0.950	3.6056	pCi/L	5	5
Selenium	76	94.7	Log	0.95	0.950	0.0021	mg/L	0.05	0.05
Thallium	76	88.2	NP	0.95	0.980	0.0010	mg/L	0.002	0.002

Table 5C. PAF, Slag Pond, Groundwater Protection Standards (GWPS)

COI	N	ND.PCT	MODEL	COV	CONF	UTL	UNITS	MCL	GWPS
Antimony	57	98.2	NP	0.95	0.946	0.0026	mg/L	0.006	0.006
Arsenic	57	21.1	Log	0.95	0.950	0.0127	mg/L	0.01	0.0127
Barium	57	12.3	NP	0.95	0.946	0.0627	mg/L	2	2
Beryllium	57	66.7	NORMAL	0.95	0.950	0.0011	mg/L	0.004	0.004
Cadmium	57	100	NP	0.95	0.946	0.0010	mg/L	0.005	0.005
Chromium	57	98.2	NP	0.95	0.946	0.0023	mg/L	0.1	0.1
Cobalt*	57	1.8	NP	0.95	0.946	0.0995	mg/L	0.006	0.0995
Fluoride	59	5.1	Log	0.95	0.950	0.6289	mg/L	4	4
Lead	57	86	NP	0.95	0.946	0.0010	mg/L	0.015	0.015
Lithium*	57	0	NP	0.95	0.946	0.1700	mg/L	0.04	0.17
Mercury	57	100	NP	0.95	0.946	0.0002	mg/L	0.002	0.002
Molybdenum*	57	40.4	Log	0.95	0.950	0.0021	mg/L	0.1	0.1
Rad226+228	57	0	Cube Root	0.95	0.950	3.6827	pCi/L	5	5
Selenium	57	93	Log	0.95	0.950	0.0021	mg/L	0.05	0.05
Thallium	57	91.2	Square	0.95	0.950	0.0003	mg/L	0.002	0.002

To compute each UTL, the following steps were taken:

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

At PAF, no likely outliers among the background data were flagged at any of the CCR units.

2) The grouped baseline data were also analyzed to determine whether they could be fit to a known statistical model. If so, a parametric UTL was computed; if not, a nonparametric UTL was constructed.

To fit potential statistical models, a series of normalizing mathematical transformations was applied to each baseline dataset. These transformations are known as power transformations, since they raise each observation to a mathematical power. The goal is to find, if possible, a transformation that normalizes the data on the transformed scale.

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

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

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

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

where $\bar{x}$ and s represent the mean and standard deviation of the (transformed) observations, and 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 6A. Descriptive Summary Statistics of Background Data, Gypsum Stack

Constituent	Unit	N	No. of NDs	Minimum	Maximum	Mean	Median
Antimony	mg/L	57	54	0.0007	0.0024	0.0012	0.0019
Arsenic	mg/L	57	0	0.0032	0.0154	0.0067	0.0066
Barium	mg/L	57	8	0.0046	0.2510	0.0128	0.0129
Beryllium	mg/L	57	38	0.0002	0.0012	0.0007	0.0007
Cadmium	mg/L	57	57	0.0010	0.0010	0.0005	0.0010
Chromium	mg/L	57	52	0.0006	0.0045	0.0012	0.0016
Cobalt	mg/L	57	2	0.0003	0.0995	0.0288	0.0036
Fluoride	mg/L	60	3	0.1410	0.6530	0.3405	0.3480
Lead	mg/L	57	50	0.0001	0.0023	0.0003	0.0003
Lithium	mg/L	57	0	0.0457	0.1700	0.0870	0.0591
Mercury	mg/L	57	57	0.0002	0.0002	0.0001	0.0002
Molybdenum	mg/L	57	20	0.0009	0.0092	0.0029	0.0015
Rad226+228	pCi/L	57	0	0.1210	3.3700	1.2544	1.0200
Selenium	mg/L	57	52	0.0009	0.0050	0.0014	0.0014
Thallium	mg/L	57	54	0.0001	0.0010	0.0001	0.0002

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.

Table 7B. Descriptive Summary Statistics of Background Data, Peabody

Constituent	Unit	N	No. of NDs	Minimum	Maximum	Mean	Median
Antimony	mg/L	76	75	0.0004	0.0049	0.0004	0.0027
Arsenic	mg/L	76	11	0.0006	0.0154	0.0055	0.0060
Barium	mg/L	76	14	0.0046	0.2800	0.0103	0.0107
Beryllium	mg/L	76	57	0.0002	0.0012	0.0007	0.0007
Cadmium	mg/L	76	74	0.0001	0.0014	0.0002	0.0006
Chromium	mg/L	76	74	0.0009	0.0029	0.0009	0.0020
Cobalt	mg/L	76	3	0.0004	0.0995	0.0239	0.0032
Fluoride	mg/L	80	6	0.1230	0.6530	0.3102	0.2900
Lead	mg/L	76	66	0.0001	0.0031	0.0002	0.0001
Lithium	mg/L	76	0	0.0355	0.1700	0.0794	0.0631
Mercury	mg/L	76	76	0.0002	0.0002	0.0001	0.0002
Molybdenum	mg/L	76	27	0.0005	0.0050	0.0023	0.0016
Rad226+228	pCi/L	76	0	0.1330	3.3700	1.1478	0.8760
Selenium	mg/L	76	72	0.0013	0.0050	0.0015	0.0014
Thallium	mg/L	76	67	0.0001	0.0010	0.0001	0.0001

Table 8C. Descriptive Summary Statistics of Background Data, Slag Pond

Constituent	Unit	N	No. of NDs	Minimum	Maximum	Mean	Median
Antimony	mg/L	57	56	0.0008	0.0026	0.0008	0.0018
Arsenic	mg/L	57	12	0.0006	0.0154	0.0032	0.0022
Barium	mg/L	57	7	0.0046	0.0627	0.0282	0.0363
Beryllium	mg/L	57	38	0.0003	0.0012	0.0007	0.0007
Cadmium	mg/L	57	57	0.0010	0.0010	0.0005	0.0010
Chromium	mg/L	57	56	0.0009	0.0023	0.0009	0.0020
Cobalt	mg/L	57	1	0.0002	0.0995	0.0303	0.0072
Fluoride	mg/L	60	3	0.0891	1.1000	0.2960	0.2390
Lead	mg/L	57	49	0.0001	0.0010	0.0003	0.0001
Lithium	mg/L	57	0	0.0251	0.1700	0.0800	0.0500
Mercury	mg/L	57	57	0.0002	0.0002	0.0001	0.0002
Molybdenum	mg/L	57	23	0.0005	0.0050	0.0011	0.0010
Rad226+228	pCi/L	57	0	0.3950	3.3700	1.5620	1.4800
Selenium	mg/L	57	53	0.0013	0.0050	0.0015	0.0014
Thallium	mg/L	57	52	0.0001	0.0010	0.0001	0.0002

2.2 Computing Trend Lines and Confidence Interval Bands

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

Since groundwater data are collected over time, variation in the measurements may be due to a trend. To account for this possibility, USEPA also recommends a variation on the confidence interval method known as a confidence interval band around a trend line. In this case, a (linear) trend line is first fit to the data, then a confidence band is constructed around the trend line. The confidence interval band can be compared against a GWPS in much the same fashion as a confidence interval, only now a comparison can be made at different points in time by comparing the 'cross-section' of the band for a given sampling date. If the interval represented by the confidence band cross-section fully exceeds the GWPS, an SSL is identified for that sampling event.

At PAF, 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 September of 2018. Cross-sections of each band were then compared to the GWPS for the most recent Assessment Monitoring event in each case for the purpose of identifying any SSLs.

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

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

By repeating this sequence of steps a large number of times (500), the uncertainty associated with the non-detects can be reasonably captured within the final CI band estimate.

2.2.1 Outliers

Prior to constructing any of the CI bands, the data at each well-constituent pair were examined for possible outliers. Any possible outliers were then tested using Rosner's outlier test. For the PAF CCR units, three observations were confirmed as outliers in the Gypsum Stack network, four outliers were identified in the Peabody area network, and three outliers were confirmed in the Slag Pond network. All of these observations were excluded from subsequent statistical calculations. Table 5 lists the outliers confirmed using Rosner's test.

Table 5. Confirmed Statistical Outliers at PAF CCR Sites

Site	Constituent	Units	Outlier Value	Well Location	Sampling Date
Gypsum Stack	Barium	mg/L	0.0361	PAF-104	05-02-2017
	Barium	mg/L	0.515	PAF-115	03-07-2019
	Barium	mg/L	1.42	PAF-116	03-07-2019
Peabody	Arsenic	mg/L	0.0506	10-4	06-29-2017
	Barium	mg/L	0.184	PAF-118	01-19-2017
	Barium	mg/L	0.384	PAF-107	11-30-2016
	Fluoride	mg/L	1.51	10-4	03-09-2017
Slag Pond	Fluoride	mg/L	1.1	PAF-109	03-09-2017
	Fluoride	mg/L	0.48	PAF-110	08-21-2018
	Fluoride	mg/L	1.66	PAF-113	02-10-2017

2.3 Comparing Confidence Interval Bands Against GWPS

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

3 Summary of Statistical Analysis

To facilitate an ‘at-a-glance’ summary of the statistical comparison results, **Table 6** is a set of ‘traffic light’ matrices, showing for each CCR network a compact representation of each well location matched against each constituent in Appendix IV. This summary is useful in planning for mitigation actions. Green cells indicate that no SSL was observed in 2018. Red cells indicate that an SSL was flagged during the most recent sampling events. Yellow cells are warnings which indicate that a well-constituent pair should be closely watched. These cases have increasing trends and a CI band whose lower limit is at least 65% of the GWPS. Often, the CI band cross-section straddles the GWPS in yellow cells.

At the PAF Gypsum Stack CCR Unit (Table 6A), no SSLs were recorded during Assessment Monitoring. Warning flags (yellow) were raised for cobalt and lithium at well 93-48A, for beryllium at well PAF-114, and for lithium at PAF-116. In summary, a total of zero SSLs and four warnings were identified across the network wells that are located near the PAF plant’s Gypsum Stack CCR Unit during the Assessment Monitoring.

At the PAF Peabody Ash Pond CCR Unit (Table 6B), one arsenic-related SSL was recorded at well PAF-119 during Assessment Monitoring. Warning flags (yellow) were raised for cobalt and lithium at well 95-48A. In summary, a total of one SSL and two warnings were identified across the network wells that are located near the PAF plant’s Peabody Ash Pond CCR Unit during the Assessment Monitoring.

At the PAF Slag Ponds CCR Unit (Table 6C), one arsenic-related SSL was recorded at well PAF-113 during Assessment Monitoring. Warning flags (yellow) were raised for cobalt and lithium at well 95-48A, and for arsenic at PAF-112. In summary, a total of one SSL and three warnings were identified across the network wells that are located near the PAF plant’s Slag Ponds CCR Unit during the Assessment Monitoring.

Table 6A. PAF Gypsum Stack - Traffic Light Matrix Based on Comparative Analysis of Statistical Analysis Results versus Groundwater Protection Standards (GWPS)

ITEM No.	TRAFFIC LIGHT MATRIX								
	Constituent of Interest	GROUNDWATER QUALITY MONITORING WELL LOCATIONS							
		95-48A	PAF-101	PAF-104	94-35A	PAF-114	PAF-103	PAF-115	PAF-116
1.	Antimony	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
2.	Arsenic	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
3.	Barium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
4.	Beryllium	GREEN	GREEN	GREEN	GREEN	YELLOW	GREEN	GREEN	GREEN
5.	Cadmium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
6.	Chromium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
7.	Cobalt	YELLOW	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
8.	Fluoride	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
9.	Lead	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
10.	Lithium	YELLOW	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	YELLOW
11.	Mercury	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
12.	Molybdenum	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
13.	Rad226+228	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
14.	Selenium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
15.	Thallium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN

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

Table 6B. PAF Peabody Ash Pond - 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									
		95-48A	10-5	PAF-105	PAF-106	PAF-119	10-6	PAF-118	PAF-117	PAF-107	10-4
16.	Antimony	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
17.	Arsenic	GREEN	GREEN	GREEN	GREEN	RED	GREEN	GREEN	GREEN	GREEN	GREEN
18.	Barium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
19.	Beryllium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
20.	Cadmium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
21.	Chromium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
22.	Cobalt	YELLOW	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
23.	Fluoride	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
24.	Lead	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
25.	Lithium	YELLOW	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
26.	Mercury	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
27.	Molybdenum	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
28.	Rad226+228	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
29.	Selenium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
30.	Thallium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN

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

Table 6C. PAF Slag Pond - Traffic Light Matrix Based on Comparative Analysis of Statistical Analysis Results versus Groundwater Protection Standards (GWPS)

ITEM No.	TRAFFIC LIGHT MATRIX							
	Constituent of Interest	GROUNDWATER QUALITY MONITORING WELL LOCATIONS						
		95-48A	PAF-108	PAF-109	PAF-110	95-47C	PAF-113	PAF-112
31.	Antimony	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
32.	Arsenic	GREEN	GREEN	GREEN	GREEN	GREEN	RED	YELLOW
33.	Barium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
34.	Beryllium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
35.	Cadmium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
36.	Chromium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
37.	Cobalt	YELLOW	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
38.	Fluoride	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
39.	Lead	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
40.	Lithium	YELLOW	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
41.	Mercury	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
42.	Molybdenum	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
43.	Rad226+228	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
44.	Selenium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
45.	Thallium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN

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

4 References

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

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