2023 Annual Groundwater Monitoring and Corrective Action Report

Tennessee Valley Authority
Bull Run Fossil Plant Dry Fly Ash Stack Lateral Expansion CCR Unit

Prepared for:
Tennessee Valley Authority
1101 Market Street
Chattanooga, TN 37402

Prepared by:
Stantec Consulting Services Inc.

January 31, 2024

In accordance with 40 CFR § 257.90(e) of the United States Environmental Protection Agency (USEPA) Disposal of Coal Combustion Residuals (CCR) from Electric Utilities final rule (CCR Rule), this 2023 Annual Groundwater Monitoring and Corrective Action Report (2023 Annual Report) documents 2023 groundwater monitoring activities at the Dry Fly Ash Stack (DFAS) Lateral Expansion CCR Unit at the Tennessee Valley Authority (TVA) Bull Run Fossil Plant (BRF). In 2017, TVA established a groundwater monitoring system and program at the BRF DFAS Lateral Expansion CCR Unit in accordance with 40 CFR § 257.90. The groundwater monitoring system was certified by a qualified Professional Engineer (PE) as required by 40 CFR § 257.91(f).

OVERVIEW

An overview of the current status of groundwater monitoring and corrective action program for the DFAS Lateral Expansion CCR Unit is provided below in accordance with 40 CFR § 257.90(e)(6).

- At the start and end of the current 2023 annual reporting period, the DFAS Lateral Expansion CCR Unit was operating under the detection monitoring program in 40 CFR § 257.94.
- CCR Constituents listed in 40 CFR § 257.94(e) Appendix III (Appendix III) with statistically significant increases (SSIs) above background and the monitoring well identifications are summarized in Table 1 for the 2023 monitoring events.
- During the 2018 detection monitoring sampling, SSIs above background levels for one or more constituents listed in Appendix III were observed for boron, calcium, sulfate, and total dissolved solids (TDS) in monitoring wells BRF-107 and well J. In addition, SSIs were observed for boron, fluoride, sulfate and TDS at monitoring well MW-3H/P-3. An assessment monitoring program was not initiated for the DFAS Lateral Expansion because a successful alternate source demonstration (ASD) was completed in April 2018. The successful ASD was conducted in response to the identification of SSI's during sampling conducted under the Detection Monitoring Program administered pursuant to 40 CFR 257.94, and concluded that the potential SSIs are due to sources other than the Dry Fly Ash Stack Lateral Expansion, as supported by significant and compelling lines of evidence detailed in Appendix D.
- During the 2020 detection monitoring events, the same SSIs of Appendix III CCR constituents at the downgradient monitoring wells were identified as in 2018 and 2019 with one exception. The SSI for TDS at monitoring well MW-3H/P-3 was not observed in 2020. The alternate source demonstration was re-evaluated in 2020 and continues to support that the SSIs are attributable to another source and not the DFAS Lateral Expansion CCR Unit.
- During the 2021 detection monitoring events, the same SSIs of Appendix III CCR constituents at the downgradient monitoring wells were identified as in 2020 with one exception. An SSI was observed for pH at monitoring well MW-3H/P-3. The alternate source demonstration was re-evaluated in 2021 and continues to support that the SSIs are attributable to another source and not the DFAS Lateral Expansion CCR Unit.

- During the 2022 detection monitoring events, the same SSIs of Appendix III CCR constituents at the downgradient monitoring wells were identified as in 2021 with one exception. An SSI was not observed for pH at monitoring well MW-3H/P-3. The alternate source demonstration was re-evaluated in 2022 and continues to support that the SSIs are attributable to another source and not the DFAS Lateral Expansion CCR Unit.

- During the 2023 detection monitoring events, the same SSIs of Appendix III CCR constituents at the downgradient monitoring wells were identified as in 2022 with one exception. An SSI was observed for TDS at monitoring well MW-3H/P-3. The alternate source demonstration was re-evaluated in 2023 and continues to support the conclusion that the SSIs are attributable to another source and not the DFAS Lateral Expansion CCR Unit.

2023 AND PROJECTED 2024 GROUNDWATER MONITORING ACTIVITIES

During 2023, TVA performed the following groundwater monitoring activities:

- Continued the detection monitoring program and performed two semiannual groundwater sampling events and two resampling events between January and August 2023 of the certified monitoring system in accordance with 40 CFR § 257.94.

- Statistical analyses of the 2023 detection monitoring results were performed in accordance with the CCR Rule 40 CFR § 257.93(h). TVA has provided the determination of SSIs above background for both semiannual detection monitoring events as shown on Table 1.

- Due to laboratory capacity issues and to avoid potential delays in obtaining analytical data, analysis of groundwater samples collected during the August 2023 sampling event was split between two analytical laboratories in Pittsburgh, PA and Cleveland, OH[1] to accelerate laboratory turnaround times and maintain data analysis and reporting schedules.

- Performed further site characterization to refine the BRF Conceptual Site Model (CSM).

- Continued 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 appropriate statistical methods.

- Reviewed new data as it became available to maintain compliance with 40 CFR § 257.90 through 257.98.

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[1] Due to the number of sites TVA monitors, it is necessary to use multiple laboratories in order to meet reporting deadlines. Consequently, laboratories have different equipment and laboratory reporting limits (RLs). When constituent concentrations fall beneath the reporting limit the laboratories J-flag results indicating an estimated value. Occasionally the established UPL may be lower than the new laboratories' reporting limit. When this occurs J-flag values are reported, and they are not considered UPL exceedances as they are estimated values. If applicable, J-flag values above the UPLs are depicted as J*-flag in the analytical tables.

- 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 2023 TVA groundwater quality monitoring program. No additional actions have been recommended except for the planned key activities for 2024 that are outlined below. The projected key activities for the 2024 reporting period are:

- Perform further site characterization to refine the BRF CSM.
- Continue semiannual detection monitoring with resampling at the certified groundwater monitoring system consistent with 40 CFR § 257.94.
- Evaluate whether one or more Appendix III constituents are detected at SSIs above established background concentrations in accordance with 40 CFR § 257.93(h).
- 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 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).

CCR UNIT DESCRIPTION

The DFAS area is located to the northeast of the main plant and coal yard and is comprised of multiple phased landfills built in sequence. The DFAS Phase I and II areas were permitted together as a Class II Landfill and went into operation in 1983 (permit No. IDL 01-103-0080). Construction of the Phase I area cap was completed in 1992. The Phase II area stacking began in 1989, overlapping the Phase I area, and continued through 2015. Construction began on the lined DFAS Lateral Expansion in 2012 and placement of ash within the unit began in 2015 and is currently ongoing, which classifies it as the only active landfill at the BRF site per the CCR Rule.[2]

[2] With oversight from the Tennessee Department of Environment and Conservation (TDEC), TVA has been conducting environmental investigations of the CCR disposal areas at BRF, including the Dry Fly Ash Stack Phase I, Phase II, and Lateral Expansion units, in accordance with TDEC Commissioner's Order, OGC 15-0177 (TDEC Order). The TDEC Order sets forth the process for TVA to investigate the CCR management units, provide an assessment of the data to TDEC, and present proposed corrective measures and remedies, including for groundwater, to TDEC for approval.

GROUNDWATER MONITORING SYSTEM

The groundwater monitoring system for the BRF DFAS Lateral Expansion CCR Unit consists of two background wells (I and MWC) and three downgradient wells (BRF-107, J, and MW-3H/P-3). The downgradient wells are installed at the waste boundary. Figure 1 is an aerial photograph that shows the DFAS Lateral Expansion and the groundwater monitoring well locations. The groundwater monitoring system was designed for a single CCR Unit (DFAS Lateral Expansion).

No monitoring wells in the certified monitoring system were installed or decommissioned during the 2023 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 TVA CCR Rule Compliance Data and Information website: https://www.tva.com/environment/environmental-stewardship/coal-combustion-residuals/bull-run.

GROUNDWATER SAMPLING AND LABORATORY ANALYTICAL TESTING

A groundwater sampling and analysis program was developed 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) as 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.

The 2023 detection monitoring was completed in compliance with 40 CFR § 257.94. Two semiannual detection monitoring groundwater sampling events were each followed by resampling events. Groundwater sampling was conducted between January and August 2023 and the results are summarized in Table 2. A summary of groundwater sample locations, well designations, analytes sampled, sampling dates, and monitoring program status is provided in Table 3.

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 for monitoring wells in the certified monitoring system and Clinch River surface water elevations are summarized in Table 4.[3] Groundwater flow directions were estimated for each sampling event, and a depiction of groundwater flow direction for the August 21, 2023 event[4] is illustrated on Figure 2. The regional groundwater directional flow at BRF is influenced by the Clinch River to the west/southwest of the site and then locally by Worthington Branch that runs to the south of the DFAS Lateral Expansion at the base of Bull Run Ridge. Worthington Branch flows west-southwest, discharging to the Clinch River. The primary groundwater flow direction is to the west/southwest toward the Clinch River. Locally, groundwater flows south across the DFAS Lateral Expansion towards Worthington Branch.

[3] Groundwater elevations were collected at additional monitoring wells during each sampling event and are summarized in Table A-1 in Appendix A.

[4] Groundwater flow direction maps for the January, February, July, and August 2023 sampling events are included in Appendix B.

The uppermost aquifer at the BRF DFAS Lateral Expansion CCR Unit consists of a thin layer of residuum underlain by fractured Chickamauga Limestone. Groundwater occurrence is variable and controlled by a series of interconnected bedrock fractures shallower than 300 feet (AECOM, 2015).

Hydraulic conductivity values at the background or downgradient groundwater monitoring wells, as summarized in Table 5, are estimated in a 2018 hydrogeologic evaluation (Terracon, 2019). Testing data indicated the uppermost saturated zone has a geometric mean hydraulic conductivity of 3.2×10^{-4} 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 (3.2×10^{-4} cm/sec)
- Horizontal hydraulic gradients calculated during the implementation of the groundwater sampling and analysis program, ranging from 0.0327 to 0.0499 feet per foot (ft/ft), and
- An effective porosity of approximately 1%[5] (Domenico and Schwarz 1990, page 26).

The average linear flow velocity in the uppermost aquifer ranges from approximately 1,079 to 1,645 feet per year. The rate and direction of groundwater flow in the bedrock for each groundwater sampling event is summarized in Table 6 in accordance with 40 CFR § 257.93(c).

STATISTICAL ANALYSIS OF GROUNDWATER DATA

The groundwater monitoring data for the 2023 detection monitoring and resampling 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 TVA CCR Rule Compliance Data and Information website: https://www.tva.com/environment/environmental-stewardship/coal-combustion-residuals/bull-run. Background groundwater quality was established for the background monitoring wells MWC and Well I.

Baseline and detection monitoring data sets for 2017 through 2023 of the CCR Rule Groundwater Quality Monitoring Program were evaluated to establish upper prediction limits (UPLs) on background data, and then compared to 2023 compliance measurements to assess any SSIs above background. Additionally, a lower prediction limit (LPL) was established for pH. To assess whether any SSIs occurred during the 2023 Detection Monitoring, results from the routine sampling events (sampling rounds 1 and 3) were flagged as a potential SSI if results for a well-constituent pair were above the UPL or, for pH, were outside the bounds of the prediction interval (i.e., below the LPL or above the UPL). Then results from the resample events associated with the routine sampling events (sampling rounds 2 and 4) were compared against the same UPL or prediction interval for pH. Only if the results from the routine sample and its associated resample were both outside the bounds of the UPL/prediction interval was a confirmed SSI identified. A summary of

[5] Effective porosity range of 0.5 to 5% (Domenico and Schwarz, 1990). Conservative value of 1% was used in linear velocity calculations in the bedrock.

the detection monitoring statistical evaluation is provided in Table 7. The 2023 Statistical Analysis Report is provided as Appendix C.

NARRATIVE DISCUSSION OF ANY TRANSITION BETWEEN MONITORING PROGRAMS

TVA evaluated the groundwater monitoring data for SSIs above background levels for the CCR constituents listed in Appendix III[6] as required by 40 CFR § 257.93(h). During the 2023 detection monitoring events, SSIs were identified for twelve well-constituent pairs including: boron, sulfate, and TDS at wells MW-3H/P-3, BRF-107, and well J; calcium at BRF-107 and well J; and fluoride at MW-3H/P-3. The groundwater analytical results from the 2023 rounds of detection monitoring indicated identical SSIs of Appendix III CCR constituents at the downgradient monitoring wells compared to the 2022 monitoring results with one exception. An SSI for TDS at monitoring well MW-3H/P-3 was observed in 2023. TVA performed confirmation of the SSIs via resampling procedures and error checking and investigated whether the SSIs above background resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality as specified in 40 CFR § 257.94(e)(2).

Following the 2017 groundwater data collection, TVA performed investigations to determine whether a source other than the CCR materials contained in the BRF DFAS Lateral Expansion CCR Unit was the cause of any verified SSIs above background as specified in 40 CFR § 257.94(e)(2). The Appendix III ASD study was completed in April 2018, certified by a qualified PE, and determined that the SSIs were a result of another source and not attributable to the DFAS Lateral Expansion CCR Unit. ASD documentation is provided in Appendix D. The ASD was re-evaluated in 2023 and continues to support the conclusion that the SSIs are attributable to another source and not the DFAS Lateral Expansion CCR Unit. Additionally, as part of the permitting and groundwater monitoring requirements of this CCR landfill for the State of Tennessee, the leachate collection system for the lined landfill is monitored for Appendix III/Appendix IV constituents. This leachate data will be used as needed as a line of evidence to evaluate if Appendix III/Appendix IV constituent trends change in the downgradient monitoring wells. 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.

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

2023 ANNUAL GROUNDWATER MONITORING AND CORRECTIVE ACTION REPORT

TVA Bull Run Fossil Plant Dry Fly Ash Stack Lateral Expansion CCR Unit

January 31, 2024

LIMITATIONS

This document entitled 2023 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:

AECOM, 2015. Part II Permit Application Hydrogeologic Site Investigation CCP Proposal Landfill. June 12, 2015.

Domenico, P.A. and Schwartz, F.W., 1990. Physical and Chemical Hydrogeology. University of Michigan. Wiley, 1990. 824 pp.

Terracon, 2019. Aquifer Testing and Equipment Blank Results. TVA CCR Rule – Bull Run Fossil Plant (BRF). Terracon Consultants, Inc. January 15, 2019.

Attachments:

Figure 1 – CCR Unit with Background and Downgradient Wells

Figure 2 – Dry Fly Ash Stack Potentiometric Map – August 21, 2023

Table 1 - Summary of Appendix III Constituent Statistically Significant Increases

Table 2 – Detection Monitoring Groundwater Sampling Results

Table 3 – Groundwater Sampling Summary

Table 4 – Groundwater and Surface Water Elevation Summary

Table 5 – Hydraulic Conductivity Data Summary

Table 6 – Rate and Direction of Groundwater Flow Summary

Table 7 – Detection Monitoring Statistical Evaluation

Appendix A – Groundwater and Surface Water Elevation Summary - Additional Monitoring Wells

Appendix B – Potentiometric Maps

Appendix C – 2023 Statistical Analysis Report

Appendix D – Alternate Source Demonstration Documentation

FIGURES

Figure No.
1

Title
CCR Units with Background and Downgradient Wells

Client/Project 239000572
Tennessee Valley Authority
Bull Run Fossil (BRF) Plant
CCR Rule

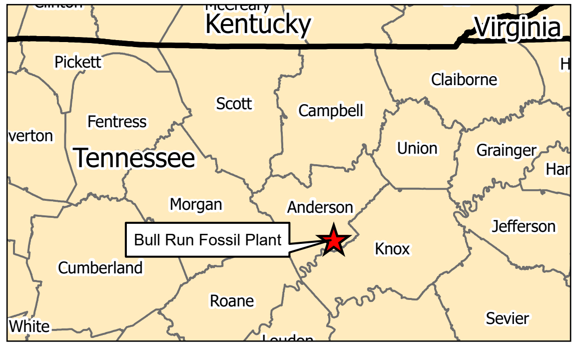
Project Location
Clinton
Anderson County, Tennessee

Prepared by DMB on 2023-12-04
TR by MP on 2023-12-04
IR by MD on 2023-12-04

N
0 800 Feet
(At original document size of 11x17) 1:9,600

Legend
- Downgradient Well
- Background Well
- Staff Gauge
- Surface Water Flow Direction
- CCR Unit Subject to CCR Rule
- TVA Property Boundary (Approximate)

Notes
1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery Source: TVA (2023)



TVA

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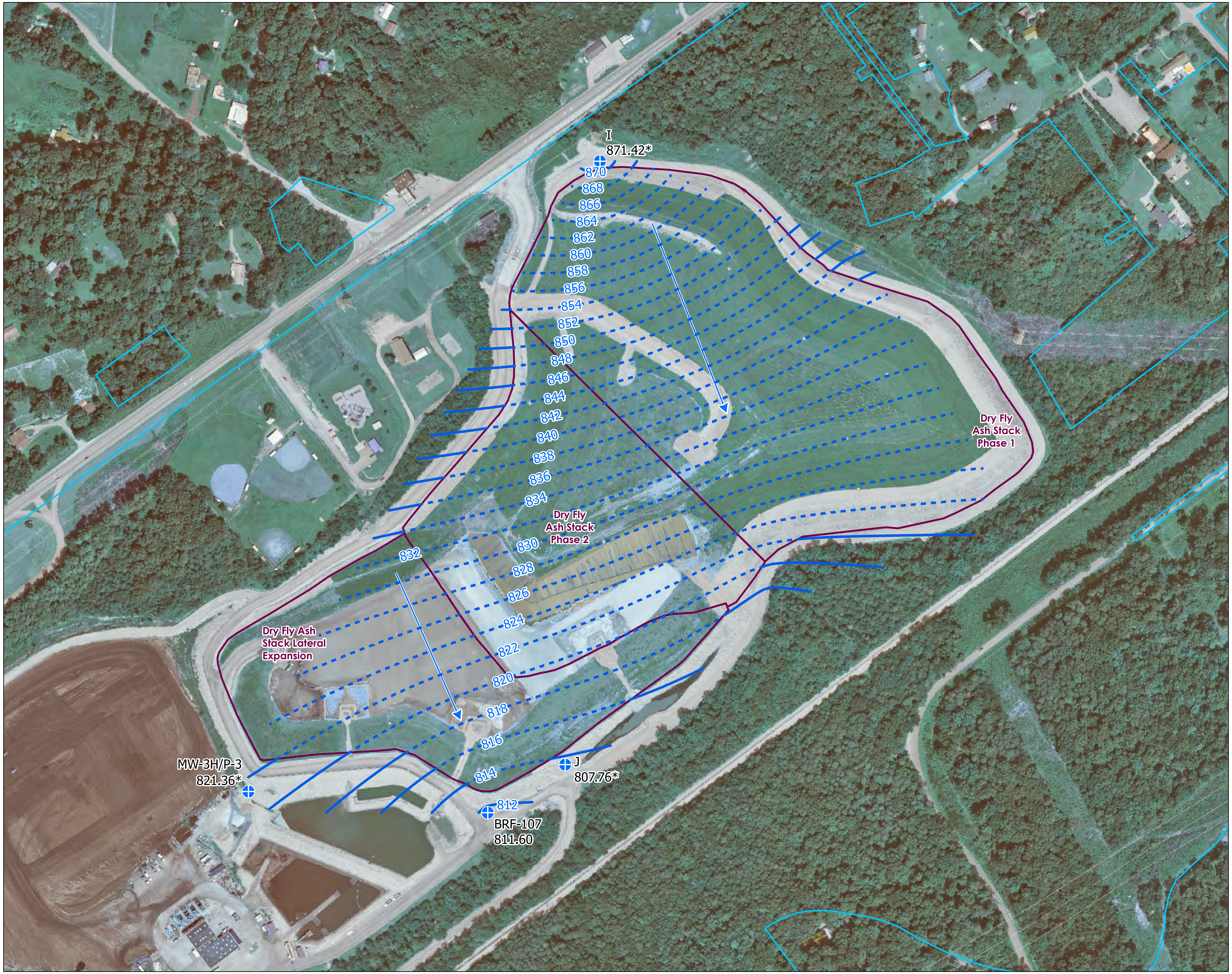


Figure No.
2

Title
Potentiometric Map August 21, 2023

Client/Project 239000572
Tennessee Valley Authority
Bull Run Fossil (BRF) Plant
CCR Rule

Project Location
Clinton
Anderson County, Tennessee

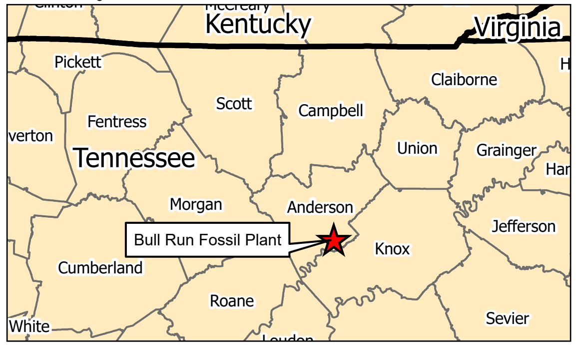
Prepared by DMB on 2023-12-04
TR by MP on 2023-12-04
IR by MD on 2023-12-04

N

0 300 Feet
(At original document size of 11x17) 1:3,600

Legend
- CCR Network Well
- Inferred Potentiometric Contour 8/21/2023 (ft amsl)
- Potentiometric Contour 8/21/2023 (ft amsl)
- Groundwater Flow Direction
- Surface Water Flow Direction
- CCR Unit Area
- TVA Property Boundary (Approximate)

Notes
1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery Source: TVA (2023)
3. Clinch River was 793.92 ft amsl on August 21, 2023.
4. "*" indicates groundwater elevation data was collected on 8/22/23.



TVA

TABLES

Table 1
Summary of Appendix III Constituent Statistically Significant Increases

Constituent	MW-3H/P-3	BRF-107	J
Boron	X	X	X
Calcium		X	X
Chloride			
Fluoride	X		
pH			
Sulfate	X	X	X
TDS	X	X	X

Notes:

X - Statistically Significant Increase

TDS - Total Dissolved Solids

Monitoring Well			BRF-107							
Sample Date			12-Jan-23		27-Feb-23		13-Jul-23		23-Aug-23	
Sample Round			1		1-Resample		2		2-Resample	
Well Designation			Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Analytical Method	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals										
Boron	ug/L	SW846 6020B	601		598		499		494	
Calcium	mg/L	SW846 6020B	219		222		215		197	
Anions										
Chloride	mg/L	EPA 300.0/SW846	7.52		7.36		7.43		6.95	
Fluoride	mg/L	EPA 300.0/SW846	0.115		< 0.0467	U*	0.0515	J	< 0.0985	U*
Sulfate	mg/L	EPA 300.0/SW846	256		256		246		262	
General Chemistry										
Total Dissolved Solids	mg/L	SM 2540C	732		737		754		753	
Field Parameters										
Temperature, Water (C)	DEG_C	FIELD MEASURE	16.2		17.0		18.0		17.7	
Turbidity, field	NTU	FIELD MEASURE	0.38		0.30		0.35		0.49	
ORP	mV	FIELD MEASURE	14.4		64.1		9.5		64.0	
Specific Cond. (Field)	mS/cm	FIELD MEASURE	1.083		1.070		1.074		1.078	
Dissolved Oxygen	mg/L	FIELD MEASURE	0.16		0.86		0.60		0.19	
pH (field)	SU	FIELD MEASURE	6.76		6.77		7.05		6.77	

Notes:

Metals Analysis performed at Eurofins Analytical Laboratories switched from Method SW 846 6020A to SW 846 6020B on 6/4/2022.

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

U - Analyte not detected

ug/L - micrograms per liter
mg/L - milligrams per liter
pCi/L - picoCurie per liter
DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units
mV - millivolts
mS/cm - milliseimens per centimeter
SU - Standard Unit

Table 2
Detection Monitoring Groundwater Sampling Results

Monitoring Well			I							
Sample Date			**12-Jan-23**		**23-Feb-23**		**12-Jul-23**		**23-Aug-23**	
Sample Round			**1**		**1-Resample**		**2**		**2-Resample**	
Well Designation			**Background**		**Background**		**Background**		**Background**	
Analyte	Units	Analytical Method	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals										
Boron	ug/L	SW846 6020B	< 102	U*	70.7	J	68.7	J	2000	
Calcium	mg/L	SW846 6020B	85.9		80.7		81.3		93.4	
Anions										
Chloride	mg/L	EPA 300.0/SW846 9056	26.3		26.2		24.9		25.3	
Fluoride	mg/L	EPA 300.0/SW846 9056	0.114		< 0.0505	U*	< 0.0653	U*	< 0.118	U*
Sulfate	mg/L	EPA 300.0/SW846 9056	5.06		6.78		4.78		5.37	
General Chemistry										
Total Dissolved Solids	mg/L	SM 2540C	317		332		313		300	
Field Parameters										
Temperature, Water (C)	DEG_C	FIELD MEASURE	15.5		18.9		20.7		20.9	
Turbidity, field	NTU	FIELD MEASURE	1.12		0.20		2.33		0.70	
ORP	mV	FIELD MEASURE	27.1		29.7		-179.3		48.3	
Specific Cond. (Field)	mS/cm	FIELD MEASURE	0.606		0.605		0.606		0.607	
Dissolved Oxygen	mg/L	FIELD MEASURE	0.41		0.53		1.82		0.48	
pH (field)	SU	FIELD MEASURE	7.26		7.27		7.35		7.19	

Notes:

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DEG_C - degrees Celsius
NTU - Nephelometric Turbidity Units
mV - millivolts
mS/cm - milliseimens per centimeter
SU - Standard Unit

Table 2
Detection Monitoring Groundwater Sampling Results

CCR Annual Groundwater Monitoring and Corrective Action Report
TVA Bull Run Fossil Plant

Monitoring Well			**J**							
Sample Date			**11-Jan-23**		**28-Feb-23**		**13-Jul-23**		**29-Aug-23**	
Sample Round			**1**		**1-Resample**		**2**		**2-Resample**	
Well Designation			**Downgradient**		**Downgradient**		**Downgradient**		**Downgradient**	
Analyte	Units	Analytical Method	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals										
Boron	ug/L	SW846 6020B	2250	J	1910		2140		2090	
Calcium	mg/L	SW846 6020B	370		378		386		372	
Anions										
Chloride	mg/L	EPA 300.0/SW846	11.9		11.7		12.1		11.9	
Fluoride	mg/L	EPA 300.0/SW846	0.0869	J	< 0.0658	U*	0.0510	J	< 0.0936	U*
Sulfate	mg/L	EPA 300.0/SW846	835		844		813		868	
General Chemistry										
Total Dissolved Solids	mg/L	SM 2540C	1570		1540		1570	J	1550	
Field Parameters										
Temperature, Water (C)	DEG_C	FIELD MEASURE	15.4		20.5		17.8		25.3	
Turbidity, field	NTU	FIELD MEASURE	0.68		0.14		0.21		0.83	
ORP	mV	FIELD MEASURE	67.3		38.2		7.9		84.2	
Specific Cond. (Field)	mS/cm	FIELD MEASURE	1.815		1.800		1.800		1.830	
Dissolved Oxygen	mg/L	FIELD MEASURE	0.18		0.69		0.63		3.37	
pH (field)	SU	FIELD MEASURE	6.88		6.83		6.82		6.89	

Notes:

Metals Analysis performed at Eurofins Analytical Laboratories switched from Method SW 846 6020A to SW 846 6020B on 6/4/2022.

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DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units
mV - millivolts
mS/cm - milliseimens per centimeter
SU - Standard Unit

Table 2
Detection Monitoring Groundwater Sampling Results

Monitoring Well			**MW-3H/P-3**							
Sample Date			**11-Jan-23**		**27-Feb-23**		**13-Jul-23**		**23-Aug-23**	
Sample Round			**1**		**1-Resample**		**2**		**2-Resample**	
Well Designation			**Downgradient**		**Downgradient**		**Downgradient**		**Downgradient**	
Analyte	Units	Analytical Method	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals										
Boron	ug/L	SW846 6020B	690		573		638	J	628	
Calcium	mg/L	SW846 6020B	43.5		41.4		42.1		55.2	
Anions										
Chloride	mg/L	EPA 300.0/SW846	10.5		10.6		10.7		10.2	
Fluoride	mg/L	EPA 300.0/SW846	0.555		0.378		0.402		0.326	
Sulfate	mg/L	EPA 300.0/SW846	60.6		65.2		59.1		65.3	
General Chemistry										
Total Dissolved Solids	mg/L	SM 2540C	406		365		397		408	
Field Parameters										
Temperature, Water (C)	DEG_C	FIELD MEASURE	13.6		16.7		24.8		21.2	
Turbidity, field	NTU	FIELD MEASURE	0.61		0.20		0.95		3.66	
ORP	mV	FIELD MEASURE	-164.7		-79.3		-124.9		-108.6	
Specific Cond. (Field)	mS/cm	FIELD MEASURE	0.686		0.688		0.699		0.699	
Dissolved Oxygen	mg/L	FIELD MEASURE	0.38		2.69		0.80		0.21	
pH (field)	SU	FIELD MEASURE	7.58		7.65		7.56		7.60	

Notes:

Metals Analysis performed at Eurofins Analytical Laboratories switched from Method SW 846 6020A to SW 846 6020B on 6/4/2022.

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

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

DETECTION MONITORING

Table 2
Detection Monitoring Groundwater Sampling Results

Monitoring Well			**MWC**							
Sample Date			**11-Jan-23**		**21-Feb-23**		**11-Jul-23**		**24-Aug-23**	
Sample Round			**1**		**1-Resample**		**2**		**2-Resample**	
Well Designation			**Background**		**Background**		**Background**		**Background**	
Analyte	Units	Analytical Method	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals										
Boron	ug/L	SW846 6020B	< 370	U*	209		162	J	156	
Calcium	mg/L	SW846 6020B	103		90.8	J	107		96.8	
Anions										
Chloride	mg/L	EPA 300.0/SW846	5.06		5.29		5.36		5.37	
Fluoride	mg/L	EPA 300.0/SW846	0.164		< 0.0832	U*	0.141		0.180	
Sulfate	mg/L	EPA 300.0/SW846	24.4		34.2		20.8		27.8	
General Chemistry										
Total Dissolved Solids	mg/L	SM 2540C	377		400		351		382	
Field Parameters										
Temperature, Water (C)	DEG_C	FIELD MEASURE	12.8		15.5		19.5		23.8	
Turbidity, field	NTU	FIELD MEASURE	1.87		0.51		0.92		0.34	
ORP	mV	FIELD MEASURE	21.3		-21.9		-165.9		-84.1	
Specific Cond. (Field)	mS/cm	FIELD MEASURE	0.656		0.708		0.696		0.704	
Dissolved Oxygen	mg/L	FIELD MEASURE	1.39		1.38		0.79		0.33	
pH (field)	SU	FIELD MEASURE	7.20		7.19		6.91		7.10	

Notes:

Metals Analysis performed at Eurofins Analytical Laboratories switched from Method SW 846 6020A to SW 846 6020B on 6/4/2022.

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

U - Analyte not detected

ug/L - micrograms per liter
mg/L - milligrams per liter
pCi/L - picoCurie per liter
DEG_C - degrees Celsius
NTU - Nephelometric Turbidity Units
mV - millivolts
mS/cm - milliseimens per centimeter
SU - Standard Unit

Table 3
Groundwater Sampling Summary

CCR Annual Groundwater Monitoring and Corrective Action Report
TVA Bull Run Fossil Plant

Well ID	Well Designation	Number of Sampling Events Conducted	January 9-12, 2023	February 20 - March 1, 2023	July 10-13, 2023	August 21-29, 2023	Groundwater Monitoring Program
Sample Round			1	1 Resample	2	2 Resample	
BRF-107	Downgradient	4	X	X	X	X	Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
I	Background	4	X	X	X	X	Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
J	Downgradient	4	X	X	X	X	Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
MW-3H/ P-3	Downgradient	4	X	X	X	X	Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
MWC	Background	4	X	X	X	X	Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents

Notes:

Appendix III Constituents - boron, calcium, chloride, fluoride, pH, sulfate, total dissolved solids (TDS)

Table 4
Groundwater and Surface Water
Elevation Summary

Groundwater Elevation Collection Date			09-Jan-23		20-Feb-23		10-Jul-23		21-Aug-23	
Monitoring Well	**Units**	**TOC Elevation**	**Depth to Water**	**GW/SW Elevation**	**Depth to Water**	**GW/SW Elevation**	**Depth to Water**	**GW/SW Elevation**	**Depth to Water**	**GW/SW Elevation**
BRF-107	ft-AMSL	825.55	13.89	811.66	13.57	811.98	13.83	811.72	13.95	811.60
I	ft-AMSL	876.57	4.66	871.91	3.74	872.83	4.55	872.02	5.15*	871.42*
J	ft-AMSL	834.39	21.21	813.18	20.49	813.90	20.62	813.77	26.63*	807.76*
MWC**	ft-AMSL	865.24	6.01	859.23	5.96	859.28	6.73	858.51	7.32*	857.92*
MW-3H/P-3	ft-AMSL	834.27	13.45	820.82	13.24	821.03	13.00	821.27	12.91*	821.36*
Surface Water										
Clinch River	ft-AMSL	NA	NA	794.02	NA	793.65	NA	794.21	NA	793.92

Notes:

* Measurement collected on 8/22/23

** Background monitoring well MWC groundwater elevations were not used in production of potentiometric maps included in Figure 2 and Appendix B.

ft-AMSL - Feet above mean sea level

GW/SW - Groundwater / Surface Water

NA - Not applicable

Well ID	Well Designation	Slug Test Hydraulic Conductivity (cm/sec)	Pumping Test Hydraulic Conductivity (cm/sec)
BRF-107	Downgradient	2.5E-04	NA
I	Background	NA	4.8E-05
J	Downgradient	NA	NA
MW-3H/ P-3	Downgradient	NA	1.2E-04
MWC	Background	4.1E-04	NA
Geometric Mean of Hydraulic Conductivity (cm/sec)		**3.2E-04**	**7.6E-05**

Notes:
cm/sec - centimeters per second
NA - not available

Table 6
Rate and Direction of Groundwater Flow Summary

CCR Annual Groundwater Monitoring and Corrective Action Report
TVA Bull Run Fossil Plant

Groundwater Elevation Collection Date	9-Jan-23	20-Feb-23	10-Jul-23	21-Aug-23
Sample Round	**1**	**1 - Resample**	**2**	**2 - Resample**
Horizontal Gradient	0.0330	0.0333	0.0327	0.0499
Hydraulic Conductivity (cm/sec)	3.2E-04	3.2E-04	3.2E-04	3.2E-04
Effective Porosity	1%	1%	1%	1%
Flow Direction (cardinal)	South-Southeast	South-Southeast	South-Southeast	South-Southeast
Linear Velocity (ft/yr)	1,088	1,100	1,079	1,645

Notes:
cm/sec - centimeters per second
ft/yr - feet per year

Constituent		Boron	Calcium	Chloride	Fluoride	pH	Sulfate	TDS
Unit		**µg/L**	**mg/L**	**mg/L**	**mg/L**	**SU**	**mg/L**	**mg/L**
2023 UPL		**157**	**101**	**26.7**	**0.148**	**6.64** – 7.73**	**33.9**	**389**
Well ID	**Date**							
BRF-107	1/12/2023	**601**	**219**	7.52	0.115	6.76	**256**	**732**
	2/27/2023	**(598)**	**(222)**	(7.36)	(< 0.0467)	(6.77)	**(256)**	**(737)**
	7/13/2023	**499**	**215**	7.43	0.0515 J	7.05	**246**	**754**
	8/23/2023	**(494)**	**(197)**	(6.95)	(< 0.0985)	(6.77)	**(262)**	**(753)**
J	1/11/2023	**2250 J**	**370**	11.9	0.0869 J	6.88	**835**	**1570**
	2/28/2023	**(1910)**	**(378)**	(11.7)	(< 0.0658)	(6.83)	**(844)**	**(1540)**
	7/13/2023	**2140**	**386**	12.1	0.0510 J	6.82	**813**	**1570 J**
	8/29/2023	**(2090)**	**(372)**	(11.9)	(< 0.0936)	(6.89)	**(868)**	**(1550)**
MW-3H/P-3	1/11/2023	**690**	43.5	10.5	**0.555**	7.58	**60.6**	406
	2/27/2023	**(573)**	(41.4)	(10.6)	**(0.378)**	(7.65)	**(65.2)**	(365)
	7/13/2023	**638 J**	42.1	10.7	**0.402**	7.56	**59.1**	**397**
	8/23/2023	**(628)**	(55.2)	(10.2)	**(0.326)**	(7.60)	**(65.3)**	**(408)**
I	1/12/2023	< 102	85.9	26.3	0.114	7.26	5.06	317
	2/23/2023	(70.7 J)	(80.7)	(26.2)	(< 0.0505)	(7.27)	(6.78)	(332)
	7/12/2023	68.7 J	81.3	24.9	< 0.0653	7.35	4.78	313
	8/23/2023	(2000)	(93.4)	(25.3)	(< 0.118)	(7.19)	(5.37)	(300)
MWC	1/11/2023	< 370	103	5.06	0.164	7.20	24.4	377
	2/21/2023	(209)	(90.8 J)	(5.29)	(< 0.0832)	(7.19)	(34.2)	(400)
	7/11/2023	162 J	107	5.36	0.141	6.91	20.8	351
	8/24/2023	(156)	(96.8)	(5.37)	(0.180)	(7.10)	(27.8)	(382)

Notes:

Bold and underlined concentration indicates a statistically significant increase (SSI) over background where both the original sample and resample exceed the UPL or, for pH, are outside the prediction interval

TDS - Total Dissolved Solids

µg/L - micrograms per liter

mg/L - milligrams per liter

SU - Standard Units

UPL - Upper Prediction Limit

** indicates the lower bound of the range is the lower prediction limit (LPL). The upper bound is the UPL.

"<": analyte was not detected and the Method Detection Limit (MDL) is presented

Values in parentheses represent resample results

Wells I and MWC are background monitoring wells

APPENDIX A
GROUNDWATER AND SURFACE WATER ELEVATION SUMMARY – ADDITIONAL MONITORING WELLS

Table A-1
Groundwater and Surface Water Elevation Summary - Additional Monitoring Wells

Groundwater Elevation Collection Date			09-Jan-23		20-Feb-23		10-Jul-23		21-Aug-23	
Monitoring Well	Units	TOC Elevation	Depth to Water	GW/SW Elevation	Depth to Water	GW/SW Elevation	Depth to Water	GW/SW Elevation	Depth to Water	GW/SW Elevation
F45R	ft-AMSL	835.35	15.25	820.10	15.00	820.35	15.31	820.04	15.34	820.01
H	ft-AMSL	855.46	10.77	844.69	9.73	845.73	11.48	843.98	11.99	843.47
BRF-115	ft-AMSL	840.56	16.16	824.40	15.65	824.91	16.74	823.82	17.29	823.27
BRF-116	ft-AMSL	836.54	18.85	817.69	18.63	817.91	18.96	817.58	19.12	817.42
Surface Water										
Clinch River	ft-AMSL	NA	NA	794.02	NA	793.65	NA	794.21	NA	793.92

Notes:

ft-AMSL - Feet above mean sea level

GW/SW - Groundwater / Surface Water

NA - Not applicable

APPENDIX B
POTENTIOMETRIC MAPS

Figure No.

B-1

Title

Potentiometric Map January 9, 2023

Client/Project 239000572

Tennessee Valley Authority
Bull Run Fossil (BRF) Plant
CCR Rule

Project Location
Clinton
Anderson County, Tennessee

Prepared by DMB on 2023-12-04
TR by MP on 2023-12-04
IR by MD on 2023-12-04

N

0 300 Feet
(At original document size of 11x17) 1:3,600

Legend

- CCR Network Well
- Non-CCR Network Well
- Staff Gauge
- Inferred Potentiometric Contour 1/9/2023 (ft amsl)
- Potentiometric Contour 1/9/2023 (ft amsl)
- Groundwater Flow Direction
- Surface Water Flow Direction
- CCR Unit Area
- TVA Property Boundary (Approximate)

Notes

1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery Source: TVA (2023)
3. Clinch River was 794.02 ft amsl on January 9, 2023.

TVA

Figure No.
B-2

Title
Potentiometric Map February 20, 2023

Client/Project — 239000572
Tennessee Valley Authority
Bull Run Fossil (BRF) Plant
CCR Rule

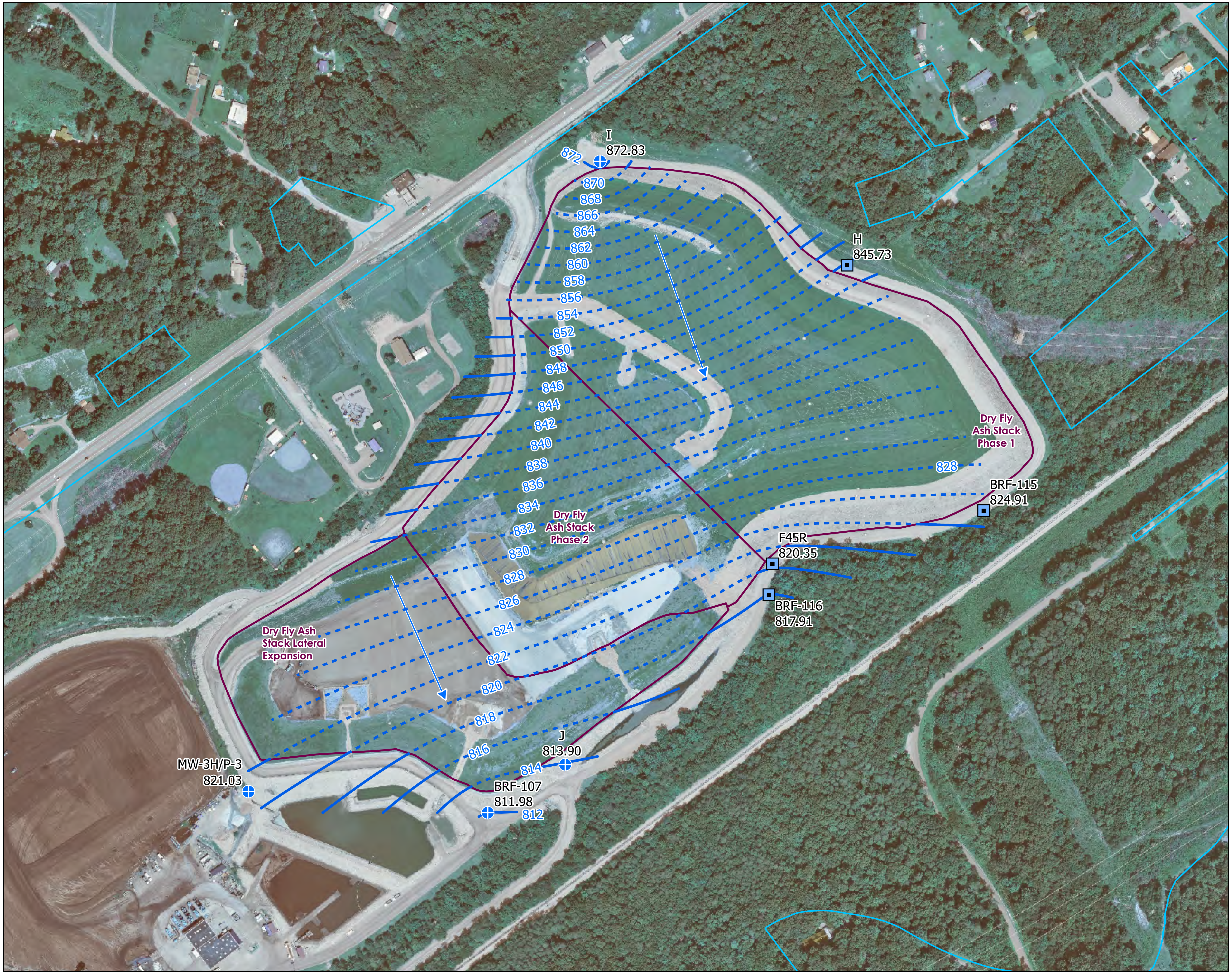
Project Location
Clinton
Anderson County, Tennessee

Prepared by DMB on 2023-12-04
TR by MP on 2023-12-04
IR by MD on 2023-12-04

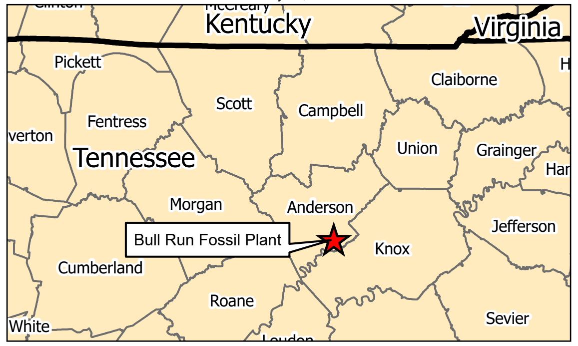
N

0 — 300 Feet
(At original document size of 11x17) 1:3,600

Legend
- CCR Network Well
- Non-CCR Network Well
- Staff Gauge
- Inferred Potentiometric Contour 2/20/2023 (ft amsl)
- Potentiometric Contour 2/20/2023 (ft amsl)
- Groundwater Flow Direction
- Surface Water Flow Direction
- CCR Unit Area
- TVA Property Boundary (Approximate)



Notes
1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery Source: TVA (2023)
3. Clinch River was 793.65 ft amsl on February 20, 2023.



TVA

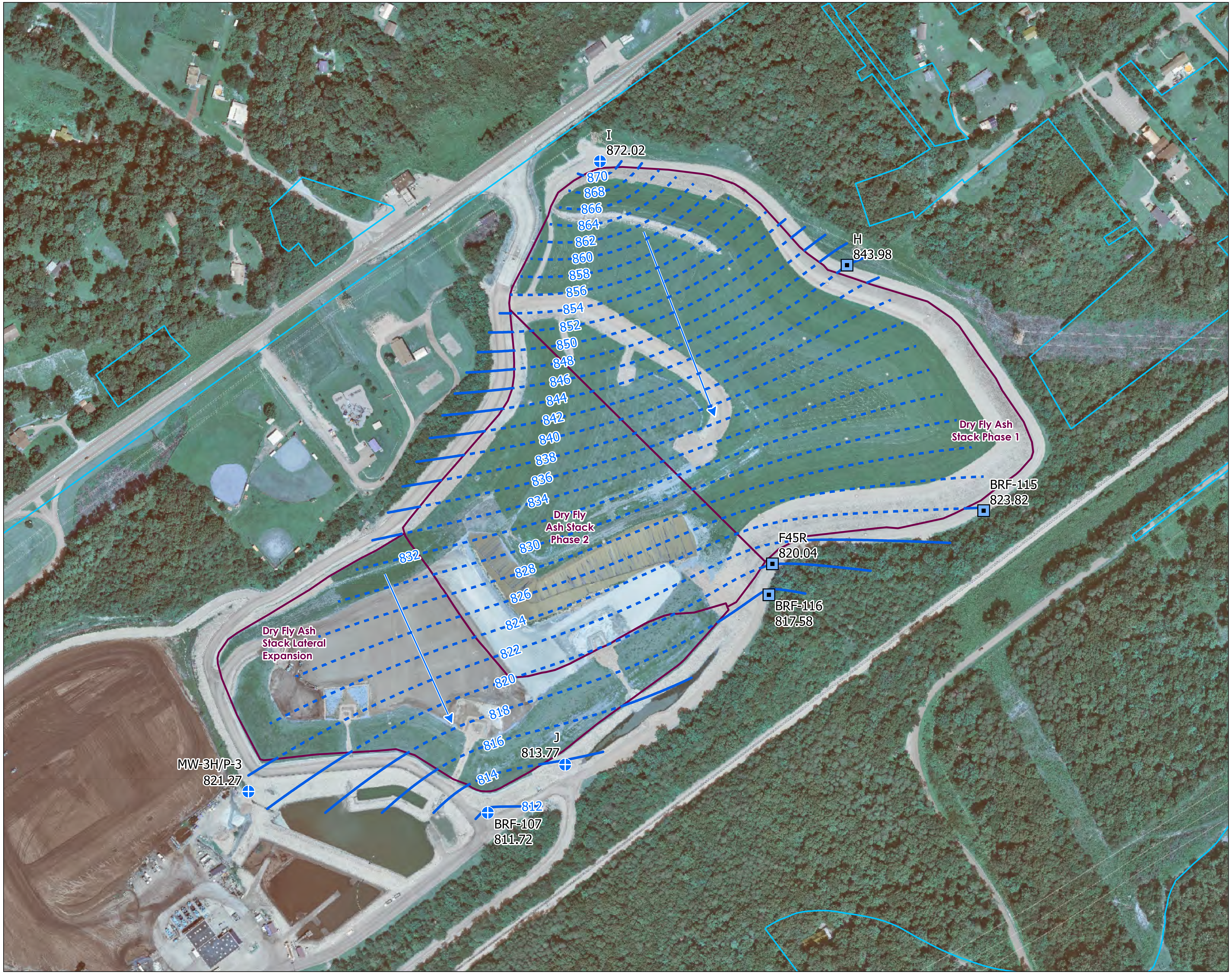


Figure No.
B-3

Title
Potentiometric Map July 10, 2023

Client/Project 239000572
Tennessee Valley Authority
Bull Run Fossil (BRF) Plant
CCR Rule

Project Location
Clinton
Anderson County, Tennessee

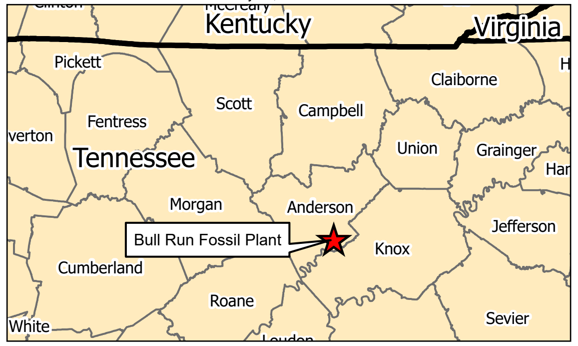
Prepared by DMB on 2023-12-04
TR by MP on 2023-12-04
IR by MD on 2023-12-04

N

0 300 Feet
(At original document size of 11x17) 1:3,600

Legend
- CCR Network Well
- Non-CCR Network Well
- Staff Gauge
- Inferred Potentiometric Contour 7/10/2023 (ft amsl)
- Potentiometric Contour 7/10/2023 (ft amsl)
- Groundwater Flow Direction
- Surface Water Flow Direction
- CCR Unit Area
- TVA Property Boundary (Approximate)

Notes
1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery Source: TVA (2023)
3. Clinch River was 794.21 ft amsl on July 10, 2023.



TVA

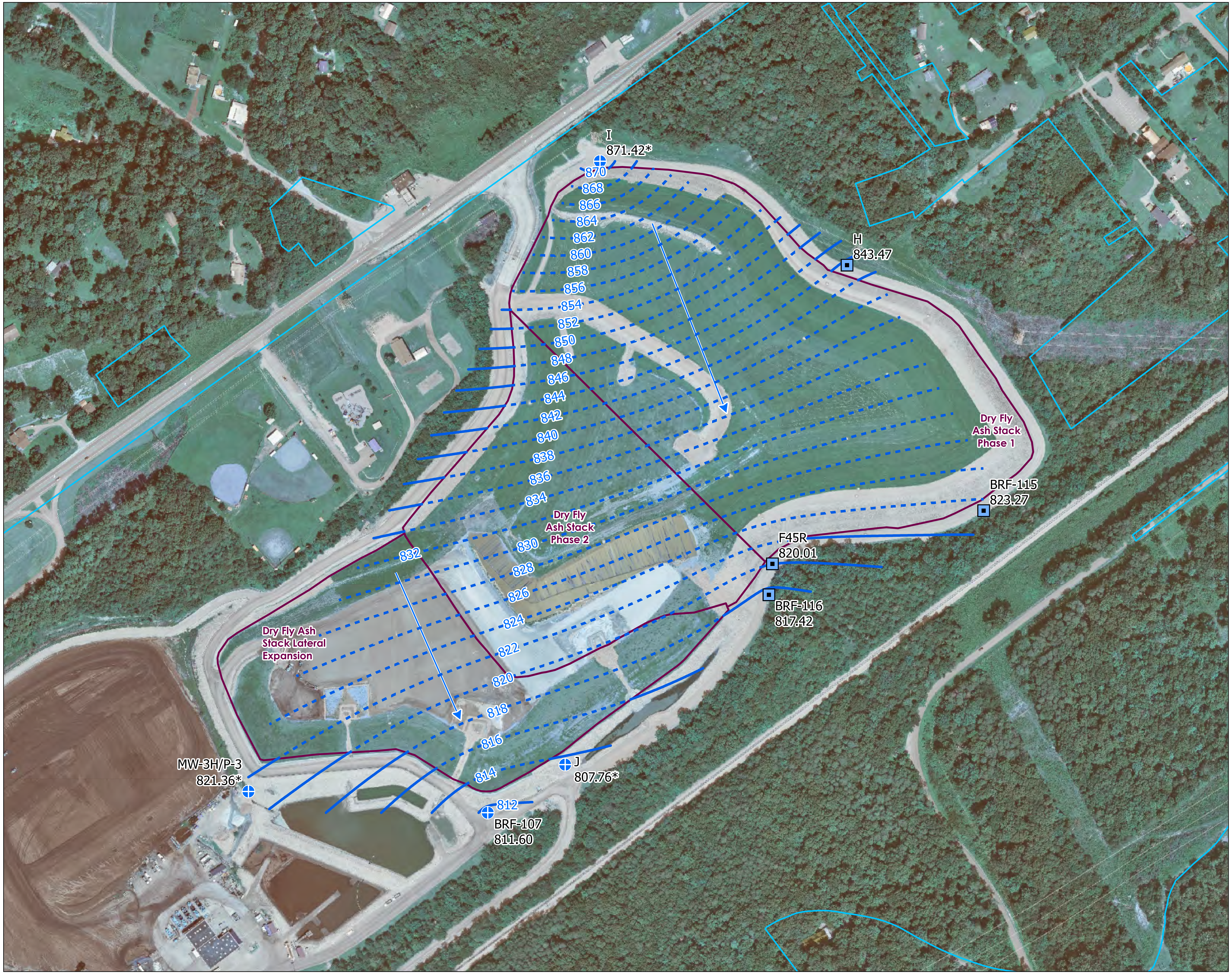
Figure No.
B-4

Title
Potentiometric Map August 21, 2023

Client/Project 239000572
Tennessee Valley Authority
Bull Run Fossil (BRF) Plant
CCR Rule

Project Location
Clinton
Anderson County, Tennessee

Prepared by DMB on 2023-12-04
TR by MP on 2023-12-04
IR by MD on 2023-12-04

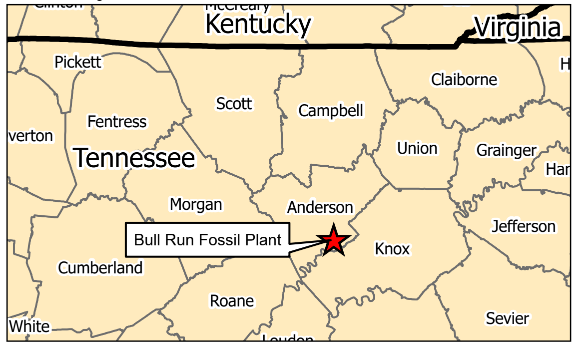


N

0 300 Feet
(At original document size of 11x17) 1:3,600

Legend
- CCR Network Well
- Non-CCR Network Well
- Staff Gauge
- Inferred Potentiometric Contour 8/21/2023 (ft amsl)
- Potentiometric Contour 8/21/2023 (ft amsl)
- Groundwater Flow Direction
- Surface Water Flow Direction
- CCR Unit Area
- TVA Property Boundary (Approximate)

Notes
1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery Source: TVA (2023)
3. Clinch River was 793.92 ft amsl on August 21, 2023.
4. "*" indicates groundwater elevation data was collected on 8/22/23.



TVA

APPENDIX C
2023 STATISTICAL ANALYSIS REPORT

Statistical Analysis Report for Bull Run Fossil Plant

2023 CCR Program, Annual Update

Kirk Cameron, PhD, MacStat Consulting, Ltd

2023-12-12

Table of contents

1 Introduction

This report summarizes the statistical analysis performed on groundwater quality constituents monitored during 2023 for the Coal Combustion Residuals (CCR) Rule's Ground Water Quality Monitoring (GWQM) Program for the CCR Unit at the Tennessee Valley Authority (TVA) Bull Run Fossil Plant (BRF). Since this unit was established, CCR sampling and monitoring for the required Appendix III and Appendix IV constituents (COI) were conducted to develop baseline conditions at this site and to identify any statistically significant exceedances of background levels.

The CCR unit at BRF is currently in Detection Monitoring during 2023 sampling, necessitating continued monitoring of the Appendix III constituents listed in the left-hand column of **Table 2**. As part of this year's efforts (i.e., 2023), the baseline datasets collected since Year-One of the CCR-Rule GWQM Program were evaluated in order to establish updated prediction limits on upgradient background data, and then to compare 2023 compliance measurements against these statistical limits to assess any statistically significant increases (SSI) above background. Summaries of the prediction limit results are provided in subsequent sections of this report.

At the BRF plant's CCR Unit, the sampling results used to identify potential SSIs were obtained during a minimum of four distinct monitoring events that were collected between November of 2023 and August of 2023 by the firm of 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.

At the BRF network, the sampling results used to compute the background statistics were obtained from a set of designated background wells (I, MWC) using data collected from November 2016 until August 2023. Groundwater samples were analyzed for 7 distinct constituents as required under Appendix III of the CCR Rule (listed in **Table 2**). Only non-filtered sample results were utilized for the statistical analysis.

For those wells at which SSIs occurred, TVA requested the construction of 'Traffic Light' matrices to facilitate an at-a-glance identification of such exceedances and to promote intra-company follow-up assessments of the possible causes (e.g., other identifiable chemicals used on site or by others located in the vicinity of the plants) and to plan for mitigation actions, whenever warranted. Sample analytical results of CCR-Rule Appendix III constituents obtained from each of the monitoring wells and events were used to perform the statistical analysis and generate the graphs shown in this report. 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**.

The 'R' Statistical Analysis package (www.r-project.org) in conjunction with R-Studio (www.rstudio.com), both popular public domain software products, 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.

Table 1: CCR Rule Monitoring Network

Background	Downgradient
I	MW-3H/P-3
MWC	BRF-107
	J

For this year's efforts, the baseline datasets of the CCR-Rule GWQM Program were augmented with routine monitoring samples in order to update the background database. The background data were then utilized to develop statistically-derived prediction limits. Finally, data from the compliance wells were statistically compared to the prediction limits to determine whether any statistical limits were exceeded, thus causing a statistically significant exceedance (SSI).

Table 2: CCR Rule Monitored Constituents

Appendix III	Appendix IV
Boron	Antimony
Calcium	Arsenic
Chloride	Barium
Fluoride	Beryllium
Sulfate	Cadmium
pH	Chromium
TDS	Cobalt
	Fluoride
	Lead
	Lithium
	Mercury
	Molybdenum
	Rad226+228
	Selenium
	Thallium

2 Statistical Analysis

At the BRF CCR network, the sampling results used to compute the background statistics were obtained only from designated background wells using historical data that were first screened for possible trends or shifts in concentration levels over time. Any early data exhibiting a substantially different pattern or average concentration level than more recent data were excluded from the calculations. The cutoff date used for selecting background data was determined on a constituent by constituent basis, but was designed to include as much data as possible reflecting current groundwater conditions.

Groundwater samples were analyzed for a total of 21 distinct constituents, as required for the CCR monitoring program. Fluoride is monitored under both Appendices. Results for the 7 Appendix III parameters are presented in this report.

The basic steps in the Detection Monitoring analysis of the 2023 data included the following:

1. Implementing an effective prediction limit statistical approach;
2. Assessing best-fitting statistical models for each background dataset, including identification of any statistical outliers, then computing interwell prediction limits; and
3. Comparing each prediction limit against 2023 compliance data, including resamples if necessary, to assess whether an SSI occurred.

To accomplish these steps, the data were first summarized and modeled. To handle any non-detects in these summary calculations, non-detect values were treated as statistically 'left-censored,' with the censoring limit equal to the reporting limit (RL). Then *Monte Carlo imputation* was employed to derive estimated summary statistics that account for the presence of non-detects. This involved picking a random value for each non-detect between 0 and the RL, computing summary statistics on the combined set of detected values and non-detects, repeating this process a large number of iterations, and then averaging results to get the final summary statistics.

2.1 Statistical Approach

TVA has established a statistical testing approach within its CCR detection monitoring program using the following decision logic and consistent with recommendations within USEPA's *Unified Guidance* document (USEPA, 2009):

1. For each Appendix III parameter and compliance well location, a comparison is made between each routinely collected sample and a site-specific upper prediction limit (UPL) computed from upgradient background data (or for pH, against a site-specific prediction interval).
2. If the routine observation exceeds the upper prediction limit (or for pH, is lower than the lower prediction limit), a potential SSI is identified. If the routine observation is within the bounds of the UPL or prediction interval, the test passes.
3. In the event of a potential SSI, one resample is compared against the UPL or prediction interval. If the resample falls within the bounds of prediction limit/interval, the test passes. If instead the resample exceeds the bounds of the limit/interval, an SSI is confirmed for that well and constituent.

2.2 Background Statistical Models and Prediction Limits

To compute each prediction limit (UPL) or prediction interval:

1. All baseline data from designated upgradient or background wells collected through August 2023 were grouped and initially screened for possible outliers. This outlier screening was performed visually on time series plots of the data, as well as systematically via the following procedure:

Probable outliers were flagged by first fitting a broad, non-linear, locally-weighted trend to each COC-well pair, using the well-known *locally-estimated scatterplot smoother* or LOESS (Cleveland, 1979). By taking the standard error (SE) from each LOESS trend, which is computed from the mean square of the residuals:

$$s_e^2 = \sum_{i=1}^{n} e_i^2/(n-2) = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2/(n-2)$$

the studentized residual (Draper & Smith, 1998) distance (i.e., gap) between each reported value and its trend estimate was computed with the formula:

$$t_i = (y_i - \hat{y})/s_e(1 - h_{ii})^{1/2}$$

where h_{ii} is the ith diagonal element of the 'hat' matrix H in regression theory. The studentized residuals t_i thus account for the typical variation exhibited by the observed data as well as the leverage (i.e., x-position) of the point being estimated.

These studentized residuals follow a standard scale similar to a standard Student's t-distribution with $(n-3)$ degrees of freedom. As a consequence, any studentized residual larger than 2.5 may be deemed a probable outlier, and residuals larger than 5 may be deemed extreme outliers (relative to the local trend).

Any flagged outliers were then *down-weighted* using a tri-cube weighting function, such that the further the point from its trend estimate, the smaller its statistical weight (w_i). Outlier residuals furthest from the trend thus received the smallest weights, while those closer to the trend were given larger weights. Further, any observations not classified as residual outliers were given the maximum weight of 1.

Handling outliers in this manner offers certain benefits, especially since flagging outliers always involves a mixture of art (i.e., professional judgment) and statistical science. In some cases, disputes can arise among stakeholders as to whether specific values ought to be treated as outliers and/or eliminated from statistical analysis. This can especially be true when there is no known physical cause of the apparent outliers (e.g., laboratory or sampling error). Down-weighting in this manner is consistent, non-subjective, and does not exclude any data; yet minimizes the impact of true outliers on subsequent UPL estimates.

At the BRF network, 3 extreme outliers were flagged in the background data.

2. The grouped baseline data were analyzed to determine whether they could be fit to a known statistical model. If so, a quasi-parametric bootstrap-t UPL was computed; if not, a non-parametric UPL was constructed. Datasets which could not be sufficiently normalized were therefore analyzed by nonparametric means.

To account for non-normal data, a range of possible mathematical transformations was applied to each background dataset, in order to identify the statistical model that maximized the weighted correlation between the observed values and normal z-scores on a probability plot. The final statistical model for each parameter was used to compute an upper prediction limit (UPL) or prediction interval (for pH). The statistical weights described above were also used to help compute the best-fitting statistical model.

3. The best-fitting statistical model for each COI was used to compute a prediction limit or interval.

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

$$PL = \bar{x} \pm \kappa s$$

where $\bar{x}$ and s represent the mean and standard deviation of the (transformed) observations, and κ is a prediction limit multiplier. If the data have been transformed, the final prediction limit/interval is derived by back-transforming the scaled limit/interval. The prediction limit multiplier is computed as function of several inputs, including the background sample size, the targeted site-wide false positive risk (SWFPR), the configuration of the monitoring network (i.e., number of wells and number of COIs per well), and the retesting strategy implemented at the site (e.g., 1-of-2, etc.).

To account for possible outliers and the statistical weighting described earlier, a slightly different strategy was implemented to compute an estimate of the kappa factor, $\hat{\kappa}$. Specifically, a large number of *bootstrap* samples were drawn from the observed data. For each bootstrap sample, a weighted mean and weighted standard deviation were computed to form the following ratio:

$$\left(\frac{x_i - \bar{x}_w}{s_w}\right)$$

where x_i is a random value drawn from the background data. Ultimately, an upper percentile of these ratios led to an estimate of the appropriate kappa factor, $\hat{\kappa}$. The bootstrap-t upper prediction limit was then computed as:

$$UPL = \bar{x}_w + \hat{\kappa} s_w$$

The UPLs computed under this methodology utilize all the data, including any possible extreme values, are reasonably robust (i.e., minimally impacted) in the presence of actual outliers, but are *quasi-parametric* — instead of nonparametric — despite the use of the bootstrap technique. This last characteristic implies that the bootstrap-t will result in an accurate UPL only when the bulk of the background data can be closely fit to a known statistical model. In cases where an adequate statistical model cannot be identified, a nonparametric UPL must be computed instead.

An empirical cutoff value of 0.95 was used for deciding when the bootstrap-t could be applied. Further, the bootstrap-t does not work very well when the dataset is multi-modal (i.e., it has multiple peaks or 'humps'), for instance when multiple background wells are grouped together but have substantially different average concentration levels (perhaps due to a heterogenous aquifer). If a test for unimodality (i.e., single peak like the normal distribution) passed, then correlations of 0.95 and above led to use of the bootstrap-t, while multi-modality or correlations below this cutoff led to calculation of a nonparametric prediction limit.

In the case of a nonparametric model, the standard approach is to compute the UPL as one of the largest of the sample background values, often the maximum. However, due to cases with apparent outliers, the standard nonparametric UPL was modified to account for the data weighting, so as to avoid selecting a probable outlier as the UPL.

For the BRF CCR network, **Table 3** lists the calculated UPLs (and LPL for pH) established for this particular Unit.

2.3 Comparing Compliance Data Against Prediction Limits

To assess whether any SSIs occurred during 2023 Detection Monitoring at TVA's BRF CCR site, the routine sampling event from sampling rounds 1 and 3 at each COI-well pair were compared against their respective prediction limit. Under a 1-of-2 retesting strategy, sampling rounds 2 and

Table 3: BRF Interwell Prediction Limits

COI	N	ND.Pct	Model	1-of-m	FPR	Units	LPL	UPL
Boron	73	34	TBOOT-Square Root	2	0.0149	ug/L	NA	157
Calcium	73	0	TBOOT-Log	2	0.0149	mg/L	NA	101
Chloride	73	0	NP	2	0.0132	mg/L	NA	26.7
Fluoride	73	23	TBOOT-Square Root	2	0.0149	mg/L	NA	0.148
pH	72	0	NP	2	0.0136	SU	6.64	7.73
Sulfate	73	1.4	NP	2	0.0128	mg/L	NA	33.9
TDS	74	0	TBOOT-Log	2	0.0149	mg/L	NA	389

4 were reserved as possible resamples. This enabled sufficient lag time between any of the routine and resample measurements to assume approximate statistical independence.

If the routine observations (sampling rounds 1 and 3) exceeded the upper prediction limit (UPL), or for pH, were outside the bounds of the prediction interval on either side, a potential SSI was flagged. Then the reserved resamples associated with the routine events (sampling rounds 2 and 4) were compared against the same limit or interval. Only if the routine observation and its associated resample both were outside the bounds of the prediction limit/interval was a confirmed SSI identified.

Table 4 is a summary of the 2023 statistical tests at the BRF CCR unit where a confirmed SSI occurred.

Table 4: Confirmed 2023 Prediction Limit SSIs at BRF CCR Site

COI	Well	Date	Result	Units	Stage	LPL	UPL	SSI
Boron	MW-3H/P-3	2023-01-11	690	ug/L	Sample	NA	157	YES
Boron	MW-3H/P-3	2023-02-27	573	ug/L	Resample	NA	157	YES
Boron	MW-3H/P-3	2023-07-13	638	ug/L	Sample	NA	157	YES
Boron	MW-3H/P-3	2023-08-23	628	ug/L	Resample	NA	157	YES
Boron	BRF-107	2023-01-12	601	ug/L	Sample	NA	157	YES
Boron	BRF-107	2023-02-27	598	ug/L	Resample	NA	157	YES
Boron	BRF-107	2023-07-13	499	ug/L	Sample	NA	157	YES
Boron	BRF-107	2023-08-23	494	ug/L	Resample	NA	157	YES
Boron	J	2023-01-11	2250	ug/L	Sample	NA	157	YES
Boron	J	2023-02-28	1910	ug/L	Resample	NA	157	YES
Boron	J	2023-07-13	2140	ug/L	Sample	NA	157	YES
Boron	J	2023-08-29	2090	ug/L	Resample	NA	157	YES
Calcium	BRF-107	2023-01-12	219	mg/L	Sample	NA	101	YES
Calcium	BRF-107	2023-02-27	222	mg/L	Resample	NA	101	YES
Calcium	BRF-107	2023-07-13	215	mg/L	Sample	NA	101	YES
Calcium	BRF-107	2023-08-23	197	mg/L	Resample	NA	101	YES
Calcium	J	2023-01-11	370	mg/L	Sample	NA	101	YES
Calcium	J	2023-02-28	378	mg/L	Resample	NA	101	YES
Calcium	J	2023-07-13	386	mg/L	Sample	NA	101	YES
Calcium	J	2023-08-29	372	mg/L	Resample	NA	101	YES
Fluoride	MW-3H/P-3	2023-01-11	0.555	mg/L	Sample	NA	0.148	YES
Fluoride	MW-3H/P-3	2023-02-27	0.378	mg/L	Resample	NA	0.148	YES
Fluoride	MW-3H/P-3	2023-07-13	0.402	mg/L	Sample	NA	0.148	YES
Fluoride	MW-3H/P-3	2023-08-23	0.326	mg/L	Resample	NA	0.148	YES
Sulfate	MW-3H/P-3	2023-01-11	60.6	mg/L	Sample	NA	33.9	YES
Sulfate	MW-3H/P-3	2023-02-27	65.2	mg/L	Resample	NA	33.9	YES

(continued)

COI	Well	Date	Result	Units	Stage	LPL	UPL	SSI
Sulfate	MW-3H/P-3	2023-07-13	59.1	mg/L	Sample	NA	33.9	YES
Sulfate	MW-3H/P-3	2023-08-23	65.3	mg/L	Resample	NA	33.9	YES
Sulfate	BRF-107	2023-01-12	256	mg/L	Sample	NA	33.9	YES
Sulfate	BRF-107	2023-02-27	256	mg/L	Resample	NA	33.9	YES
Sulfate	BRF-107	2023-07-13	246	mg/L	Sample	NA	33.9	YES
Sulfate	BRF-107	2023-08-23	262	mg/L	Resample	NA	33.9	YES
Sulfate	J	2023-01-11	835	mg/L	Sample	NA	33.9	YES
Sulfate	J	2023-02-28	844	mg/L	Resample	NA	33.9	YES
Sulfate	J	2023-07-13	813	mg/L	Sample	NA	33.9	YES
Sulfate	J	2023-08-29	868	mg/L	Resample	NA	33.9	YES
TDS	MW-3H/P-3	2023-07-13	397	mg/L	Sample	NA	389	YES
TDS	MW-3H/P-3	2023-08-23	408	mg/L	Resample	NA	389	YES
TDS	BRF-107	2023-01-12	732	mg/L	Sample	NA	389	YES
TDS	BRF-107	2023-02-27	737	mg/L	Resample	NA	389	YES
TDS	BRF-107	2023-07-13	754	mg/L	Sample	NA	389	YES
TDS	BRF-107	2023-08-23	753	mg/L	Resample	NA	389	YES
TDS	J	2023-01-11	1570	mg/L	Sample	NA	389	YES
TDS	J	2023-02-28	1540	mg/L	Resample	NA	389	YES
TDS	J	2023-07-13	1570	mg/L	Sample	NA	389	YES
TDS	J	2023-08-29	1550	mg/L	Resample	NA	389	YES

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 III. This summary is useful in planning for mitigation actions. Green cells indicate that no SSI was observed during any of the semi-annual evaluations of 2023. Red cells indicate the opposite: an SSI was flagged during at least one of the semi-annual evaluations.

At the BRF CCR network, a total of 23 Detection Monitoring SSIs were identified at Program network wells during the 2023 annual evaluation.

Table 5: Traffic Light Matrix for BRF CCR Unit

	Well Locations		
COI	**MW-3H/P-3**	**BRF-107**	**J**
Boron	RED	RED	RED
Calcium	GRN	RED	RED
Chloride	GRN	GRN	GRN
Fluoride	RED	GRN	GRN
Sulfate	RED	RED	RED
TDS	RED	RED	RED
pH	GRN	GRN	GRN

Color-Coding Key:
RED = Results outside prediction limit bounds;
GRN = Results within prediction limit bounds

4 References

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Draper, N. R., & Smith, H. (1998). *Applied regression analysis, 3rd edition*. Wiley: NY.

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APPENDIX D
ALTERNATE SOURCE DEMONSTRATION DOCUMENTATION

NOTICE OF SUCCESSFUL ALTERNATE SOURCE DEMONSTRATION

BULL RUN FOSSIL PLANT

DRY FLY ASH STACK LATERAL EXPANSION

In accordance with the provisions of 40 C.F.R. 257.94(e)(2), Tennessee Valley Authority (TVA) commissioned an Alternate Source Demonstration (ASD) study for the above-named CCR unit located within the Bull Run Fossil plant's reservation. The study provided successful proof that the ASD of Appendix III constituents measured were due to sources other than the CCR unit named above. As required by 40 C.F.R. 257.94(e)(2), TVA will include the demonstration, as certified by the qualified Professional Engineer (PE) named below, in its "Annual Groundwater Monitoring and Corrective Action Report". TVA will continue its detection monitoring program for the Dry Fly Ash Stack Lateral Expansion.

QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

I, Stephen H. Bickel, being a Professional Engineer in good standing in the State of Tennessee do hereby certify, to the best of my knowledge, information, and belief, that the information contained in this certification is prepared in accordance with the accepted practice of engineering; that the information contained herein is accurate as of the date of my signature below; and that the successful Alternate Source Demonstration (ASD) as described above meets the requirements of 40 CFR § 257.94(e)(2). Opinions relating to this ASD, environmental, geologic, and hydrogeologic conditions or other conclusions are based on available data; actual conditions may vary from those encountered at the times and locations where data are obtained, despite the use of due care.

SIGNATURE: Stephen H Bickel

PRINTED NAME: Stephen Bickel, PE

ADDRESS: 10509 Timberwood Circle, Suite 100, Louisville, KY 40223

TELEPHONE: (502) 212-5075

Attachments:

ASD for CCR Unit Dry Fly Ash Stack Lateral Expansion located within the boundaries of the Bull Run Fossil Plant's Reservation.

DATE: 4/13/2018

STEPHEN H. BICKEL
REGISTERED ENGINEER
AGRICULTURE
COMMERCE
No. 113134
STATE OF TENNESSEE

SUCCESSFUL ALTERNATE SOURCE DEMONSTRATION EXECUTIVE SUMMARY

BULL RUN FOSSIL PLANT

DRY FLY ASH STACK LATERAL EXPANSION

A successful Alternate Source Demonstration (ASD) was conducted on behalf of the Tennessee Valley Authority (TVA) for Bull Run Fossil (BRF) Plant in accordance with 40 C.F.R. 257.94(e)(2) of the Coal Combustion Residuals (CCR) rule. This ASD was conducted in response to the identification of potential statistically significant increases (SSIs) during sampling conducted under the Detection Monitoring program [40 C.F.R. 257.94] in connection with the regulated Dry Fly Ash Stack Lateral Expansion unit.

The ASD determined that the potential SSIs identified in the Dry Fly Ash Stack Lateral Expansion Detection Monitoring program were attributable to pre-existing groundwater conditions that long preceded the construction of the regulated CCR unit. The conclusion that the potential SSIs are due to sources other than the Dry Fly Ash Stack Lateral Expansion is supported by the following lines of evidence:

- The Appendix III constituents with potential SSIs had been detected in downgradient Well J beginning in 1991, more than 20 years prior to the construction of Dry Fly Ash Stack Lateral Expansion in 2012.
- The magnitude of historical concentrations of the Appendix III constituents from the 1991-2011 time period in downgradient Well J are comparable to current concentrations (2011 to present).
- The newly-engineered landfill was constructed with a geomembrane liner and leachate collection system. Construction began in 2012.
- The presence of constituents that caused the potential SSIs cannot be attributed to the Dry Fly Ash Stack Lateral Expansion because they were documented to exist prior to the placement of CCR materials into this unit.

SUMMARY

Based on completion of the successful ASD for the Dry Fly Ash Stack Lateral Expansion, and in accordance with 40 C.F.R. 257.94(e)(2), the site will remain in detection monitoring as of April 15, 2018.