

---

**2023 Annual Groundwater Monitoring Report for FAR I  
Residual Solid Waste Landfill  
Cardinal Operating Company – Cardinal Upland Disposal  
Facility  
306 County Road 7E  
Brilliant, Ohio**

---

January 25, 2024

Submitted to:

Cardinal Operating Company  
306 County Road 7E  
Brilliant, Ohio 43913

Submitted by:

Cox-Colvin & Associates, Inc.  
7750 Corporate Blvd.  
Plain City, Ohio 43064  
(614) 526-2040



## Table of Contents

1.0	Introduction.....	1
1.1	Site Summary.....	1
1.2	CCR Unit Description.....	1
1.3	Regional Physiographic Setting.....	1
2.0	Groundwater Monitoring System .....	3
3.0	Groundwater Monitoring Program .....	4
3.1	Statistical Analysis Plan.....	4
3.2	Monitoring Frequency .....	4
4.0	Key Actions Completed.....	5
4.1	Groundwater Elevation and Flow .....	5
4.2	Groundwater Sampling .....	5
4.3	Data Evaluation.....	5
4.3.1	Background Levels .....	5
4.3.2	Groundwater Protection Standards .....	6
4.4	Corrective Actions .....	6
5.0	Problems Encountered and Resolutions.....	7
6.0	Projected Key Activities .....	8
7.0	References.....	9

## **Figures**

- 1-1 Site Location Map
- 1-2 CCR Unit and Monitoring Wells
- 4-1 Potentiometric Surface Map - Shallow Aquifer - April 10, 2023
- 4-2 Potentiometric Surface Map - Shallow Aquifer - October 9, 2023

## **Tables**

- 4-1 Groundwater Flow Calculations April 2023
- 4-2 Groundwater Flow Calculations October 2023
- 4-3 Summary of CCR Groundwater Samples
- 4-4 Downgradient Well Monitoring Results – First Semi-Annual Event
- 4-5 Background Well Monitoring Results – First Semi-Annual Event
- 4-6 Downgradient Well Monitoring Results – Second Semi-Annual Event
- 4-7 Background Well Monitoring Results – Second Semi-Annual Event
- 4-8 Appendix III Constituent Background Levels

## **Executive Summary**

Cox-Colvin & Associates, Inc. (Cox-Colvin) has prepared this 2023 Annual Groundwater Monitoring Report for the FAR I Residual Solid Waste (RSW) Landfill at the Cardinal Plant in Brilliant, Ohio. This report has been prepared in accordance with §257.90(e) of the Federal Coal Combustion Residuals Rules (“CCR Rules”, 40 CFR Subpart D), which requires owners and/or operators of existing CCR landfills and surface impoundments to prepare a groundwater monitoring and corrective action report no later than January 31, annually. This report summarizes groundwater monitoring activities conducted, pursuant to the CCR Rules, from January 1, 2023, through December 31, 2023.

At the start of the 2023 annual reporting period, the RSW Landfill was operating under the detection monitoring program (40 CFR 257.94). The RSW Landfill remained in the detection monitoring program throughout the 2023 annual reporting period.

Two semi-annual assessment monitoring events were completed during this annual reporting period – the first in April 2023 and the second in October 2023. During this annual reporting period, no statistically significant increases (SSIs) above background were identified. As such, no testing for statistically significant levels (SSLs) above groundwater protection standards (GWPSs) was necessary or performed.

## 1.0 Introduction

Cox-Colvin & Associates, Inc. (Cox-Colvin) has prepared this 2023 Annual Groundwater Monitoring Report for the FAR I Residual Solid Waste (RSW) Landfill at the Cardinal Plant in Brilliant, Ohio (Figure 1-1, Site). This report has been prepared in accordance with §257.90(e) of the Federal Coal Combustion Residuals Rules (“CCR Rules”, 40 CFR Subpart D), which requires owners and/or operators of existing CCR landfills and surface impoundments to prepare a groundwater monitoring and corrective action report no later than January 31, annually. This report summarizes groundwater monitoring activities conducted pursuant to the CCR Rules from January 1, 2023, through December 31, 2023.

### 1.1 Site Summary

The Site is located one mile west and south of Brilliant, Ohio in Jefferson County and is operated by Cardinal Operating Company (Cardinal). Located along the Ohio River, the generating plant consists of three coal-powered units with an 1,800-megawatt (MW) capacity. Units 1 and 2 began operation in 1967 and Unit 3 began operation in 1977. Each generating unit is equipped with an electrostatic precipitator (ESP) for removal of fly ash particulate matter, a selective catalytic reduction (SCR) system for removal of nitrogen oxide, and flue gas desulfurization (FGD) systems for removal of sulfur dioxide (Geosyntec 2016).

### 1.2 CCR Unit Description

The RSW Landfill unit is a dry landfill disposal facility located approximately one mile north of the Site in a portion of Blockhouse Hollow (also referred to as Blockhouse Run in references and drawings) that was formerly surface mined for the Pittsburgh No. 8 coal. The FAR I RSW Landfill is an existing, active CCR landfill which receives gypsum waste, fly ash, and bottom ash from the Bottom Ash Pond (BAP). Two of the six cells of the RSW Landfill were in operation at the time the CCR Rules became effective. Construction of future cells would be considered lateral expansions. The RSW Landfill previously used FAR II as a leachate and stormwater collection pond (Geosyntec 2016), but these are now managed in settling tanks following initiation of FAR II closure activities in 2021.

The FAR I RSW Landfill and associated monitoring wells are shown in Figure 1-2.

### 1.3 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. Above the current grade of the RSW Landfill

lies the Monongahela Group, which consists 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 (Geosyntec 2016).

The uppermost aquifer at the FAR I RSW Landfill is comprised of unconsolidated mine waste and shallow sandstone and limestone deposits overlying a discontinuous shale aquitard above the Morgantown Sandstone. Groundwater in the uppermost aquifer generally flows south-southeast towards the Ohio River with hydraulic conductivity ranging from  $1 \times 10^{-1}$  to  $1 \times 10^{-4}$  centimeters per second (cm/s). The hydraulic conductivity of the confining shale layer ranges from  $1 \times 10^{-7}$  to  $1 \times 10^{-9}$  cm/s (Geosyntec 2016).

## 2.0 Groundwater Monitoring System

The FAR I RSW Landfill's groundwater monitoring network was designed to comply with §257.91 of the CCR Rules. 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 Evaluation (Geosyntec 2016).

The FAR I RSW Landfill groundwater monitoring network consists of 16 monitoring wells, shown in Figure 1-2. Nine (9) upgradient monitoring wells (CA-0623A, OAE 2005 10C, S-2, S-GS-3, S-4, S-5, S-6, S-17, and S-19A) are used to establish background conditions and seven (7) downgradient monitoring wells (S-GS-1, S-GS-2, S-1, S-7, S-10, S-18, and S-20) are used as compliance wells.

No CCR monitoring wells were installed or decommissioned during 2023.

## **3.0 Groundwater Monitoring Program**

In accordance with §257.94 of the CCR Rules, the FAR I RSW Landfill remained in the detection monitoring program through December 2023.

### **3.1 Statistical Analysis Plan**

Evaluation of analytical data is performed in accordance with the Statistical Analysis Plan (Geosyntec 2020), which describes a logic process regarding the statistical analysis of groundwater data collected in compliance with the Federal CCR Rules. No revisions were made to the Statistical Analysis Plan during 2023.

### **3.2 Monitoring Frequency**

In accordance with §257.94 of the CCR Rules, monitoring wells are sampled semi-annually for constituents listed in Appendix III of the CCR Rules.

There was no suspension of groundwater monitoring requirements at the FAR I RSW Landfill under §257.90(g) of the CCR Rules.

## 4.0 Key Actions Completed

The sections below summarize key actions completed in 2023 with respect to CCR Rules groundwater monitoring and corrective actions at the FAR I RSW Landfill.

### 4.1 Groundwater Elevation and Flow

Prior to sampling, a synoptic round of groundwater level measurements was collected from the background and downgradient monitoring wells. Potentiometric surface maps based on groundwater elevations measured on April 10, 2023, and October 9, 2023, are presented in Figures 4-1 and 4-2, respectively. The potentiometric maps show that groundwater near the RSW Landfill flows southeast towards the Ohio River. Groundwater flow rate calculations relative to the RSW Landfill are summarized in Tables 4-1 and 4-2.

### 4.2 Groundwater Sampling

Table 4-3 contains a summary of groundwater samples collected for analysis in association with CCR activities at the FAR I RSW Landfill. The first (Spring) semi-annual monitoring event of 2023 was completed in April, with resampling in June 2023. The second (Fall) semi-annual monitoring event of 2023 was completed in October 2023. A total of 36 samples were collected (Table 4-3). Analytical results are summarized in Tables 4-4 through 4-7.

### 4.3 Data Evaluation

Data evaluations performed in 2023 consisted of the following:

- Comparison of Spring 2023 monitoring data, including resampling data, to background levels for Appendix III constituents
- Comparison of Fall 2023 monitoring data, including resampling data, to background levels for Appendix III constituents

As discussed below, no statistically significant increases (SSIs) above background were identified. As such, no testing for statistically significant levels (SSLs) above groundwater protection standards (GWPSs) was necessary or performed.

#### 4.3.1 Background Levels

Background levels in the FAR I RSW Landfill groundwater were updated for Appendix III constituents<sup>1</sup> in October 2023. In October 2023, these background levels were updated

---

<sup>1</sup> “Appendix III” and “Appendix IV” constituents refer to those constituents listed in the respective

using additional data collected since 2019 and 2021. Background levels are provided in Table 4-8.

There were no confirmed SSIs above background concentrations during 2023 groundwater monitoring.

#### **4.3.2 Groundwater Protection Standards**

Because there were no SSIs above background levels, the FAR I RSW Landfill remains in detection monitoring. In the absence of an SSI, there is no reason to anticipate SSLs of Appendix IV constituents above GWPSs. In accordance with CCR Rules, laboratory analysis of Appendix IV constituents was, therefore, neither necessary nor performed.

### **4.4 Corrective Actions**

In the absence of an identified release from the FAR I RSW Landfill, no corrective actions or remedies were either necessary or performed during 2023.

---

appendices of the CCR Rules. In compliance with §257.94(b) of the CCR Rules, groundwater samples collected in 2016 and 2017 were analyzed for both Appendix III and IV constituents in order to establish an initial background dataset. Since that time, there has been no need to use the background data set to establish background levels of Appendix IV constituents.

## 5.0 Problems Encountered and Resolutions

Problems with low water levels at monitoring wells during detection monitoring in 2023 were encountered at the RSW Landfill. Monitoring well S-17 was purged dry during sampling in both semi-annual detection monitoring events and CA-0623A was purged dry during the second semi-annual sampling event; therefore, samples were not collected due to insufficient recovery. Because S-17 and CA-0623A are upgradient (background) wells, and not downgradient (compliance) monitoring wells, not collecting these samples will not result in a failure to identify an SSI.

During the April 2023 sampling event, chloride at S-10, and fluoride at S-GS-1 were detected at concentrations above their background levels. In accordance with the Statistical Analysis Plan (Geosyntec 2020), resampling was performed in June 2023. The concentrations of these constituents during June 2023 resampling were below their respective background levels. As such, no SSI was identified.

No monitoring wells were abandoned or added to the network during 2023.

Because there was not an SSI above background levels, no alternative source demonstrations under §257.94(e)(2) were considered or performed during 2023.

## **6.0 Projected Key Activities**

It is anticipated that the FAR I RSW Landfill will remain in detection monitoring in 2024. The following activities are projected for the FAR I RSW Landfill:

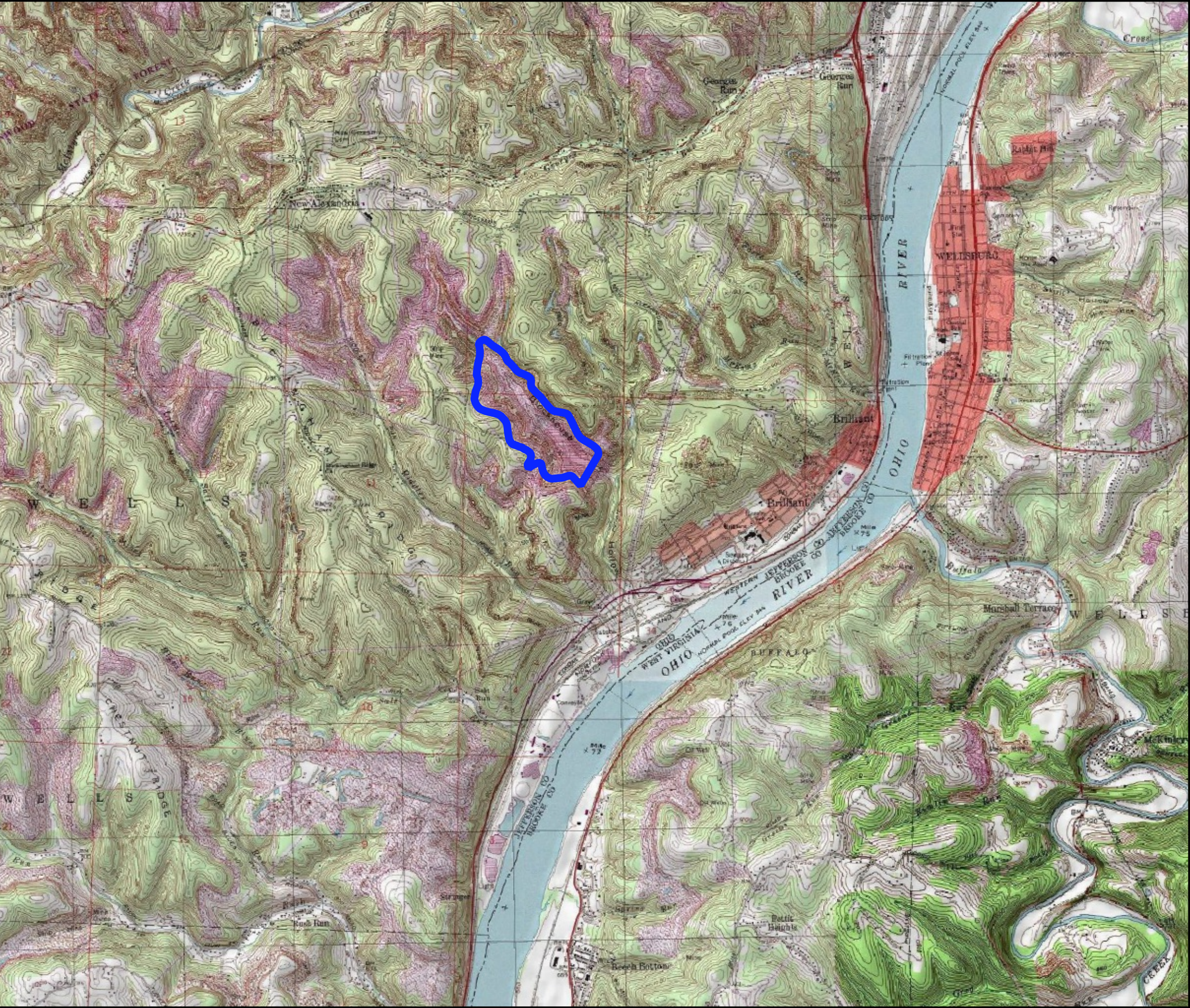
- The 2023 Annual Groundwater Monitoring Report will be entered into the facility's operating record and posted to the public internet site.
- Two semi-annual groundwater detection monitoring program sampling events will be conducted, and the resulting data will be evaluated for SSIs over background levels. The FAR I RSW Landfill's monitoring status will be confirmed following the SSI evaluation.
- The 2024 Annual Groundwater Monitoring Report will be prepared for submittal in January 2025.

## 7.0 References


Geosyntec. 2016. *Groundwater Monitoring Network Evaluation; Cardinal Site - Former Fly Ash Reservoir I - Residual Solid Waste Landfill; Brilliant, Ohio*. Oak Brook, IL: Geosyntec Consultants.

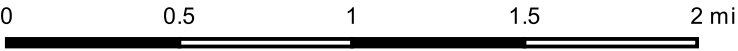
Geosyntec. 2020. *Statistical Analysis Plan; Cardinal Power Plant; Brilliant, Ohio (Revision 1)*. Columbus, Ohio: Geosyntec Consultants.

# Figures



Legend

-  FAR I RSW Landfill
- USGS Topographical Map



Figure

1-1

Site Location Map  
FAR I RSW Landfill  
Cardinal Plant  
Brilliant, Ohio



2020 Aerial Imagery from Ohio Statewide Imagery Program (QSIP)

Legend

- FAR I RSW Landfill
- Monitoring Wells
  - Background
  - Downgradient



0 1,000 2,000 3,000 ft








Figure

1-2

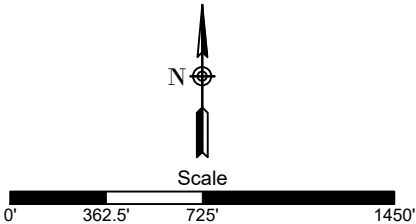
CCR Unit and Monitoring Wells  
FAR I RSW Landfill  
Cardinal Plant  
Brilliant, Ohio



# Legend

-  FAR I Monitor Well
-  Approximate Groundwater Elevation Contour
-  Groundwater Elevation on April 10, 2023
-  FAR I RSW Landfill
-  Anomalous groundwater elevation was not used during contouring.

Source of Aerial Photograph: Ohio Statewide Imagery Program, 2020.



Figure

4-1

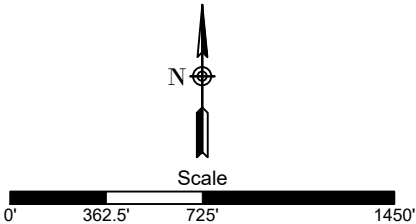
Potentiometric Surface Map - Shallow  
Aquifer - April 10, 2023,  
Fly Ash Reservoir (FAR) I,  
Cardinal Plant,  
Brilliant, Ohio



# Legend

- FAR I Monitor Well
- 1005 Approximate Groundwater Elevation Contour
- 975.51 Groundwater Elevation on October 9, 2023
- FAR I RSW Landfill

Source of Aerial Photograph: Ohio Statewide Imagery Program, 2020.



Figure

## 4-2

Potentiometric Surface Map - Shallow  
Aquifer - October 9, 2023,  
Fly Ash Reservoir (FAR) I,  
Cardinal Plant,  
Brilliant, Ohio

# Tables

Table 4-1. Groundwater Flow Calculations April 2023, FAR I RSW Landfill, Cardinal Plant, Brilliant, Ohio

Program	Groundwater Zone	Well	Hyrdraulic Location <sup>1</sup>	Depth to Water (ft)	Potentiometric Elevation (ft) <sup>2</sup>	Gradient <sup>3</sup> (ft/ft)	Hydraulic Conductivity <sup>4</sup> (cm/sec)			Effective Porosity	Groundwater Velocity (ft/day)			Well Diameter <sup>5</sup> (in.)	Residence Time <sup>6</sup> (days)		
							Low	Representative	High		Low	Representative	High		Low	Representative	High
FAR I	Fly Ash Shallow	CA-0623A	Upgradient	149.85	1012.87	0.01386	0.0001	0.05	0.1	0.32	0.01	<b>6.14</b>	12.28	6	0.04	<b>0.08</b>	40.71
FAR I	Fly Ash Shallow	OAE-2005-10-C	Upgradient	226.84	1014.01	0.01751	0.0001	0.05	0.1	0.32	0.02	<b>7.76</b>	15.51	6	0.03	<b>0.06</b>	32.23
FAR I	Fly Ash Shallow	S-1	Downgradient	8.86	993.55	0.04277	0.0001	0.05	0.1	0.32	0.04	<b>18.94</b>	37.89	3	0.01	<b>0.01</b>	6.60
FAR I	Fly Ash Shallow	S-2	Upgradient	37.83	1001.58	0.08316	0.0001	0.05	0.1	0.32	0.07	<b>36.83</b>	73.66	3	0.00	<b>0.01</b>	3.39
FAR I	Fly Ash Shallow	S-4	Upgradient	28.32	989.01	0.02912	0.0001	0.05	0.1	0.32	0.03	<b>12.90</b>	25.79	3	0.01	<b>0.02</b>	9.69
FAR I	Fly Ash Shallow	S-5	Upgradient	19.78	982.42	-	0.0001	0.05	0.1	0.32	-	-	-	3	-	-	-
FAR I	Fly Ash Shallow	S-6	Upgradient	11.01	995.65	0.01140	0.0001	0.05	0.1	0.32	0.01	<b>5.05</b>	10.10	3	0.02	<b>0.05</b>	24.75
FAR I	Fly Ash Shallow	S-7	Downgradient	42.11	968.50	0.03125	0.0001	0.05	0.1	0.32	0.03	<b>13.84</b>	27.68	3	0.01	<b>0.02</b>	9.03
FAR I	Fly Ash Shallow	S-10	Downgradient	30.60	974.59	0.00976	0.0001	0.05	0.1	0.32	0.01	<b>4.32</b>	8.65	6	0.06	<b>0.12</b>	57.82
FAR I	Fly Ash Shallow	S-17	Upgradient	195.31	1002.69	0.01650	0.0001	0.05	0.1	0.32	0.01	<b>7.31</b>	14.62	6	0.03	<b>0.07</b>	34.20
FAR I	Fly Ash Shallow	S-18	Downgradient	157.12	998.25	0.00818	0.0001	0.05	0.1	0.32	0.01	<b>3.62</b>	7.24	6	0.07	<b>0.14</b>	69.02
FAR I	Fly Ash Shallow	S-19A	Upgradient	100.59	998.01	0.03431	0.0001	0.05	0.1	0.32	0.03	<b>15.20</b>	30.39	6	0.02	<b>0.03</b>	16.45
FAR I	Fly Ash Shallow	S-20	Downgradient	41.09	964.79	0.05250	0.0001	0.05	0.1	0.32	0.05	<b>23.25</b>	46.51	6	0.01	<b>0.02</b>	10.75
FAR I	Fly Ash Shallow	S-GS-1	Downgradient	21.07	993.50	0.00750	0.0001	0.05	0.1	0.32	0.01	<b>3.32</b>	6.64	6	0.08	<b>0.15</b>	75.26
FAR I	Fly Ash Shallow	S-GS-2	Downgradient	25.86	985.89	0.00764	0.0001	0.05	0.1	0.32	0.01	<b>3.38</b>	6.77	6	0.07	<b>0.15</b>	73.89
FAR I	Fly Ash Shallow	S-GS-3	Upgradient	62.34	977.08	0.01119	0.0001	0.05	0.1	0.32	0.01	<b>4.96</b>	9.91	6	50.45	<b>0.10</b>	0.05

K:\CCA\PROJECTS\Buckeye\_Power\Cardinal\FAR I RSW Landfill\Annual Groundwater and Corrective Measures Reports\2023\Tables\[Table 4-1 - April GW Flow.xlsx]Table 4-1

Measurements and calculations represent conditions on April 10, 2023.

- A calculation for S-5 was not completed because the water level was found to be anomalously low (See Figure 4-1).

<sup>1</sup> *Groundwater Monitoring Network Evaluation; Cardinal Site – Forner Fly Ash Reservoir I - Residual Solid Waste Landfill, Brilliant, Ohio* prepared by Geosyntec Consultants in July 2016.

<sup>2</sup> Elevations datum is National Geodetic Vertical Datum of 1929 (NGVD29).

<sup>3</sup> Hydraulic gradient was calculated from a potentiometric surface using GDAL software tools (<https://gdal.org/programs/gdaldem.html>).

<sup>4</sup> Low and high conductivity values are from the 2016 Groundwater Monitoring Network Evaluation, with a representative value chosen at the midpoint of this range.

<sup>5</sup> Well diameter represents the diameter of the borehole (sandpack).

<sup>6</sup> Residence time is an estimation of how long it would take groundwater to travel a distance equivalent to the well diameter at the calculated velocity.

Table 4-2. Groundwater Flow Calculations October 2023, FAR I RSW Landfill, Cardinal Plant, Brilliant, Ohio

Program	Groundwater Zone	Well	Hyrdraulic Location <sup>1</sup>	Depth to Water (ft)	Potentiometric Elevation (ft) <sup>2</sup>	Gradient <sup>3</sup> (ft/ft)	Hydraulic Conductivity <sup>4</sup> (cm/sec)			Effective Porosity	Groundwater Velocity (ft/day)			Well Diameter <sup>5</sup> (in.)	Residence Time <sup>6</sup> (days)		
							Low	Representative	High		Low	Representative	High		Low	Representative	High
FAR I	Fly Ash Shallow	CA-0623A	Upgradient	153.61	1009.11	0.01375	0.0001	0.05	0.1	0.32	0.0122	<b>6.09</b>	12.18	6	0.04	<b>0.08</b>	41.06
FAR I	Fly Ash Shallow	OAE-2005-10-C	Upgradient	230.70	1010.15	0.01000	0.0001	0.05	0.1	0.32	0.0089	<b>4.43</b>	8.86	6	0.06	<b>0.11</b>	56.44
FAR I	Fly Ash Shallow	S-1	Downgradient	13.29	989.12	0.04383	0.0001	0.05	0.1	0.32	0.0388	<b>19.41</b>	38.83	3	0.01	<b>0.01</b>	6.44
FAR I	Fly Ash Shallow	S-2	Upgradient	41.53	997.92	0.08343	0.0001	0.05	0.1	0.32	0.0739	<b>36.95</b>	73.90	3	0.00	<b>0.01</b>	3.38
FAR I	Fly Ash Shallow	S-4	Upgradient	21.30	996.03	0.00234	0.0001	0.05	0.1	0.32	0.0021	<b>1.03</b>	2.07	3	0.12	<b>0.24</b>	120.83
FAR I	Fly Ash Shallow	S-5	Upgradient	4.59	997.61	0.01381	0.0001	0.05	0.1	0.32	0.0122	<b>6.12</b>	12.23	3	0.02	<b>0.04</b>	20.44
FAR I	Fly Ash Shallow	S-6	Upgradient	12.19	994.47	0.00946	0.0001	0.05	0.1	0.32	0.0084	<b>4.19</b>	8.38	3	0.03	<b>0.06</b>	29.82
FAR I	Fly Ash Shallow	S-7	Downgradient	49.36	961.25	0.00234	0.0001	0.05	0.1	0.32	0.0021	<b>1.03</b>	2.07	3	0.12	<b>0.24</b>	120.83
FAR I	Fly Ash Shallow	S-10	Downgradient	37.39	967.80	0.06829	0.0001	0.05	0.1	0.32	0.0605	<b>30.25</b>	60.50	6	0.01	<b>0.02</b>	8.27
FAR I	Fly Ash Shallow	S-17	Upgradient	198.03	999.97	0.01000	0.0001	0.05	0.1	0.32	0.0089	<b>4.43</b>	8.86	6	0.06	<b>0.11</b>	56.44
FAR I	Fly Ash Shallow	S-18	Downgradient	160.99	994.38	0.00925	0.0001	0.05	0.1	0.32	0.0082	<b>4.10</b>	8.20	6	0.06	<b>0.12</b>	61.00
FAR I	Fly Ash Shallow	S-19A	Upgradient	102.73	995.87	0.07250	0.0001	0.05	0.1	0.32	0.0642	<b>32.11</b>	64.22	6	0.01	<b>0.02</b>	7.79
FAR I	Fly Ash Shallow	S-20	Downgradient	45.84	960.04	0.04679	0.0001	0.05	0.1	0.32	0.0415	<b>20.73</b>	41.45	6	0.01	<b>0.02</b>	12.06
FAR I	Fly Ash Shallow	S-GS-1	Downgradient	23.14	991.43	0.00428	0.0001	0.05	0.1	0.32	0.0038	<b>1.90</b>	3.79	6	0.13	<b>0.26</b>	131.86
FAR I	Fly Ash Shallow	S-GS-2	Downgradient	29.92	981.83	0.00809	0.0001	0.05	0.1	0.32	0.0072	<b>3.58</b>	7.16	6	0.07	<b>0.14</b>	69.80
FAR I	Fly Ash Shallow	S-GS-3	Upgradient	63.91	975.51	0.01663	0.0001	0.05	0.1	0.32	0.0147	<b>7.37</b>	14.73	6	0.03	<b>0.07</b>	33.94

K:\CCA\PROJECTS\Buckeye\_Power\Cardinal\FAR I RSW Landfill\Annual Groundwater and Corrective Measures Reports\2023\Tables\[Table 4-2 - October GW Flow.xlsx]Table 4-2

Measurements and calculations represent conditions on October 9, 2023.

<sup>1</sup> Groundwater Monitoring Network Evaluation; Cardinal Site – Former Fly Ash Reservoir I - Residual Solid Waste Landfill, Brilliant, Ohio prepared by Geosyntec Consultants in July 2016.

<sup>2</sup> Elevations datum is National Geodetic Vertical Datum of 1929 (NGVD29).

<sup>3</sup> Hydraulic gradient was calculated from a potentiometric surface using GDAL software tools (<https://gdal.org/programs/gdaldem.html>).

<sup>4</sup> Low and high conductivity values are from the 2016 Groundwater Monitoring Network Evaluation, with a representative value chosen at the midpoint of this range.

<sup>5</sup> Well diameter represents the diameter of the borehole (sandpack).

<sup>6</sup> Residence time is an estimation of how long it would take groundwater to travel a distance equivalent to the well diameter at the calculated velocity.

Table 4-3 Summary of CCR Groundwater Samples, FAR I RSW Landfill, Cardinal Plant, Brilliant, Ohio

Well Name	Type of Well	Sample Date	Constituents Analyzed	Purpose
CA-0623A	Upgradient	4/24/2023	Appendix III	Detection monitoring program
CA-0623A	Upgradient	10/10/2023	Appendix III	Detection monitoring program
OAE-2005-10-C	Upgradient	4/11/2023	Appendix III	Detection monitoring program
OAE-2005-10-C	Upgradient	10/10/2023	Appendix III	Detection monitoring program
S-1	Downgradient	4/18/2023	Appendix III	Detection monitoring program
S-1	Downgradient	10/12/2023	Appendix III	Detection monitoring program
S-2	Upgradient	4/25/2023	Appendix III	Detection monitoring program
S-2	Upgradient	10/12/2023	Appendix III	Detection monitoring program
S-4	Upgradient	4/20/2023	Appendix III	Detection monitoring program
S-4	Upgradient	4/20/2023	Appendix III	Detection monitoring program (Duplicate)
S-4	Upgradient	10/12/2023	Appendix III	Detection monitoring program
S-5	Upgradient	4/18/2023	Appendix III	Detection monitoring program
S-5	Upgradient	10/11/2023	Appendix III	Detection monitoring program
S-6	Upgradient	4/18/2023	Appendix III	Detection monitoring program
S-6	Upgradient	10/11/2023	Appendix III	Detection monitoring program
S-7	Downgradient	4/18/2023	Appendix III	Detection monitoring program
S-7	Downgradient	10/13/2023	Appendix III	Detection monitoring program
S-10	Downgradient	4/13/2023	Appendix III	Detection monitoring program
S-10	Downgradient	6/8/2023	Appendix III	Detection monitoring program
S-10	Downgradient	10/11/2023	Appendix III	Detection monitoring program
S-18	Downgradient	4/12/2023	Appendix III	Detection monitoring program
S-18	Downgradient	10/10/2023	Appendix III	Detection monitoring program
S-19A	Upgradient	4/13/2023	Appendix III	Detection monitoring program
S-19A	Upgradient	10/11/2023	Appendix III	Detection monitoring program
S-20	Downgradient	4/13/2023	Appendix III	Detection monitoring program
S-20	Downgradient	10/11/2023	Appendix III	Detection monitoring program
S-GS-1	Downgradient	4/12/2023	Appendix III	Detection monitoring program
S-GS-1	Downgradient	6/8/2023	Appendix III	Detection monitoring program
S-GS-1	Downgradient	10/11/2023	Appendix III	Detection monitoring program
S-GS-1	Downgradient	10/11/2023	Appendix III	Detection monitoring program (Duplicate)
S-GS-2	Downgradient	4/12/2023	Appendix III	Detection monitoring program
S-GS-2	Downgradient	6/8/2023	Appendix III	Detection monitoring program
S-GS-2	Downgradient	10/11/2023	Appendix III	Detection monitoring program
S-GS-3	Upgradient	4/12/2023	Appendix III	Detection monitoring program
S-GS-3	Upgradient	4/12/2023	Appendix III	Detection monitoring program (Duplicate)
S-GS-3	Upgradient	10/10/2023	Appendix III	Detection monitoring program

K:\CCA\PROJECTS\Buckeye\_Power\Cardinal\FAR I RSW Landfill\Annual Groundwater and Corrective Measures Reports\2023\Tables\Table 4-3 - Sample Summary.xlsx\Table 4-3

Table 4-4. Downgradient Well Monitoring Results - First Semi-Annual Event, Cardinal Plant, FAR I RSW Landfill, Brilliant, Ohio

Sample Name Sample Date Laboratory Lab ID	Concentration Units	S-1 4/18/2023 Pace Analytical 50342685003	S-7 4/18/2023 Pace Analytical 50342685004	S-10 4/13/2023 Pace Analytical 50342280004	S-10 6/8/2023 Pace Analytical 50347115001	S-18 4/12/2023 Pace Analytical 50342280001	S-20 4/13/2023 Pace Analytical 50342280002	S-GS-1 4/12/2023 Pace Analytical 50342051003	S-GS-1 6/8/2023 Pace Analytical 50347115002	S-GS-2 4/12/2023 Pace Analytical 50342051004	S-GS-2 6/8/2023 Pace Analytical 50347115003
<b>APPENDIX III CONSTITUENTS</b>											
Boron	MG/L	<b>0.806</b>	<b>2.01</b>	<b>0.81</b>	NA	<b>0.521</b>	<b>0.266</b>	<b>0.84</b>	NA	<b>0.452</b>	NA
Calcium	MG/L	<b>319</b>	<b>270</b>	<b>298</b>	NA	<b>90.9</b>	<b>298</b>	<b>110</b>	NA	<b>5.15</b>	NA
Chloride	MG/L	<b>4.4</b>	<b>30.7</b>	<b>31.5</b>	<b>26.5</b>	<b>3.6</b>	<b>3.8</b>	<b>22.6</b>	NA	<b>96.3</b>	NA
Fluoride	MG/L	<b>0.25</b>	<b>0.18</b>	<b>0.26</b>	NA	<b>0.38</b>	<b>0.32</b>	<b>0.79</b>	<b>0.78</b>	<b>3.3</b>	<b>3.2</b>
Sulfate	MG/L	<b>975</b>	<b>1010</b>	<b>871</b>	NA	<b>499</b>	<b>908</b>	<b>818</b>	NA	<b>10.2</b>	NA
Total Dissolved Solids	MG/L	<b>1730</b>	<b>1920</b>	<b>1640</b>	NA	<b>938</b>	<b>1680</b>	<b>1660</b>	NA	<b>1510</b>	NA
pH	SU	<b>7.28</b>	<b>7.42</b>	<b>6.91</b>	NA	<b>7.08</b>	<b>6.77</b>	<b>7.23</b>	NA	<b>8.26</b>	NA

K:\CCA\PROJECTS\Buckeye\_Power\Cardinal\FAR I RSW Landfill\Annual Groundwater and Corrective Measures Reports\2023\Tables\Table 4-4 - Downgradient Well Results - Spring.xlsx\Sheet1

NA - Not Analyzed

**Bold** - Detection

Table 4-5. Background Well Monitoring Results - First Semi-Annual Event, Cardinal Plant, FAR I RSW Landfill, Brilliant, Ohio

Sample Name		CA-0623A	OAE-2005-10-C	S-2	S-4	S-4 Dup	S-5	S-6	S-17*	S-19A	S-GS-3	S-GS-3 Dup
Sample Date		4/24/2023	4/11/2023	4/25/2023	4/20/2023	4/20/2023	4/18/2023	4/18/2023		4/13/2023	4/12/2023	4/12/2023
Laboratory	Concentration	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	NA	Pace Analytical	Pace Analytical	Pace Analytical
Lab ID	Units	50343328001	50342040001	50343328002	50342936001	50342936002	50342685001	50342685002	NA	50342280003	50342051001	50342051002
APPENDIX III CONSTITUENTS												
Boron	MG/L	0.479	0.462	2.22	0.217	0.218	0.028	2.29	NA	0.386	0.315	0.311
Calcium	MG/L	1.05	4.12	383	482	480	271	384	NA	416	5.44	5.35
Chloride	MG/L	17.1	12.2	4.2	8.9	8.9	7.2	36.2	NA	2.2	468	476
Fluoride	MG/L	2.6	1.2	0.066	0.27	0.28	0.13	0.17	NA	0.39	2.3	2.3
Sulfate	MG/L	20.2	218	1720	1220	1030	683	1280	NA	1750	1.9	3.1
Total Dissolved Solids	MG/L	629	1220	2790	2500	2460	1270	2250	NA	2870	1840	1820
pH	SU	9.13	8.24	5.85	6.06	NA	7.22	7.08	NA	6.99	8.36	NA

K:\CCA\PROJECTS\Buckeye\_Power\Cardinal\FAR I RSW Landfill\Annual Groundwater and Corrective Measures Reports\2023\Tables\Table 4-5 - Background Well Results - Spring.xlsx\Sheet1

\* A sample was not collected because there was insufficient groundwater in monitor well S-17 during the sampling event.

NA Not Analyzed

**Bold** Detection

Table 4-6. Downgradient Well Monitoring Results - Second Semi-Annual Event, Cardinal Plant, FAR I RSW Landfill, Brilliant, Ohio

Sample Name Sample Date Laboratory Lab ID	Concentration Units	S-1 10/12/2023 Pace Analytical 50356469002	S-7 10/13/2023 Pace Analytical 50356503001	S-10 10/11/2023 Pace Analytical 50356469005	S-18 10/10/2023 Pace Analytical 50356469004	S-20 10/11/2023 Pace Analytical 50356469008	S-GS-1 10/11/2023 Pace Analytical 50356456003	S-GS-1 DUP 10/11/2023 Pace Analytical 50356456004	S-GS-2 10/11/2023 Pace Analytical 50356456005
<b>APPENDIX III CONSTITUENTS</b>									
Boron	MG/L	<b>0.71</b>	<b>1.76</b>	<b>0.57</b>	<b>0.52</b>	<b>0.26</b>	<b>0.89</b>	<b>0.87</b>	<b>0.46</b>
Calcium	MG/L	<b>336</b>	<b>257</b>	<b>309</b>	<b>131</b>	<b>298</b>	<b>98.2</b>	<b>96.3</b>	<b>5.1</b>
Fluoride	MG/L	<b>0.16</b>	<b>0.16</b>	<b>0.24</b>	<b>0.35</b>	<b>0.32</b>	<b>0.77</b>	<b>0.77</b>	<b>3.3</b>
Chloride	MG/L	<b>4.3</b>	<b>35.8</b>	<b>17.9</b>	<b>2.3</b>	<b>2.6</b>	<b>22.4</b>	<b>22.2</b>	<b>85.1</b>
Sulfate	MG/L	<b>927</b>	<b>1030</b>	<b>865</b>	<b>427</b>	<b>895</b>	<b>801</b>	<b>798</b>	<b>15.6</b>
Total Dissolved Solids	MG/L	<b>1860</b>	<b>1930</b>	<b>1700</b>	<b>896</b>	<b>1770</b>	<b>1740</b>	<b>1730</b>	<b>1550</b>
pH	SU	<b>6.87</b>	<b>7.04</b>	<b>7.12</b>	<b>6.99</b>	<b>6.89</b>	<b>7.23</b>	<b>7.23</b>	<b>8.16</b>

K:\CCA\PROJECTS\Buckeye\_Power(Cardinal)\FAR I RSW Landfill\Annual Groundwater and Corrective Measures Reports\2023\Tables\Table 4-6 - Downgradient Well Results - Fall.xlsx\Sheet4

NA Not Analyzed

**Bold** Detection

Table 4-7. Background Well Monitoring Results - Second Semi-Annual Event, Cardinal Plant, FAR I RSW Landfill, Brilliant, Ohio

Sample Name		CA-0623A	OAE-2005-10-C	S-2	S-4	S-5	S-6	S-17*	S-19A	S-GS-3
Sample Date		10/10/2023	10/10/2023	10/12/2023	10/12/2023	10/11/2023	10/11/2023	10/10/2023	10/11/2023	10/10/2023
Laboratory	Concentration	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	NA	Pace Analytical	Pace Analytical
Lab ID	Units	50356469011	50356469006	50356469001	50356469007	50356469010	50356469009	NA	50356469003	50356456001
<b>APPENDIX III CONSTITUENTS</b>										
Boron	MG/L	<b>0.47</b>	<b>0.49</b>	<b>2.15</b>	<b>0.16</b>	<b>0.23</b>	<b>2.27</b>	NA	<b>0.41</b>	<b>0.34</b>
Calcium	MG/L	<b>1.05</b>	<b>4.94</b>	<b>379</b>	<b>339</b>	<b>331</b>	<b>406</b>	NA	<b>420</b>	<b>4.81</b>
Fluoride	MG/L	<b>2.1</b>	<b>1.2</b>	<b>0.31</b>	<b>0.16</b>	<b>0.14</b>	<b>0.11</b>	NA	<b>0.35</b>	<b>2.3</b>
Chloride	MG/L	<b>18.7</b>	<b>18.1</b>	<b>3.9</b>	<b>6.1</b>	<b>8.8</b>	<b>34</b>	NA	<b>2.9</b>	<b>462</b>
Sulfate	MG/L	<b>19.3</b>	<b>205</b>	<b>1590</b>	<b>680</b>	<b>819</b>	<b>1200</b>	NA	<b>1690</b>	<b>0.67</b>
Total Dissolved Solids	MG/L	<b>580</b>	<b>1220</b>	<b>2940</b>	<b>1780</b>	<b>1650</b>	<b>2370</b>	NA	<b>2880</b>	<b>1760</b>
pH	SU	<b>8.68</b>	<b>7.99</b>	<b>6.81</b>	<b>6.58</b>	<b>7.11</b>	<b>6.98</b>	NA	<b>6.94</b>	<b>8.26</b>

K:\CCA\PROJECTS\Buckeye\_Power(Cardinal)\FAR I RSW Landfill\Annual Groundwater and Corrective Measures Reports\2023\Tables\Table 4-7 - Background Well Results - Fall.xlsx\Sheet3

\* A sample was not collected because there was insufficient groundwater in monitor wells S-17 and CA-0623A during the sampling event.

NA - Not Analyzed

**Bold** - Detection

Table 4-8. Appendix III Constituents Upper Prediction Limits, October 2023, Cardinal Plant, FAR I RSW Landfill, Brilliant, Ohio

	Concentration Units	S-1 Intrawell Upper Prediction Limit Oct. 2023	S-7 Intrawell Upper Prediction Limit Oct. 2023	S-10 Intrawell Upper Prediction Limit Oct. 2023	S-18 Intrawell Upper Prediction Limit Oct. 2023	S-20 Intrawell Upper Prediction Limit Oct. 2023	S-GS-1 Intrawell Upper Prediction Limit Oct. 2023	S-GS-2 Intrawell Upper Prediction Limit Oct. 2023
<b>APPENDIX III CONSTITUENTS</b>								
Boron	MG/L	1.042	2.197	2.039	0.635	0.344	1.053	0.696
Calcium	MG/L	355	276	340	229	385	131	17.63
Chloride	MG/L	7	39.4	30.9	3.8	4.1	25.1	120.1
Fluoride	MG/L	0.27	0.24	0.30	0.41	0.35	0.8	3.58
Sulfate	MG/L	1400	1155	1253	1123	1253	1039	183.9
Total Dissolved Solids	MG/L	1917	1983	1822	1907	2134	1966	2049
pH*	SU	6.67 / 7.56	6.79 / 7.89	6.57 / 7.56	6.66 / 7.34	6.30 / 7.94	6.72 / 8.86	7.42 / 8.60

K:\CCA\PROJECTS\Buckeye\_Power\Cardinal\FAR I RSW Landfill\Annual Groundwater and Corrective Measures Reports\2023\Tables\Table 4-8 - Appendix III Values.xlsx\Sheet1

\* Both Upper Prediction Limit and Lower Prediction Limit