

**2019 ANNUAL GROUNDWATER
MONITORING REPORT**

FEDERAL CCR RULE

**CARDINAL PLANT – FLY ASH RESERVOIR II
BRILLIANT, OHIO**

Submitted to



Cardinal Operating Compnay

306 County Road 7E
Brilliant, Ohio 43913

Submitted by



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LIST OF ACRONYMS AND ABBREVIATIONS

ACM	Assessment of Corrective Measures
CCR	Coal Combustion Residuals
CFR	Code of Federal Regulations
ESP	Electrostatic Precipitator
FAD	Fly Ash Dam
FAR	Fly Ash Reservoir
FGD	Flue Gas Desulfurization
GWPS	Groundwater Protection Standards
MCL	Maximum Contaminant Level
NPDES	National Pollutant Discharge Elimination System
RSL	Risk-Based Screening Level
RSW	Residual Solid Waste
SCR	Selective Catalytic Reduction
SSI	Statistically Significant Increase
SSL	Statistically Significant Level
USEPA	United States Environmental Protection Agency

1. INTRODUCTION

The Federal Coal Combustion Residuals (CCR) Rule (40 Code of Federal Regulations [CFR] Part 257.90(e)) (USEPA, 2015) requires owners and or operators of existing CCR landfills and surface impoundments to prepare a Groundwater Monitoring and Corrective Action Report (Report) no later than January 31 annually. Geosyntec Consultants (Geosyntec) has prepared this Report for the Fly Ash Reservoir (FAR) II, an existing CCR unit at the Cardinal Plant in Brilliant, Ohio (Site). This Report summarizes the groundwater monitoring activities conducted pursuant to the CCR Rule through December 31, 2019.

2. SITE SUMMARY

2.1 Site Description

The Site is located one mile south of Brilliant, Ohio in Jefferson County (**Figure 1**) and is operated by Buckeye Power, Inc. (Buckeye Power). Located along the Ohio River, the generating station consists of three coal-powered units with an 1,800-megawatt capacity and annual coal use of 5.2 million tons (Geosyntec, 2017a). Units 1 and 2 began operation in 1967 and Unit 3 began operation in 1977. As of 2012, all three units were equipped with an electrostatic precipitator (ESP), a selective catalytic reduction (SCR) system, and a flue gas desulfurization (FGD) system.

FAR II is an existing wet fly ash disposal reservoir that is located approximately one mile north of the plant site and immediately east of the FAR I Residual Solid Waste (RSW) Landfill. The reservoir is contained within Blockhouse Hollow (also referred to as Blockhouse Run in references and drawings) by Fly Ash Dam (FAD) 2 and the decommissioned FAD I. FAR II receives sluiced fly ash from the generating units' ESPs and collected stormwater and leachate from the FAR I RSW Landfill. FAR II/FAD 2 has a permitted discharge through the National Pollutant Discharge Elimination System (NPDES) Outfall 019 (Geosyntec, 2017a).

2.2 Regional Physiographic Setting

The Site is underlain by horizontal sequences of lower Permian and upper Pennsylvanian sedimentary rock. The Conemaugh Group, 500 feet (ft) thick in Jefferson County, consists of shale, sandstone, limestone, claystone, and coal. This group includes the Morgantown Sandstone underlain by the Elk Lick Limestone, the Skelly Limestone and Shale, the Ames Limestone, and the Cow Run Sandstone (Geosyntec, 2017a). Above the current grade of the RSW Landfill lies the Monongahela Group consisting of shale, sandstone, limestone, coal, claystone, and siltstone. Overlying the Monongahela Group, at approximately 1,250 feet in elevation, is the Permian-age Dunkard Group.

The uppermost aquifer at the Site lies within the Morgantown Sandstone, which is overlain by a shale aquitard. Groundwater in the uppermost aquifer generally flows south-southeast towards the Ohio River with hydraulic conductivity ranging from 1×10^{-1} to 1×10^{-4} centimeters per second

(cm/s). The hydraulic conductivity of the confining shale layer ranges from 1×10^{-7} to 1×10^{-9} cm/s (AEP, 2006).

3. GROUNDWATER MONITORING SYSTEM

The FAR II's groundwater monitoring network was designed to comply with 40 CFR 257.91. The groundwater monitoring network utilizes monitoring wells initially installed as part of a separate site-wide hydrogeologic investigation and is used to monitor groundwater quality in the uppermost aquifer at the Site. Monitoring well construction and soil boring logs were provided in the *Groundwater Monitoring Network Design Report* (Geosyntec, 2017a).

The FAR II groundwater monitoring network consists of twenty-three monitoring wells, as shown in **Figure 2**. Five upgradient monitoring wells (CA-0622A, M-12, M-1302, M-6, and MGS-5) are used to measure background conditions and eighteen downgradient monitoring wells (FA-8, M-10, M-1003, M-1004, M-11, M-13, M-1309, M-14, M-15, M-16, M-21, M-22, M-23, M-8, MGS-1, MGS-2, MGS-3, and MGS-4) are used as compliance wells.

4. CCR RULE GROUNDWATER KEY ACTIVITIES COMPLETED

4.1 2018 Statistical Evaluation Activities

A Groundwater Protection Standard (GWPS) was established for each Appendix IV parameter in accordance with the United States Environmental Protection Agency (USEPA's) *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities – Unified Guidance* (Unified Guidance; USEPA, 2009) and the Site's Statistical Analysis Plan (Geosyntec, 2017b). The established GWPSs were determined to be the greater value of the background concentration and the maximum contaminant level (MCL) or risk-based screening level (RSL) for each Appendix IV parameter. GWPSs determined in 2018 are provided in the *2018 Annual Groundwater Monitoring Report* (Geosyntec, 2019a). A statistical evaluation of the 2018 assessment monitoring data compared against the GWPS was completed in January 2019 and is described in the *Statistical Analysis Summary – Fly Ash Reservoir* (Geosyntec, 2019b). The statistical analysis report identified statistically significant levels (SSLs) of lithium and molybdenum above their respective GWPS at monitoring wells FA-8 and M-11. An alternate source was not identified for the SSLs and the CCR unit transitioned to corrective measures, as discussed in **Section 4.3**.

4.2 2019 Sampling and Data Evaluation Activities

4.2.1 Assessment Monitoring Program

Assessment monitoring sampling events were conducted in March and October 2019 in accordance with 40 CFR 257.95(b) and 40 CFR 257.95(d)(1). Samples were analyzed for all Appendix III and Appendix IV parameters, with results provided in **Table 1**. A revision of the

GWPS and statistical evaluation of the 2019 assessment monitoring data is ongoing and will be completed outside of the timeframe of this report.

4.2.2 Groundwater Elevation and Flow Velocities

Prior to sampling, a synoptic round of groundwater level measurements was collected from the compliance and background monitoring wells. Potentiometric surface maps based on groundwater elevations measured during the March and October 2019 assessment monitoring events are presented on **Figure 3** and **Figure 4**, respectively. The potentiometric maps show that groundwater near FAR II flows southeast towards the Ohio River. The groundwater residence times within the wells at the FAR II ranged from 0.6 days at M-GS-2 to 21.6 days at M-12. A summary of hydraulic gradients and groundwater residence times at the FAR II is provided in **Table 2**.

4.2.3 Data Usability

Upon receipt of laboratory analytical reports, the data were evaluated for usability. Analytical data were checked for the following:

- Samples were analyzed within the method specified hold times;
- Samples were received within holding temperature;
- Chain of custody forms were complete;
- Precision was within control limits using relative percent differences of blind duplicate samples;
- Matrix spike and matrix spike duplicate recoveries and laboratory control samples were within the control limits; and
- Potential for positive bias was evaluated using method blanks.

Samples collected in March 2019 from monitoring wells M-15 and M-1302 were not analyzed by USEPA method 9056 for chloride, fluoride, and sulfate within an acceptable hold time as a result of laboratory error. Monitoring wells M-15 and M-1302 were re-sampled in May 2019 and analyzed for the USEPA 9056 anions only. All other data received during 2019 were considered complete and usable.

4.3 Corrective Measures Program

Following detection of lithium and molybdenum SSLs at FA-8 and M-11, a Notification of Exceedance of Groundwater Protection Standards was published to the public internet site on February 7, 2019 in accordance with 40 CFR 257.105(h) (Buckeye Power, 2019). As required for characterization of the nature and extent of the release, monitoring well M-2000 was installed in accordance with 40 CFR 257.95(g)(1) on March 8, 2019 and sampled during the March and October 2019 assessment monitoring events. Monitoring well installation and sampling efforts are described in the *Groundwater Characterization Report, Cardinal Site – Fly Ash Reservoir II*

(Geosyntec, 2019c). The boring and construction log for monitoring well M-2000 is provided as **Attachment A**.

An Assessment of Corrective Measures (ACM) Report was completed in July 2019 in accordance with 40 CFR 257.96 and published to the public internet site (Geosyntec, 2019d). The ACM report lists four potential corrective measures that may be appropriate for addressing the elevated lithium and molybdenum concentrations in Site groundwater. A public meeting was held on September 4, 2019 in Steubenville, Ohio where the selection and implementation of potential corrective measures outlined in the ACM Report were reviewed and discussed.

4.4 Problems Encountered and Resolutions

No problems were encountered during 2019 which were related to assessment monitoring activities at the FAR II. Monitoring well M-2000 was installed in 2019 to facilitate characterization of the nature and extent of the release within the corrective measures program. No monitoring wells were gauged dry or abandoned within the well network during 2019.

Samples for chloride, fluoride, and sulfate at M-14 and M-16 were not collected during the March 2019 event due to sampling error. Samples were instead collected from M-14 and M-16 in July 2019 and submitted for analysis of anions. The mercury sample collected at M-1309 on October 10, 2019 was unable to be analyzed due to laboratory error. An additional sample was collected from M-1309 in November 2019 and submitted for mercury analysis. The March 2019 samples for chloride, fluoride, and sulfate at M-15 and M-1302 were analyzed out of hold time. These data will not be included in any statistical evaluation and additional samples were collected in May 2019. All other analytical data received were deemed to be of acceptable quality.

5. STATUS OF MONITORING PROGRAM

The Site was in the assessment monitoring program from May 2018 through January 2019 and transitioned to the corrective measures program in February 2019. Assessment monitoring events were conducted in March and October 2019. FAR II will remain in the corrective measures program in 2020.

6. PLANNED KEY ACTIVITIES FOR 2020

The following activities are planned for 2020 at the FAR II:

- The 2019 Annual Groundwater Monitoring Report will be entered into the facility's operating record and posted to the public internet site;
- The assessment monitoring statistics revision for data collected in 2019 will be completed and the potential for SSLs of Appendix IV parameters and Statistically Significant Increases (SSIs) of Appendix III parameters over background will be evaluated;

- Two semi-annual groundwater assessment monitoring program events will be conducted;
- A semi-annual report describing the progress in selecting and designing the remedy will be prepared and posted to the public internet site;
- A remedy, outlined in the ACM, will be selected in accordance with 40 CFR 257.97. A final report describing the selected remedy, and initiation of remedial activities will be prepared and posted to the public internet site; and
- The 2020 Annual Groundwater Monitoring Report will be prepared for submittal in January 2021.

7. REFERENCES

American Electric Power (AEP) and Geosyntec Consultants, Inc. 2006. Hydrogeological Investigation Report. May.

Buckeye Power Generating I, Inc. (Buckeye Power). 2019. Notification of Exceedance of Groundwater Protection Standards at Fly Ash Reservoir II. February.

Geosyntec Consultants, Inc. 2017a. Groundwater Monitoring Network Evaluation, Cardinal Site – Fly Ash Reservoir II, February.

Geosyntec Consultants, Inc. 2017b. Statistical Analysis Plan. January.

Geosyntec Consultants, Inc. 2019a. 2018 Annual Groundwater Monitoring Report, Federal CCR Rule, Cardinal Plant – Fly Ash Reservoir. January.

Geosyntec Consultants, Inc. 2019b. Statistical Analysis Summary – Fly Ash Reservoir II. January.

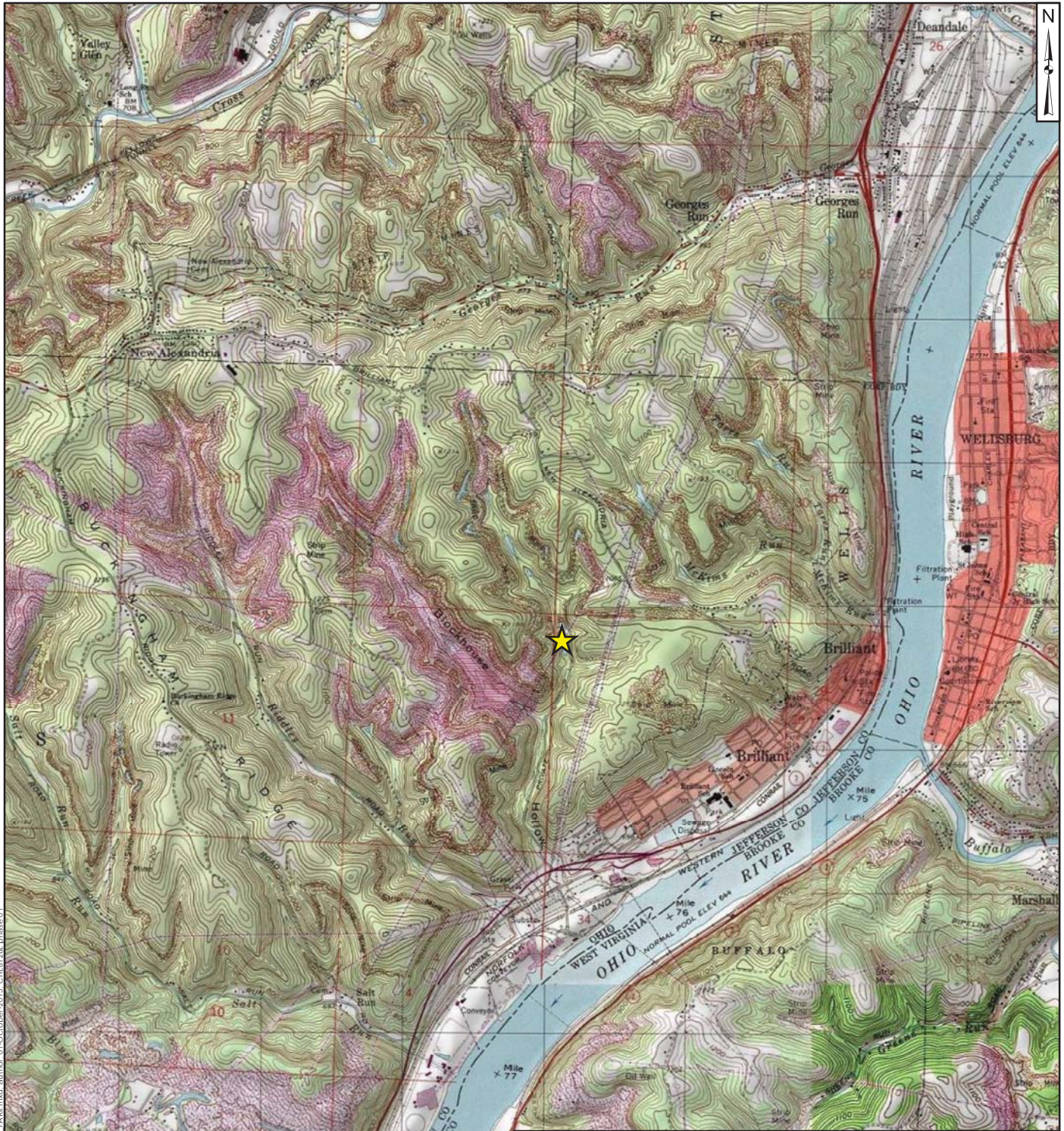
Geosyntec Consultants, Inc. 2019c. Groundwater Characterization Report, Cardinal Site – Fly Ash Reservoir II. July.

Geosyntec Consultants, Inc. 2019d. Assessment of Corrective Measures, Cardinal Site – Fly Ash Reservoir II. July.

United States Environmental Protection Agency (USEPA). 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities - Unified Guidance. EPA 530/R-09-007. March.

United States Environmental Protection Agency (USEPA). 2015. Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities (Final Rule). Fed. Reg. 80 FR 21301, pp. 21301-21501, 40 CFR Parts 257 and 261, April.

FIGURES



Legend



Site Location

Notes

- All locations are approximate.
- Topographic maps courtesy of National Geographic Society.

5,000 2,500 0 5,000 Feet



Site Location Map FAR II

Cardinal Power Plant
Brilliant, Ohio

Geosyntec
consultants

Figure

1

Ann Arbor, Michigan

01-October-2015



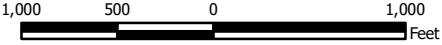
Monitoring Well Network

- ◆ Compliance Sampling Location
- ◆ Background Sampling Location
- ◆ Corrective Measures Delineation Well
- ▲ Jules Verne Seep

▭ Fly Ash Reservoir (FAR) II

Notes

- Monitoring well coordinates provided by Buckeye Power.
-Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Fly Ash Reservoir II (Geosyntec, 2017) provided by Buckeye Power.



**Site Layout
Fly Ash Reservoir II**

AEP Cardinal Generating Plant
Brilliant, Ohio

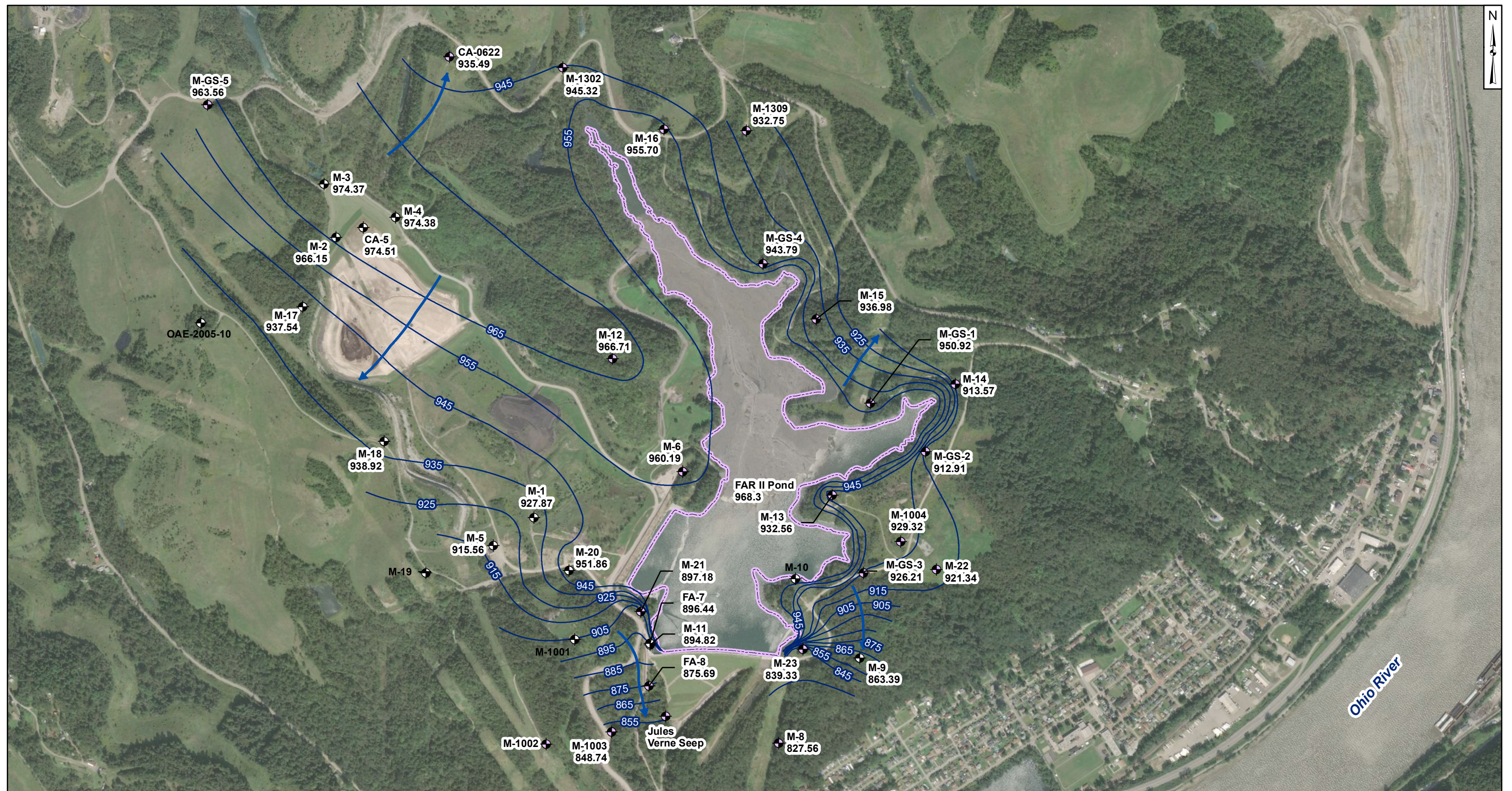
Geosyntec
consultants

Columbus, Ohio






2020/01/14

Figure

2

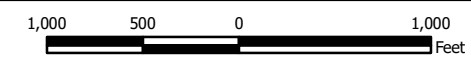


Legend

-  FAR II Network Monitoring Well
 State/Other Program Monitoring Well
 Fly Ash Reservoir (FAR) II
 Groundwater Elevation Contour
 Approximate Groundwater Flow Direction

Notes

- Monitoring well coordinates and water level data (collected on March 21, 2019) provided by Buckeye Power.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Fly Ash Reservoir II (Geosyntec, 2017) provided by AEP.
- Groundwater discharge observed from Jules Verne Seep location.
- OAE-2005-10, M-10, M-19, and M-1001 were not gauged in March 2019.
- Groundwater elevation units are feet above mean sea level.



**Potentiometric Surface Map - Morgantown Aquifer
Fly Ash Reservoir II
March 2019**

Buckeye Power Cardinal Generating Plant
Brilliant, Ohio

Geosyntec
consultants

Figure

X

Columbus, Ohio

2020/01/03

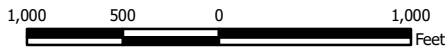


Legend

- FAR II Network Monitoring Well
- State/Other Program Monitoring Well
- Groundwater Elevation Contour
- Approximate Groundwater Flow Direction
- Fly Ash Reservoir (FAR) II

Notes

- Monitoring well coordinates and water level data (collected on October 26, 2019) provided by Buckeye Power.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Fly Ash Reservoir II (Geosyntec, 2017) provided by AEP.
- Groundwater elevation units are feet above mean sea level.
- Groundwater discharge observed from Jules Verne Seep location.
- OAE-2005-10, M-12, M-17, M-19, M-1001, M-1002, and MP-1 were not gauged in October 2019.
- An obstruction was noted in M-1309 at elevation 967.61 ft amsl
- * Well not used for contouring due to inconsistent/anamolous reading.



Potentiometric Surface Map - Morgantown Aquifer Fly Ash Reservoir II October 2019	
Buckeye Power Cardinal Generating Plant Brilliant, Ohio	
Geosyntec consultants	
Columbus, Ohio	2019/12/31

Figure
X

TABLES

Table 1 - Groundwater Data Summary
Cardinal Plant - Fly Ash Reservoir II

Parameter	Unit	CA-0622A		FA-8		M-6		M-8		M-10		M-11	
		3/26/2019	10/1/2019	4/4/2019	10/9/2019	3/28/2019	10/3/2019	4/1/2019	10/3/2019	4/2/2019	10/3/2019	4/5/2019	10/9/2019
Antimony	µg/L	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.700	0.620
Arsenic	µg/L	29.2	25.8	7.70	9.20	4.10	4.70	0.940	1.10	0.500 U	0.500 U	3.00	5.40
Barium	µg/L	934	952	24.5	22.2	435	442	127	120	78.0	80.6	23.9	20.8
Beryllium	µg/L	0.100 U	0.100 U	0.100 U	0.100 U	1.50	1.80	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U
Boron	µg/L	284	337	4,980	4,740	231	239	26.6	25.8	580	536	4,670	5,000
Cadmium	µg/L	0.100 U	0.100 U	0.240	0.150	0.230	0.260	0.100 U	0.100 U	0.100 U	0.190	0.400	0.180
Calcium	µg/L	75,400	74,200	198,000	218,000	16,000	15,600	108,000	102,000	14,100	12,400	195,000	219,000
Chloride	mg/L	4,900	3,470	43.4	46.6	32.9	39.8	6.00	6.10	12.6	12.6	44.2	45.7
Chromium	µg/L	1.50	1.20	1.00 U	1.10	9.20	11.8	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Cobalt	µg/L	0.620	0.630	0.870	0.920	4.90	5.60	0.660	0.500 U	0.500 U	0.500 U	1.20	1.20
Combined Radium	pCi/L	11.6	11.9	0.188	1.17	6.51	5.15	0.476	0.776	1.68	0.815	0.453	1.28
Fluoride	mg/L	0.470	0.0500 U	0.600	0.570	1.20	1.10	0.0880	0.0500 U	0.690	0.670	0.580	0.550
Lead	µg/L	0.500 U	0.500 U	0.500 U	0.500 U	22.0	25.9	0.590	0.730	0.850	1.20	0.980	0.640
Lithium	µg/L	89.8	86.7	198	194	18.3	18.6	10.0 U	10.0 U	19.6	20.0	193	188
Mercury	µg/L	0.00108	0.00185	0.000500 U	0.000570	0.0104	0.00694	0.00116	0.00214	0.000570	0.000500 U	0.000500 U	0.000610
Molybdenum	µg/L	3.40	1.90	321	303	1.00 U	1.20	0.500 U	0.500 U	2.40	2.30	316	338
Selenium	µg/L	0.500 U	1.00	2.00	0.500 U	1.00 U	1.70	0.500 U	0.500 U	0.500 U	0.500 U	4.50	0.640
Sulfate	mg/L	72.0	40.4	885	762	2.00	7.70	95.8	99.9	133	134	960	781
Thallium	µg/L	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U
Total Dissolved Solids	mg/L	6,680	7,250	1,430	1,360	478	695	421	409	711	710	1,400	1,360
pH	SU	7.49	7.85	7.12	7.02	7.71	7.95	7.37	7.33	8.40	8.44	8.01	7.15

Notes:
mg/L: milligrams per liter
µg/L: micrograms per liter
SU: standard unit
pCi/L: picocuries per liter
U: Parameter was not present in concentrations above method detection limit and is reported as the reporting limit
J: Estimated value. Parameter was detected in concentrations below the reporting limit
- : Not sampled
All samples were collected as part of the assessment monitoring program in accordance with 40 CFR 257.90(e)(3).

Table 1 - Groundwater Data Summary
Cardinal Plant - Fly Ash Reservoir II

Parameter	Unit	M-12		M-13		M-14			M-15			M-16		
		4/3/2019	10/9/2019	4/3/2019	10/8/2019	3/27/2019	7/2/2019	10/7/2019	3/25/2019	5/1/2019	9/30/2019	3/27/2019	7/2/2019	10/1/2019
Antimony	µg/L	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	-	0.500 U	0.500 U	-	0.500 U	0.500 U	-	0.500 U
Arsenic	µg/L	5.60	2.10	1.40	1.00	0.500 U	-	0.500 U	2.00	-	2.00	0.500 U	-	0.500 U
Barium	µg/L	89.1	28.3	218	159	14.6	-	14.3	43.2	-	45.4	37.1	-	37.4
Beryllium	µg/L	0.100	0.100 U	0.930	0.100 U	0.100 U	-	0.100 U	0.100 U	-	0.100 U	0.100 U	-	0.100 U
Boron	µg/L	324	290	261	285	224	-	231	228	-	258	192	-	184
Cadmium	µg/L	0.130	0.100 U	0.100 U	0.100 U	0.100 U	-	0.100 U	0.100 U	-	0.100 U	0.100 U	-	0.100 U
Calcium	µg/L	371,000	188,000	14,600	15,400	513	-	603	1,550	-	1,490	2,240	-	2,260
Chloride	mg/L	184	270	2.10	2.10	-	1.80	1.50	-	25.7	26.0	-	10.0	10.2
Chromium	µg/L	1.00 U	1.00 U	3.40	1.00 U	1.00 U	-	1.00 U	1.00 U	-	1.00 U	1.00 U	-	1.00 U
Cobalt	µg/L	31.7	6.20	1.20	0.500 U	0.500 U	-	0.500 U	0.500 U	-	0.500 U	0.500 U	-	0.500 U
Combined Radium	pCi/L	1.14	1.19	3.87	1.56	0.680	-	1.22	0.681	-	0.00	0.553	-	0.805
Fluoride	mg/L	0.990	1.30	1.70	1.80	-	0.730	0.780	-	1.40	1.30	-	0.350	0.350
Lead	µg/L	1.20	0.500 U	3.30	0.530	0.500 U	-	0.500 U	0.500 U	-	0.500 U	0.500 U	-	0.500 U
Lithium	µg/L	106	108	15.8	10.8	10.0 U	-	10.0 U	10.0 U	-	10.0 U	10.4	-	11.0
Mercury	µg/L	0.00583	0.00169	0.00267	0.000510	0.000500 U	-	0.000500 U	0.000500 U	-	0.000500 U	0.000500 U	-	0.000500 U
Molybdenum	µg/L	0.500 U	0.500 U	0.730	0.680	0.500 U	-	0.500 U	0.500 U	-	0.500 U	0.500 U	-	0.500 U
Selenium	µg/L	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	-	0.500 U	0.500 U	-	0.500 U	0.500 U	-	0.610
Sulfate	mg/L	1,590	1,020	28.8	30.5	-	0.800	1.10	-	3.00	1.50	-	332	276
Thallium	µg/L	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	-	0.500 U	0.500 U	-	0.500 U	0.500 U	-	0.500 U
Total Dissolved Solids	mg/L	2,910	2,290	510	492	347	-	347	540	-	552	780	-	757
pH	SU	667	7.22	8.15	7.48	9.19	-	8.83	9.13	-	9.03	8.34	-	8.81

Notes:
mg/L: milligrams per liter
µg/L: micrograms per liter
SU: standard unit
pCi/L: picocuries per liter
U: Parameter was not present in concentrations above method detection limit and is reported as the reporting limit
J: Estimated value. Parameter was detected in concentrations below the reporting limit
- : Not sampled
All samples were collected as part of the assessment monitoring program in accordance with 40 CFR 257.90(e)(3).

Table 1 - Groundwater Data Summary
Cardinal Plant - Fly Ash Reservoir II

Parameter	Unit	M-21		M-22		M-23		M-1003		M-1004		M-1302		
		4/3/2019	10/8/2019	4/3/2019	10/9/2019	4/1/2019	10/3/2019	4/8/2019	10/9/2019	4/2/2019	10/7/2019	3/25/2019	5/1/2019	10/1/2019
Antimony	µg/L	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	-	0.500 U
Arsenic	µg/L	5.40	3.60	0.500 U	0.500 U	3.40	0.930	0.530	0.500 U	1.50	1.50	0.500 U	-	0.500 U
Barium	µg/L	14.1	13.8	25.1	21.8	27.3	8.50	84.2	79.4	47.2	44.8	107	-	106
Beryllium	µg/L	1.40	0.780	0.100 U	0.100 U	0.250	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	-	0.100 U
Boron	µg/L	3,210	3,100	3,990	3,760	695	696	128	130	2,310	2,680	244	-	295
Cadmium	µg/L	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	-	0.100 U
Calcium	µg/L	237,000	176,000	188,000	178,000	125,000	105,000	69,100	68,300	97,900	115,000	3,490	-	3,340
Chloride	mg/L	51.9	63.8	44.0	43.9	12.0	13.4	5.80	6.20	31.8	35.6	-	26.6	28.4
Chromium	µg/L	1.00 U	1.00 U	1.00 U	1.00 U	3.50	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	-	1.00 U
Cobalt	µg/L	1.80	0.910	0.500 U	1.50	2.60	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	-	0.500 U
Combined Radium	pCi/L	0.573	0.980	0.776	1.18	2.30	2.21	2.10	3.24	0.890	1.25	0.771	-	0.421
Fluoride	mg/L	0.100	0.130	0.520	0.380	0.330	0.390	0.230	0.200	1.20	1.20	-	1.20	1.70
Lead	µg/L	3.70	1.00	0.500 U	0.500 U	3.30	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	-	0.500 U
Lithium	µg/L	80.0	66.5	52.6	52.5	57.9	48.6	10.0 U	10.0 U	21.0	18.0	13.1	-	11.7
Mercury	µg/L	0.00366	0.00156	0.000680	0.000500 U	0.0127	0.000500 U	0.000500 U	0.000640	0.000500 U	0.000510	0.000510 U	-	0.000510 U
Molybdenum	µg/L	21.3	16.6	56.5	79.1	0.500 U	0.500 U	0.500 U	0.500 U	9.40	11.6	0.500 U	-	0.500 U
Selenium	µg/L	0.500 U	0.500 U	0.500 U	0.500 U	0.560	0.530	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	-	0.590
Sulfate	mg/L	1,170	968	382	400	1,570	1,750	98.3	112	272	341	-	111	60.9
Thallium	µg/L	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	-	0.500 U
Total Dissolved Solids	mg/L	1,810	1,760	896	905	3,320	3,210	466	437	859	869	699	-	721
pH	SU	7.21	7.21	7.11	7.09	7.21	7.14	7.56	7.39	7.48	7.27	8.79	-	8.51

Notes:
mg/L: milligrams per liter
µg/L: micrograms per liter
SU: standard unit
pCi/L: picocuries per liter
U: Parameter was not present in concentrations above method detection limit and is reported as the reporting limit
J: Estimated value. Parameter was detected in concentrations below the reporting limit
- : Not sampled
All samples were collected as part of the assessment monitoring program in accordance with 40 CFR 257.90(e)(3).

Table 1 - Groundwater Data Summary
Cardinal Plant - Fly Ash Reservoir II

Parameter	Unit	M-1309			M-2000		MGS-1		MGS-2		MGS-3		MGS-4		MGS-5	
		4/4/2019	10/10/2019	11/12/2019	4/5/2019	10/9/2019	3/27/2019	10/7/2019	4/2/2019	10/9/2019	4/3/2019	10/4/2019	4/1/2019	10/8/2019	3/26/2019	10/2/2019
Antimony	µg/L	0.500 U	0.500 U	-	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U
Arsenic	µg/L	2.20	2.00	-	0.530	0.880	0.500 U	0.500 U	11.7	12.9	36.7	10.3	5.40	5.10	14.1	12.5
Barium	µg/L	33.6	34.6	-	86.7	25.1	92.0	89.6	38.6	45.7	12.2	9.40	12.3	13.0	103	105
Beryllium	µg/L	0.100 U	0.100 U	-	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U
Boron	µg/L	285	283	-	254	4,970	288	321	214	169	536	879	193	204	335	271
Cadmium	µg/L	0.100 U	0.100 U	-	0.100 U	0.100	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U
Calcium	µg/L	5,690	4,390	-	218,000	216,000	13,200	13,300	20,900	46,300	284,000	147,000	8,170	8,040	2,950	2,730
Chloride	mg/L	37.8	38.9	-	46.6	50.0	32.7	38.3	20.6	21.1	16.8	27.6	12.1	12.1	170	206
Chromium	µg/L	1.00 U	1.00 U	-	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
Cobalt	µg/L	0.500 U	0.500 U	-	0.500 U	1.10	0.500 U	0.500 U	0.770	1.20	0.660	0.840	0.500 U	0.500 U	0.500 U	0.500 U
Combined Radium	pCi/L	0.936	1.71	-	1.72	1.24	0.316	0.901	0.307	0.177	1.37	0.850	0.0710	0.221	0.181	0.527
Fluoride	mg/L	1.10	1.20	-	0.370	0.380	0.650	0.640	0.370	0.370	0.170	0.140	0.510	0.510	5.40	6.60
Lead	µg/L	0.500 U	0.500 U	-	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U
Lithium	µg/L	23.4	17.2	-	201	190	17.7	16.6	13.5	13.2	38.0	47.6	10.0 U	10.0 U	16.7	14.0
Mercury	µg/L	0.00170	-	0.000850	0.000500 U	0.000500 U	0.000500 U	0.000500 U	0.000500 U	0.000500 U	0.000500 U	0.000500 U	0.000500 U	0.000500 U	0.000500 U	0.000500 U
Molybdenum	µg/L	1.50	1.10	-	0.500 U	208	0.500 U	0.500 U	4.30	10.3	2.30	2.10	4.20	5.50	2.30	1.90
Selenium	µg/L	0.500 U	0.500 U	-	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U
Sulfate	mg/L	94.6	88.1	-	820	830	78.9	91.2	164	162	1,330	1,290	98.1	86.7	3.50	1.60
Thallium	µg/L	0.500 U	0.500 U	-	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U
Total Dissolved Solids	mg/L	693	687	-	721	1,440	616	597	618	651	2,030	2,000	572	522	1,030	1,070
pH	SU	7.94	7.57	-	6.83	6.80	7.75	7.47	7.62	7.51	679	6.59	8.46	8.13	8.70	8.50

Notes:
mg/L: milligrams per liter
µg/L: micrograms per liter
SU: standard unit
pCi/L: picocuries per liter
U: Parameter was not present in concentrations above method detection limit and is reported as the reporting limit
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- : Not sampled
All samples were collected as part of the assessment monitoring program in accordance with 40 CFR 257.90(e)(3).

Table 2: Residence Time Calculation Summary
Cardinal Plant - Fly Ash Reservoir II

Geosyntec Consultants, Inc.

CCR Management Unit	Monitoring Well	Well Diameter (inches)	2019-03		2019-10	
			Groundwater Velocity (ft/year)	Groundwater Residence Time (days)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)
Fly Ash Reservoir II	CA-0622/A ^[1]	2.0	9.4	6.5	13.0	4.7
	FA-8 ^[2]	2.0	20.5	3.0	17.7	3.4
	M-10 ^[2]	0.75	NC	NC	35.0	0.7
	M-1003 ^[2]	2.0	20.0	2.7	13.8	3.8
	M-1004 ^[2]	2.0	9.1	6.7	5.0	12.1
	M-11 ^[2]	1.0	15.7	1.9	17.5	1.7
	M-12 ^[1]	2.0	2.8	21.6	NC	NC
	M-13 ^[2]	2.0	11.6	5.2	5.7	10.6
	M-1302 ^[1]	2.0	7.9	7.7	25.4	2.4
	M-1309 ^[2]	2.0	5.2	11.8	NC	NC
	M-14 ^[2]	2.0	65.8	0.9	62.9	1.0
	M-15 ^[2]	2.0	17.2	3.5	16.9	3.6
	M-16 ^[2]	2.0	12.2	5.0	21.9	2.8
	M-21 ^[2]	2.0	7.5	8.2	8.9	6.9
	M-22 ^[2]	2.0	3.7	16.3	3.8	15.9
	M-23 ^[2]	2.0	4.3	14.0	3.9	15.5
	M-6 ^[1]	1.0	13.3	4.6	11.9	5.1
	M-8 ^[2]	2.0	7.0	8.7	13.1	4.7
	M-GS-1 ^[2]	2.0	13.9	4.4	19.1	3.2
	M-GS-2 ^[2]	2.0	100.9	0.6	89.1	0.7
	M-GS-3 ^[2]	2.0	20.7	2.9	20.7	2.9
	M-GS-4 ^[2]	2.0	39.6	1.5	20.0	3.0
	M-GS-5 ^[1]	2.0	4.6	13.4	9.5	6.4

Notes:

[1] - Background Well

[2] - Downgradient Well

NC - Groundwater residence time could not be calculated

ATTACHMENT A

Monitoring Well M-2000 Construction Diagram

HULL

Environment / Energy / Infrastructure

Cardinal Operating Company
306 County Road 7E
Brilliant, Ohio
BPG003

Date Started : 3-6-2019
Date Completed : 3-8-2019
Logged by : Mielecki
Reviewed by : J. Ardner
Drilling Contractor : Terra Testing
Drilling Method : 4.25" HSA
Sampling Method : 4" Core Barrel
Total Depth (ft.) : 77.0'

LOG OF BORING M-2000

(Page 1 of 4)

Depth in Feet	Sample Interval/ Sample Recovery	Sampler Type/ Sample Number	Sample	GRAPHIC	Water Level	Soil Samples	Water Levels	Well: M-2000
						<div>☒ Sample Intervals</div> <div>■ Sample Sent to Lab</div>	<div>▼ Static</div> <div>▽ During Drilling</div>	
						DESCRIPTION		
0						Straight drill using 4.25-inch Hollow Stem Augers to bedrock refusal.		
1						Bottom Ash (0-32')		
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

Concrete Seal

2" PVC Riser

Bentonite Seal

HULL

Environment / Energy / Infrastructure

Cardinal Operating Company
306 County Road 7E
Brilliant, Ohio
BPG003

Date Started : 3-6-2019
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Sampling Method : 4" Core Barrel
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LOG OF BORING M-2000

(Page 2 of 4)

Depth in Feet	Sample Interval/ Sample Recovery	Sampler Type/ Sample Number	Sample	GRAPHIC	Water Level	Soil Samples	Water Levels	Well: M-2000
						<div>☒ Sample Intervals</div> <div>■ Sample Sent to Lab</div>	<div>▼ Static</div> <div>▽ During Drilling</div>	
DESCRIPTION								
20						Bottom Ash (Continued).		
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33						Weathered SANDSTONE; augers set at 35.0 feet.		
34								
35	2/0.8	RC-1 35.0-37.0				Medium, reddish orange, moderately weathered, strong, SANDSTONE; fractured. Rock Quality Designation (RQD) = 0%		
36								
37	5/3.9	RC-2 37.0-42.0				Medium-grained, yellowish brown, moderately weathered, SANDSTONE; thin; fractured. RQD = 36.2%		
38								
39								
40								

Bentonite Seal
2" PVC Riser

HULL

Environment / Energy / Infrastructure

Cardinal Operating Company
306 County Road 7E
Brilliant, Ohio
BPG003

Date Started : 3-6-2019
Date Completed : 3-8-2019
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Drilling Contractor : Terra Testing
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Total Depth (ft.) : 77.0'

LOG OF BORING M-2000

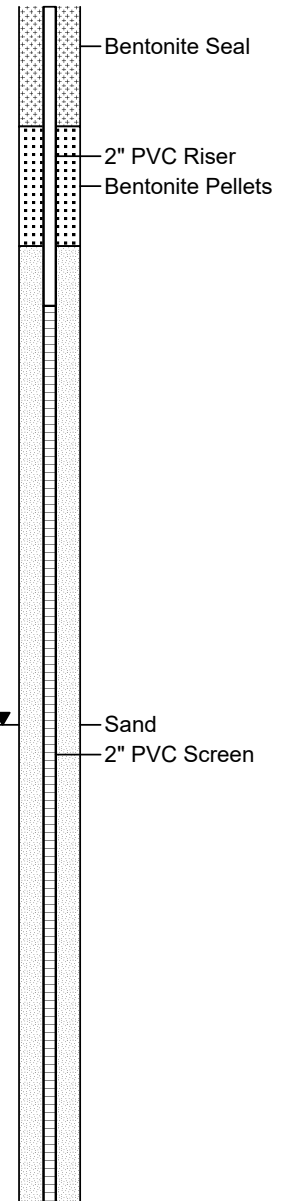
(Page 3 of 4)

Depth in Feet	Sample Interval/ Sample Recovery	Sampler Type/ Sample Number	Sample	GRAPHIC	Water Level	Soil Samples	Water Levels	Well: M-2000
						<div><div></div> Sample Intervals</div> <div><div></div> Sample Sent to Lab</div>	<div><div></div> Static</div> <div><div></div> During Drilling</div>	
DESCRIPTION								
40						Medium-grained, yellowish brown, moderately weathered, SANDSTONE; thin; fractured.		
41								
42	5/5	RC-3 42.0-47.0				Same as above; highly to moderately fractured. RQD = 56.7%		
43								
44								
45								
46								
47	3/1.1	RC-4 47.0-50.0				Medium grained, greenish grey, moderately weathered, moderately strong, SANDSTONE; thin; fractured; becoming wet. RQD = 0%		
48								
49								
50	2/2	RC-5 50.0-52.0				Medium grained, yellowish brown to grey, slightly weathered, moderately strong, SANDSTONE; thin; moderately fractured. RQD = 75%		
51								
52	5/4.8	RC-6 52.0-57.0				Medium grained, yellow brown to grey, moderately weathered, moderately strong, SANDSTONE; siliceous bedding; slightly rough; thin; moderately fractured. RQD = 54.4%		
53								
54								
55								
56								
57	5/5	RC-7 57.0-62.0				Medium grained, very thin to medium, yellow brown to grey, moderately weathered, moderately strong; bedding fractured to moderately fractured. RQD = 56.7%		
58								
59								
60								

Bentonite Seal

2" PVC Riser

Bentonite Pellets



HULL

Environment / Energy / Infrastructure

Cardinal Operating Company
306 County Road 7E
Brilliant, Ohio
BPG003

Date Started : 3-6-2019
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Sampling Method : 4" Core Barrel
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LOG OF BORING M-2000

(Page 4 of 4)

Depth in Feet	Sample Interval/ Sample Recovery	Sampler Type/ Sample Number	Sample	GRAPHIC	Water Level	Soil Samples	Water Levels	Well: M-2000
						<div>⊠</div> Sample Intervals	<div>▼</div> Static	
						<div>■</div> Sample Sent to Lab	<div>▽</div> During Drilling	
DESCRIPTION								
60	5/4.6	RC-8 62.0-67.0	<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><d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