

# **Annual Groundwater Monitoring Report**

Cardinal Operating Company

Cardinal Plant

Bottom Ash Pond

Brilliant, OH

**January 2018**

Prepared by:

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Columbus, Ohio 43215



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## **I. Overview**

This *Annual Groundwater Monitoring Report* (Report) has been prepared to report the status of activities for the preceding year for the Bottom Ash Pond at Cardinal Operating Company's, Cardinal Power Plant. The Cardinal Plant is a three-unit coal-fired generating station with Unit 1 owned by AEP Generation Resources, Inc., a wholly-owned subsidiary of American Electric Power Company (AEP), and Units 2 and 3 owned by Buckeye Power, Inc. (Buckeye). The Cardinal Operating Company collectively manages and operates the Cardinal Plant. The USEPA's CCR rules require that the Annual Groundwater Monitoring Report be posted to the operating record for the preceding year no later than January 31, 2018.

In general, the following activities were completed:

- Monitoring wells were installed and developed to establish a certified groundwater monitoring system around each CCR unit, in accordance with the requirements of 40 CFR 257.91 pursuant AEP's *Groundwater Monitoring Network Evaluation (2016)*;
- Groundwater samples were collected and analyzed for Appendix III and Appendix IV constituents, as specified in 40 CFR 257.94 *et seq.* and AEP's *Groundwater Sampling and Analysis Plan (2016)*;
- Groundwater data underwent various validation tests, including tests for completeness, valid values, transcription errors, and consistent units;
- Background groundwater values for each Appendix III and Appendix IV constituent were collected;
- Detection Monitoring sampling was initiated;
- A statistical process in accordance with 40 CFR 257.93 to evaluate groundwater data was prepared, certified, and posted to AEP's CCR website in April 2017 [AEP's *Statistical Analysis Plan* (AEP 2017)]. The statistical process was guided by USEPA's *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* ("Unified Guidance", USEPA, 2009). Data evaluation is underway.

The major components of this annual report, to the extent applicable at this time, are presented in sections that follow:

- A map, aerial photograph or a drawing showing the CCR management unit(s), all groundwater monitoring wells and monitoring well identification numbers.;
- Identification of any monitoring wells that were installed or decommissioned during the preceding year, along with a statement as to why that happened;
- All of the monitoring data collected, including the rate and direction of groundwater flow, plus a summary showing the number of samples collected per monitoring well, the

dates the samples were collected and whether the sample was collected as part of detection monitoring or assessment monitoring programs (Attached as **Appendix I**);

- A summary of any transition between monitoring programs or an alternate monitoring frequency, for example the date and circumstances for transitioning from detection monitoring to assessment monitoring, in addition to identifying the constituents detected at a statistically significant increase over background concentrations (Attached as **Appendix II**, where applicable); and
- Other information required to be included in the annual report such as alternate source demonstration or assessment of corrective measures, if applicable.

In addition, this report summarizes key actions completed, and where applicable, describes any problems encountered and actions taken to resolve those problems. The report includes a projection of key activities for the upcoming year.




## **II. Groundwater Monitoring Well Locations and Identification Numbers**

The figure that follows depicts the PE-certified groundwater monitoring network, the monitoring well locations and their corresponding identification.



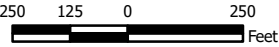


**Monitoring Well Network**

-  Compliance Sampling Location
-  Background Sampling Location
-  Bottom Ash Pond

**Notes**

- Monitoring well coordinates provided by AEP.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Bottom Ash Pond (Geosyntec, 2016) provided by AEP.



**Site Layout  
Bottom Ash Complex**

AEP Cardinal Generating Plant  
Brilliant, Ohio

**Geosyntec**  
consultants

Columbus, Ohio

2018/01/25

Figure

**1**



### **III. Monitoring Wells Installed or Decommissioned**

There were no monitoring wells installed or decommissioned in 2017. The network design, as summarized in the *Groundwater Monitoring Network Design Report* (July 2016) and as posted at the CCR web site for Cardinal Plant, did not change. That design report, viewable on the AEP CCR web site, discusses the facility location, the hydrogeological setting, the hydrostratigraphic units, the uppermost aquifer, downgradient monitoring well locations and the upgradient monitoring well locations.

### **IV. Groundwater Quality Data and Static Water Elevation Data, With Flow Rate and Direction and Discussion**

Appendix I contains tables showing the groundwater quality data collected during the establishment of background quality. Static water elevation data from each monitoring event also are shown in Appendix I, along with the groundwater velocity calculations, groundwater flow direction and potentiometric maps developed after each sampling event.

### **V. Discussion About Transition Between Monitoring Requirements or Alternate Monitoring Frequency**

As of this first annual groundwater report date there has been no transition between detection monitoring and assessment monitoring. Detection monitoring will continue in 2018. The sampling frequency of twice per year will be maintained for the Appendix III parameters (boron, calcium, chloride, fluoride, pH, sulfate and total dissolved solids).

Regarding defining an alternate monitoring frequency, the groundwater velocity and monitoring well production is high enough at this facility that no modification of the twice-per-year detection monitoring effort is needed.

### **VI. Other Information Required**

At the appropriate time the geochemical analyses, coupled with the statistical analyses of the groundwater quality data, will determine whether an alternate source or alternate sources are affecting groundwater chemistry. In those cases where an alternative source(s) demonstration is made, those analyses and supporting information will be presented as well.

### **VII. Description of Any Problems Encountered in 2017 and Actions Taken**

No significant problems were encountered. The low flow sampling effort went smoothly and the schedule was met to support this first annual groundwater report preparation.

### **VIII. A Projection of Key Activities for the Upcoming Year**

Key activities for 2018 include:

- Detection monitoring on a twice per year schedule

- Evaluation of the first detection monitoring results from a statistical analysis viewpoint, looking for any statistically significant increases, or decreases when pH is considered.
- Responding to any new data received in light of what the CCR rule requires
- Preparation of the second annual groundwater report

## **APPENDIX I**

Tables follow, showing the groundwater monitoring data collected and the rate and direction of groundwater flow. The dates that the samples were collected also is shown.

## **Groundwater Data Tables**

Table 1 - Groundwater Data Summary  
Cardinal Plant - Bottom Ash Pond

Parameter	Unit	MW-BAP-1								
		6/28/2016	8/10/2016	10/20/2016	1/12/2017	5/3/2017	5/31/2017	6/20/2017	8/1/2017	9/26/2017
		Background								Detection
Antimony	µg/L	0.0700	0.0800	0.0800	0.0600	0.0700	0.0400 J	0.0400 J	0.0300 J	-
Arsenic	µg/L	1.45	1.05	1.60	1.13	1.56	0.780	0.530	0.400	-
Barium	µg/L	93.6	107	107	86.5	85.3	72.6	63.6	61.5	-
Beryllium	µg/L	0.0720	0.0370	0.0600	0.0430	0.0610	0.0300	0.0100 J	0.0100 J	-
Boron	mg/L	1.71	1.83	1.73	1.95	2.27	2.11	2.40	2.69	2.70
Cadmium	µg/L	0.120	0.110	0.110	0.130	0.150	0.120	0.100	0.0900	-
Calcium	mg/L	167	162	166	157	159	148	153	170	175
Chloride	mg/L	98.4	93.4	94.5	96.1	95.2	94.3	95.4	100	93.7
Chromium	µg/L	1.80	1.30	2.00	1.45	2.10	0.811	0.355	0.185	-
Cobalt	µg/L	1.49	1.20	1.29	1.10	1.30	0.951	0.740	0.665	-
Combined Radium	pCi/L	0.343	0.210	1.24	1.09	0.301	1.17	0.602	0.452	-
Fluoride	mg/L	0.380	0.330	0.350	0.340	0.330	0.300	0.300	0.410	0.330
Lead	µg/L	2.09	1.03	1.69	1.24	1.72	0.786	0.314	0.0730	-
Lithium	mg/L	0.0350	0.0190	0.0150	0.0210	0.0200	0.0170	0.0290	0.0220	-
Mercury	µg/L	0.0100	<0.002 U	0.00700	<0.002 U	0.00600	0.00400 J	<0.002 U	0.00300 J	-
Molybdenum	µg/L	19.6	27.5	28.6	26.4	26.8	27.4	29.0	29.2	-
Selenium	µg/L	0.200	0.200	0.400	0.200	0.300	0.100	0.0600 J	0.0400 J	-
Total Dissolved Solids	mg/L	953	916	942	918	948	952	957	926	977
Sulfate	mg/L	402	397	407	405	411	419	458	471	469
Thallium	µg/L	0.0500	0.122	0.226	0.0710	0.0580	0.0590	0.0500 J	0.0500 J	-
pH	SU	7.06	7.17	7.08	7.06	6.98	7.62	7.28	6.94	6.76

Notes:  
µg/L: micrograms per liter  
mg/L: milligrams per liter  
pCi/L: picocuries per liter  
SU: standard unit  
U: Non-detect value. Parameters which were not detected are shown as less than the method detection limit (MDL).  
J: Estimated value. Component was detected in concentrations below the reporting limit  
-: Not sampled  
For statistical analysis, parameters which were not detected were replaced with the reporting limit.

Table 1 - Groundwater Data Summary  
Cardinal Plant - Bottom Ash Pond

Parameter	Unit	MW-BAP-2								
		6/28/2016	8/10/2016	10/20/2016	1/12/2017	5/3/2017	5/31/2017	6/20/2017	8/1/2017	9/26/2017
		Background								
Antimony	µg/L	0.0700	0.0400 J	0.100	0.0300 J	0.0500 J	0.0300 J	0.0300 J	0.0300 J	-
Arsenic	µg/L	11.3	11.1	29.6	26.0	10.6	13.1	11.1	17.1	-
Barium	µg/L	94.3	89.5	123	104	104	106	91.5	93.8	-
Beryllium	µg/L	0.0200 J	0.0200 J	0.0830	0.0350	0.0320	0.0200 J	0.0100 J	0.0200 J	-
Boron	mg/L	2.28	2.04	1.79	2.08	2.20	2.09	2.16	1.95	1.73
Cadmium	µg/L	0.0400	0.0300	0.0900	0.0500	0.0400	0.0400	0.0200 J	0.0200	-
Calcium	mg/L	98.7	89.5	92.3	86.4	82.4	87.6	84.6	86.0	86.8
Chloride	mg/L	74.1	75.9	79.6	72.9	72.0	70.7	71.9	71.4	68.2
Chromium	µg/L	0.500	0.300	1.80	0.650	0.704	0.292	0.213	0.371	-
Cobalt	µg/L	1.52	1.36	2.17	1.59	1.61	1.37	1.21	1.20	-
Combined Radium	pCi/L	0.749	0.588	0.849	0.776	0.376	1.21	0.993	1.09	-
Fluoride	mg/L	0.350	0.330	0.790	0.620	0.420	0.330	0.340	0.460	0.330
Lead	µg/L	0.439	0.307	2.16	0.965	0.770	0.325	0.234	0.330	-
Lithium	mg/L	0.0110	0.0100	0.00600	0.0160	0.0130	0.00900	0.0200	0.0100	-
Mercury	µg/L	<0.002 U	<0.002 U	0.00400 J	0.00200 J	<0.002 U	<0.002 U	<0.002 U	<0.002 U	-
Molybdenum	µg/L	37.6	38.4	31.9	26.2	42.1	46.6	49.0	46.1	-
Selenium	µg/L	0.0900 J	0.0800 J	0.400	0.100	0.200	0.0900 J	0.0700 J	0.0800 J	-
Total Dissolved Solids	mg/L	612	544	628	583	557	562	563	560	552
Sulfate	mg/L	239	228	190	176	213	222	234	218	230
Thallium	µg/L	0.0300 J	0.0300 J	0.0750	0.0300 J	0.0300 J	0.0200 J	0.0200 J	0.0200 J	-
pH	SU	6.75	6.31	6.76	6.73	6.85	7.15	7.10	6.74	6.94

Notes:  
µg/L: micrograms per liter  
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J: Estimated value. Parameter was detected in concentrations below the reporting limit  
-: Not sampled  
For statistical analysis, parameters which were not detected were replaced with the reporting limit.

Table 1 - Groundwater Data Summary  
Cardinal Plant - Bottom Ash Pond

Parameter	Unit	MW-BAP-3								
		6/28/2016	8/11/2016	10/20/2016	1/12/2017	5/3/2017	5/31/2017	6/20/2017	8/1/2017	9/26/2017
		Background								
Antimony	µg/L	0.0300 J	0.0400 J	0.0200 J	0.0300 J	0.0200 J	0.0200 J	0.0200 J	0.0200 J	-
Arsenic	µg/L	0.420	0.750	0.690	0.990	0.390	0.360	0.320	0.310	-
Barium	µg/L	49.1	65.3	55.8	52.2	47.7	51.7	46.7	47.4	-
Beryllium	µg/L	0.00800 J	0.0220	0.00900 J	0.00900 J	0.00600 J	0.00500 J	<0.004 U	0.00500 J	-
Boron	mg/L	1.92	2.03	1.80	1.77	1.87	1.91	2.05	2.12	2.03
Cadmium	µg/L	0.0400	0.0500	0.0500	0.0700	0.0600	0.100	0.0900	0.0800	-
Calcium	mg/L	64.1	63.0	65.7	62.6	60.6	60.3	62.1	67.0	69.1
Chloride	mg/L	59.8	58.8	60.1	60.7	61.9	61.8	62.8	63.4	63.8
Chromium	µg/L	0.500	0.800	0.400	0.427	0.257	0.128	0.111	0.126	-
Cobalt	µg/L	0.759	0.962	0.759	0.779	0.721	0.675	0.591	0.579	-
Combined Radium	pCi/L	0.358	0.760	1.74	0.546	0.853	0.506	0.373	0.00513	-
Fluoride	mg/L	0.170	0.100 J	0.100 J	0.160	0.160	0.100 J	0.100 J	0.100 J	0.100 J
Lead	µg/L	0.164	0.487	0.184	0.216	0.0910	0.0880	0.0650	0.0660	-
Lithium	mg/L	0.0180	0.00500	<0.0002 U	0.0120	0.00300	<0.0002 U	0.0130	0.00500	-
Mercury	µg/L	0.00200 J	0.00300 J	0.00200 J	0.00300 J	<0.002 U	<0.002 U	0.00700	<0.002 U	-
Molybdenum	µg/L	2.13	5.63	2.45	2.70	3.57	2.51	2.21	1.87	-
Selenium	µg/L	0.0500 J	0.0900 J	0.0700 J	0.0300 J	0.0600 J	<0.03 U	<0.03 U	<0.03 U	-
Total Dissolved Solids	mg/L	418	400	396	390	402	410	421	424	421
Sulfate	mg/L	130	134	129	119	131	135	145	148	146
Thallium	µg/L	0.0500 J	0.0610	0.0590	0.0500 J	0.0400 J	0.0500 J	0.0500 J	0.0500 J	-
pH	SU	6.65	6.70	6.70	6.67	6.74	7.22	6.95	6.52	6.53

Notes:  
µg/L: micrograms per liter  
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pCi/L: picocuries per liter  
SU: standard unit  
U: Non-detect value. Parameters which were not detected are shown as less than the method detection limit (MDL).  
J: Estimated value. Component was detected in concentrations below the reporting limit  
-: Not sampled  
For statistical analysis, parameters which were not detected were replaced with the reporting limit.



Table 1 - Groundwater Data Summary  
Cardinal Plant - Bottom Ash Pond

Parameter	Unit	MW-BAP-4								
		6/30/2016	8/10/2016	10/20/2016	1/12/2017	5/2/2017	5/31/2017	6/20/2017	8/1/2017	9/26/2017
		Background								
Antimony	µg/L	0.0600	0.0700	0.100	0.0900	0.0500 J	0.0400 J	0.0300 J	0.0500	-
Arsenic	µg/L	36.3	42.2	42.4	44.8	41.9	35.9	42.7	43.7	-
Barium	µg/L	54.9	54.7	69.8	59.9	44.9	51.7	41.9	49.9	-
Beryllium	µg/L	0.119	0.117	0.227	0.176	0.0710	0.111	0.0460	0.0920	-
Boron	mg/L	0.115	0.0620	0.0640	0.0200	0.160	0.0240	0.0380	0.0340	0.0330
Cadmium	µg/L	0.110	0.100	0.180	0.140	0.0500	0.100	0.0300	0.0600	-
Calcium	mg/L	233	220	214	197	197	181	190	202	203
Chloride	mg/L	30.0	30.6	28.6	27.5	27.5	27.6	27.5	27.6	27.1
Chromium	µg/L	1.70	2.40	4.40	4.16	1.48	1.96	0.834	1.89	-
Cobalt	µg/L	18.7	18.2	19.8	20.3	19.2	20.2	18.0	19.9	-
Combined Radium	pCi/L	0.535	0.722	1.17	0.703	0.377	0.599	0.645	1.07	-
Fluoride	mg/L	0.150	0.160	0.100 J	0.100 J	0.100 J	0.100 J	0.100 J	0.100 J	0.100 J
Lead	µg/L	3.20	2.78	5.67	4.63	1.66	2.94	0.955	2.06	-
Lithium	mg/L	0.0150	0.0120	0.00600	0.0120	0.00900	0.00500	0.0200	0.0130	-
Mercury	µg/L	<0.002 U	0.00400 J	0.00700	0.00500	<0.002 U	0.00400 J	<0.002 U	<0.002 U	-
Molybdenum	µg/L	1.35	4.51	1.87	1.76	1.56	1.00	2.15	1.52	-
Selenium	µg/L	0.500	0.500	0.900	0.700	0.300	0.400	0.200	0.400	-
Total Dissolved Solids	mg/L	1400	1320	1300	1200	1250	1270	1280	1330	1250
Sulfate	mg/L	661	629	617	620	584	590	655	631	618
Thallium	µg/L	0.0300 J	0.0630	0.106	0.102	0.0300 J	0.0300 J	0.0200 J	0.0400 J	-
pH	SU	6.37	6.28	6.72	6.37	6.45	6.63	6.81	6.27	6.36

Notes:  
µg/L: micrograms per liter  
mg/L: milligrams per liter  
pCi/L: picocuries per liter  
SU: standard unit  
U: Non-detect value. Parameters which were not detected are shown as less than the method detection limit (MDL).  
J: Estimated value. Component was detected in concentrations below the reporting limit  
-: Not sampled  
For statistical analysis, parameters which were not detected were replaced with the reporting limit.

Table 1 - Groundwater Data Summary  
Cardinal Plant - Bottom Ash Pond

Parameter	Unit	MW-BAP-5								
		6/28/2016	8/10/2016	10/20/2016	1/12/2017	5/2/2017	5/31/2017	6/20/2017	8/1/2017	9/26/2017
		Background								
Antimony	µg/L	0.0700	0.0900	0.120	0.0600	0.0700	0.0500	0.0300 J	0.0300 J	-
Arsenic	µg/L	11.3	12.1	16.1	8.78	11.5	11.7	9.10	10.6	-
Barium	µg/L	92.7	102	118	87.9	88.2	95.3	77.7	83.1	-
Beryllium	µg/L	0.0680	0.112	0.157	0.0610	0.0950	0.0750	0.0450	0.0390	-
Boron	mg/L	0.0720	0.0430	0.0580	0.0430	0.116	0.0730	0.0500	0.0430	0.0590
Cadmium	µg/L	0.0300	0.0500	0.0600	0.0200	0.0400	0.0300	0.0200 J	0.0100 J	-
Calcium	mg/L	228	209	226	207	201	176	200	206	209
Chloride	mg/L	13.4	13.5	14.3	15.3	14.8	13.3	15.7	14.7	15.3
Chromium	µg/L	2.00	3.40	5.70	2.35	2.83	2.10	1.33	1.16	-
Cobalt	µg/L	1.28	2.03	3.06	1.34	1.92	1.47	0.966	0.855	-
Combined Radium	pCi/L	0.652	1.03	1.50	1.41	0.364	0.894	0.788	0.686	-
Fluoride	mg/L	0.100 J	0.0900 J	0.0800	0.0900 J	0.100 J	0.0600 J	0.0800 J	0.0800 J	0.0900
Lead	µg/L	1.92	3.08	4.60	1.72	2.77	1.95	1.18	1.04	-
Lithium	mg/L	0.0200	0.0100	0.00700	0.00800	0.0100	0.0120	0.0160	0.0120	-
Mercury	µg/L	<0.002 U	0.00300 J	0.00300 J	<0.002 U	<0.002 U	<0.002 U	<0.002 U	<0.002 U	-
Molybdenum	µg/L	0.800	1.22	1.15	0.740	0.620	0.940	0.520	0.520	-
Selenium	µg/L	0.200	0.400	0.700	0.200	0.400	0.300	0.200	0.100	-
Total Dissolved Solids	mg/L	1050	1060	1010	1050	1010	955	1080	1050	1050
Sulfate	mg/L	449	456	433	474	418	404	472	448	442
Thallium	µg/L	0.0300 J	0.0590	0.114	0.0580	0.0590	0.0400 J	0.0300 J	0.0200 J	-
pH	SU	6.60	6.70	6.59	6.60	6.60	7.07	6.94	6.55	6.72

Notes:  
µg/L: micrograms per liter  
mg/L: milligrams per liter  
pCi/L: picocuries per liter  
SU: standard unit  
U: Non-detect value. Parameters which were not detected are shown as less than the method detection limit (MDL).  
J: Estimated value. Component was detected in concentrations below the reporting limit  
-: Not sampled  
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# **Groundwater Flow Direction Maps**



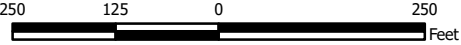


**Legend**

- Groundwater Monitoring Well
- Approximate Groundwater Flow Direction
- Groundwater Elevation Contour

**Notes**

- Monitoring well coordinates and water level data (collected from June 21 to June 22, 2016) provided by AEP.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Bottom Ash Pond (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.



**Potentiometric Surface Map - Uppermost Aquifer  
Bottom Ash Complex  
June 2016**

AEP Cardinal Generating Plant  
Brilliant, Ohio

**Geosyntec**  
consultants

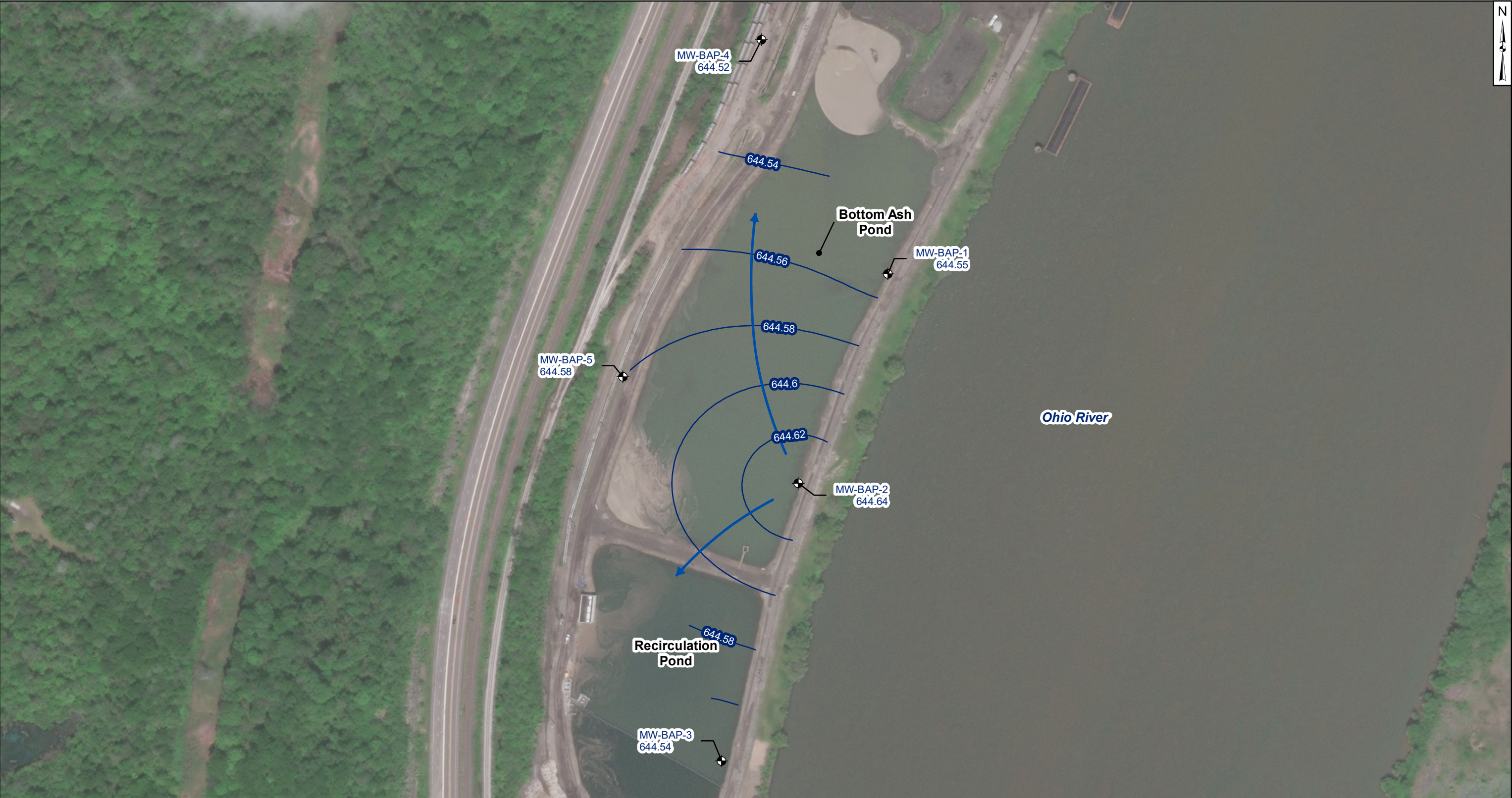
Columbus, Ohio

2017/08/16

Figure

**1**

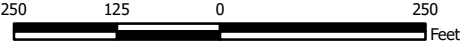




- Legend**
- Groundwater Monitoring Well
  - Groundwater Elevation Contour
  - Approximate Groundwater Flow Direction

**Notes**

- Monitoring well coordinates and water level data (collected from August 1 to August 2, 2016) provided by AEP.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Bottom Ash Pond (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.
- Flow in the area was reversed during the gauging period due to intermittent operation of plant supply wells. Flow in the area is generally to the east toward the Ohio River.



**Potentiometric Surface Map - Uppermost Aquifer  
Bottom Ash Complex  
August 2016**

AEP Cardinal Generating Plant  
Brilliant, Ohio

**Geosyntec**  
consultants

Columbus, Ohio

2018/01/16

Figure  
**2**



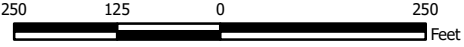


**Legend**

- Groundwater Monitoring Well
- Approximate Groundwater Flow Direction
- Groundwater Elevation Contour

**Notes**

- Monitoring well coordinates and water level data (collected from October 3 to October 4, 2016) provided by AEP.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Bottom Ash Pond (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.



<b>Potentiometric Surface Map - Uppermost Aquifer</b> <b>Bottom Ash Complex</b> <b>October 2016</b>  AEP Cardinal Generating Plant Brilliant, Ohio	
Columbus, Ohio	2017/08/16
<b>Figure 3</b>	



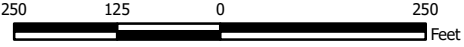


**Legend**

- Groundwater Monitoring Well
- Approximate Groundwater Flow Direction
- Groundwater Elevation Contour

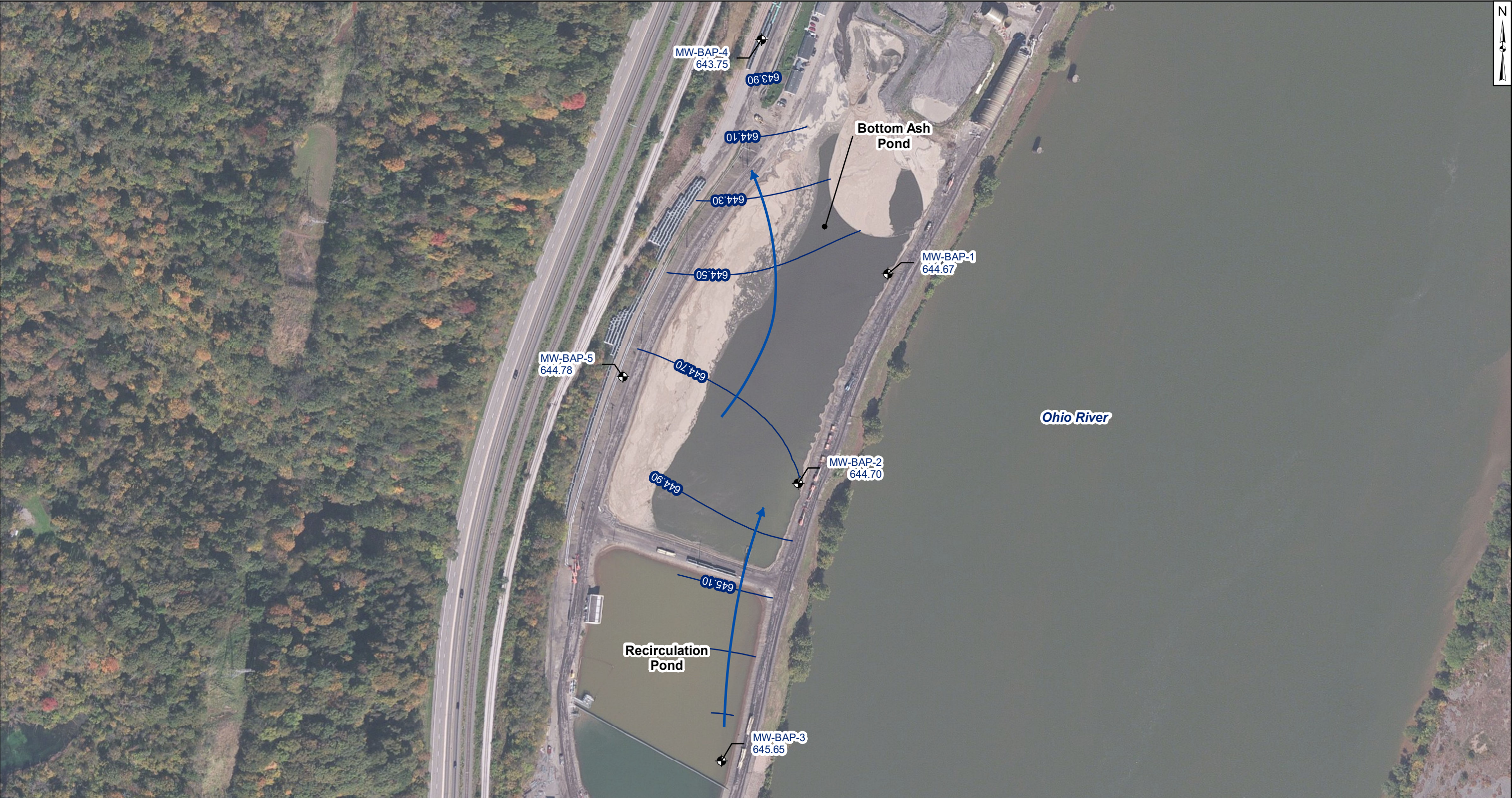
**Notes**

- Monitoring well coordinates and water level data (collected on November 14, 2016) provided by AEP.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Bottom Ash Pond (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.



<b>Potentiometric Surface Map - Uppermost Aquifer</b> <b>Bottom Ash Complex</b> <b>November 2016</b> AEP Cardinal Generating Plant Brilliant, Ohio	
<b>Geosyntec</b> consultants	
Columbus, Ohio	2017/08/16
<b>Figure</b> <b>4</b>	

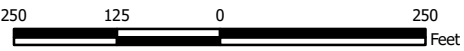




- Legend**
- Groundwater Monitoring Well
  - Groundwater Elevation Contour
  - Approximate Groundwater Flow Direction

**Notes**

- Monitoring well coordinates and water level data (collected on December 12, 2016) provided by AEP.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Bottom Ash Pond (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.
- Flow in the area was reversed during the gauging period due to intermittent operation of plant supply wells. Flow in the area is generally to the east toward the Ohio River.



**Potentiometric Surface Map - Uppermost Aquifer  
Bottom Ash Complex  
December 2016**

AEP Cardinal Generating Plant  
Brilliant, Ohio

**Geosyntec**  
consultants

Columbus, Ohio

2018/01/02

Figure  
**5**

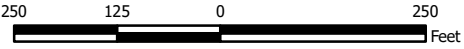




- Legend**
- Groundwater Monitoring Well
  - Approximate Groundwater Flow Direction
  - Groundwater Elevation Contour

**Notes**

- Monitoring well coordinates and water level data (collected on January 9, 2016) provided by AEP.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Bottom Ash Pond (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.



**Potentiometric Surface Map - Uppermost Aquifer  
Bottom Ash Complex  
January 2017**

AEP Cardinal Generating Plant  
Brilliant, Ohio

**Geosyntec**  
consultants

Columbus, Ohio

2017/08/16

Figure  
**6**



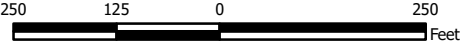


**Legend**

- Groundwater Monitoring Well
- Approximate Groundwater Flow Direction
- Groundwater Elevation Contour

**Notes**

- Monitoring well coordinates and water level data (collected on February 8, 2017) provided by AEP.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Bottom Ash Pond (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.



**Potentiometric Surface Map - Uppermost Aquifer  
Bottom Ash Complex  
February 2017**

AEP Cardinal Generating Plant  
Brilliant, Ohio

**Geosyntec**  
consultants

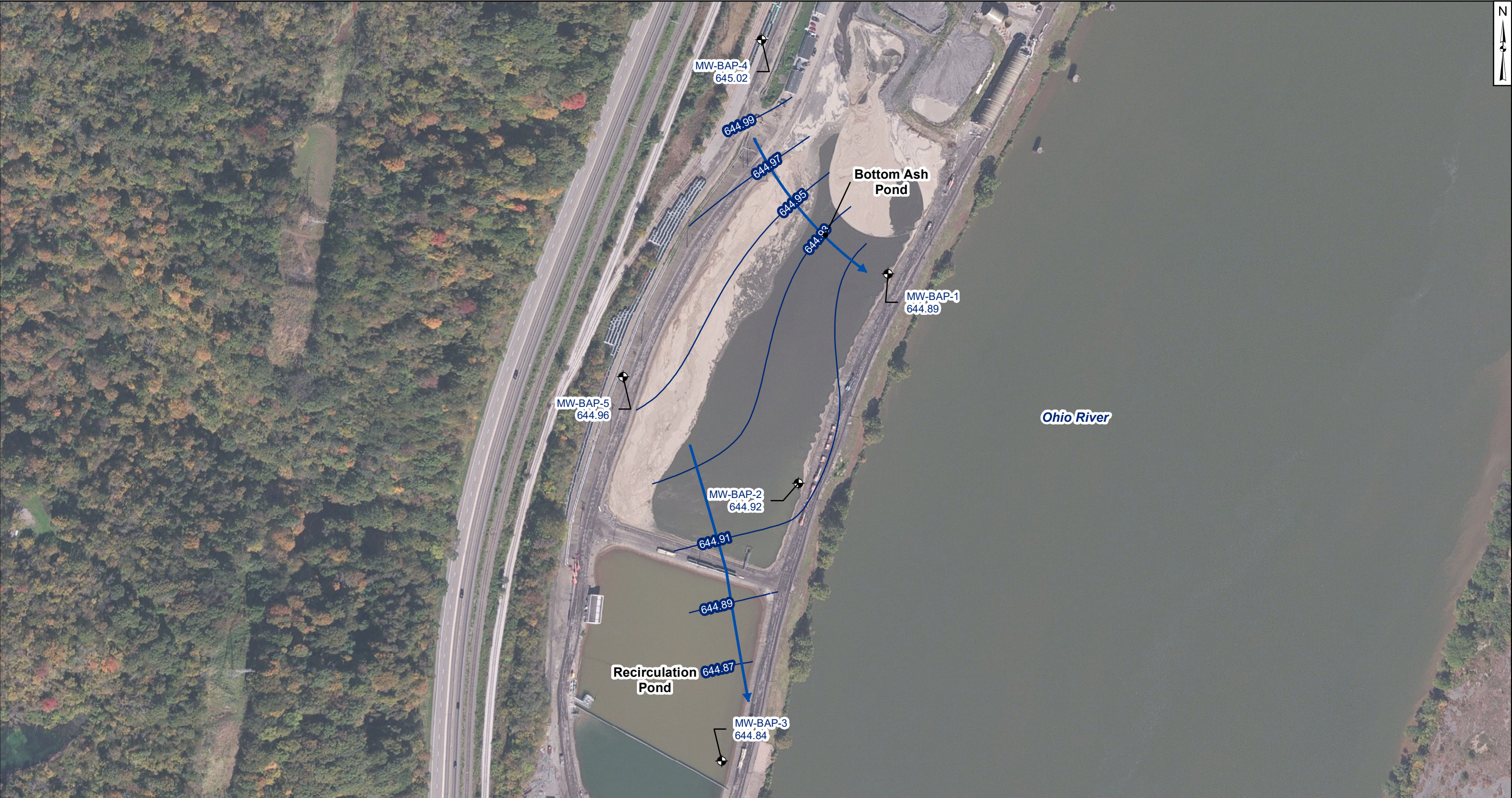
Columbus, Ohio

2017/08/16

Figure

**7**



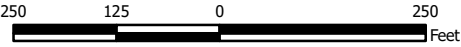


**Legend**

- Groundwater Monitoring Well
- Approximate Groundwater Flow Direction
- Groundwater Elevation Contour

**Notes**

- Monitoring well coordinates and water level data (collected on April 10, 2017) provided by AEP.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Bottom Ash Pond (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.



**Potentiometric Surface Map - Uppermost Aquifer  
Bottom Ash Complex  
April 2017**

AEP Cardinal Generating Plant  
Brilliant, Ohio

**Geosyntec**  
consultants

Columbus, Ohio

2017/08/23

Figure

**8**



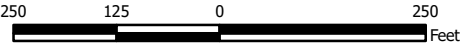


**Legend**

- Groundwater Monitoring Well
- Approximate Groundwater Flow Direction
- Groundwater Elevation Contour

**Notes**

- Monitoring well coordinates and water level data (collected on May 23, 2017) provided by AEP.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Bottom Ash Pond (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.



**Potentiometric Surface Map - Uppermost Aquifer  
Bottom Ash Complex  
May 2017**

AEP Cardinal Generating Plant  
Brilliant, Ohio

**Geosyntec**  
consultants

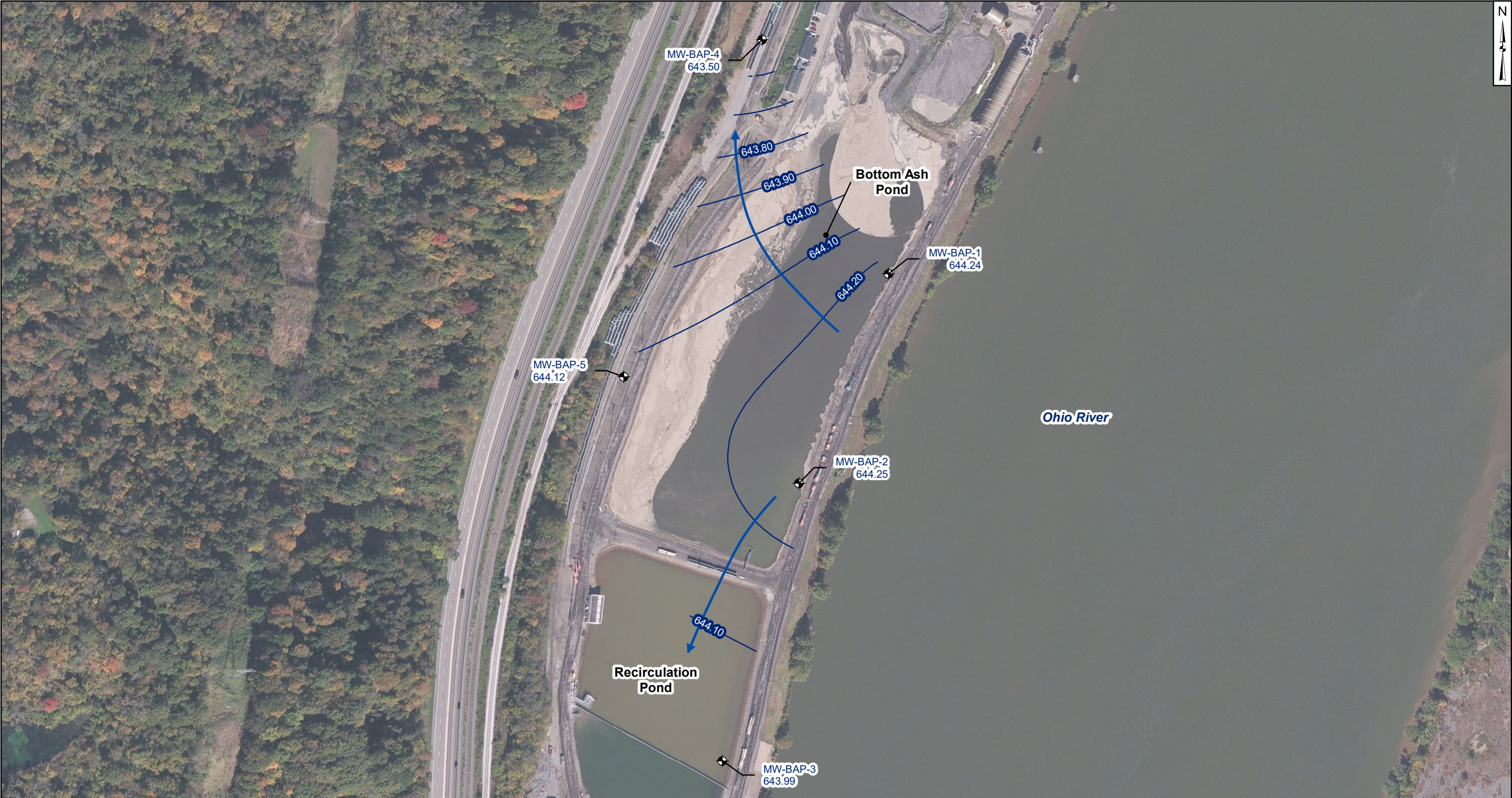
Columbus, Ohio

2017/08/23

Figure

**9**

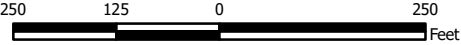




- Legend**
- Groundwater Monitoring Well
  - Groundwater Elevation Contour
  - Approximate Groundwater Flow Direction

**Notes**

- Monitoring well coordinates and water level data (collected on June 19, 2017) provided by AEP.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Bottom Ash Pond (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.
- Flow in the area was reversed during the gauging period due to intermittent operation of plant supply wells. Flow in the area is generally to the east toward the Ohio River.



**Potentiometric Surface Map - Uppermost Aquifer  
Bottom Ash Complex  
June 2017**

AEP Cardinal Generating Plant  
Brilliant, Ohio

**Geosyntec**  
consultants

Columbus, Ohio      2018/01/02

Figure  
**10**

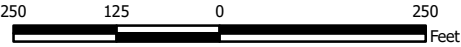




- Legend**
- Groundwater Monitoring Well
  - Groundwater Elevation Contour
  - Approximate Groundwater Flow Direction

**Notes**

- Monitoring well coordinates and water level data (collected on July 25, 2017) provided by AEP.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Bottom Ash Pond (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.



**Potentiometric Surface Map - Uppermost Aquifer  
Bottom Ash Complex  
July 2017**

AEP Cardinal Generating Plant  
Brilliant, Ohio

**Geosyntec**  
consultants

Columbus, Ohio

2017/08/16

Figure

**11**



# **Groundwater Flow Velocity Calculations**

Table 1: Residence Time Calculation Summary  
Cardinal Plant - Bottom Ash Pond

Geosyntec Consultants, Inc.

			2016-06		2016-08		2016-10		2016-11		2016-12	
CCR Management Unit	Monitoring Well	Well Diameter (inches)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)
Bottom Ash Pond	MW-BAP-1 <sup>[2]</sup>	2.0	5.3	11.5	23.5	2.6	34	1.8	24.7	2.5	204	0.30
	MW-BAP-2 <sup>[2]</sup>	2.0	2.9	21	24.1	2.5	20.3	3.0	29.7	2.0	208	0.29
	MW-BAP-3 <sup>[2]</sup>	2.0	13.8	4.4	20.2	3.0	26.6	2.3	15.2	4.0	455	0.13
	MW-BAP-4 <sup>[1]</sup>	2.0	18.9	3.2	9.8	6.2	49	1.2	52	1.2	235	0.26
	MW-BAP-5 <sup>[1]</sup>	2.0	2.9	21	14.1	4.3	26.0	2.3	57	1.1	155	0.39

			2017-01		2017-04		2017-05		2017-06		2017-07		2017-10	
CCR Management Unit	Monitoring Well	Well Diameter (inches)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)
Bottom Ash Pond	MW-BAP-1 <sup>[2]</sup>	2.0	45	1.4	31	2.0	112	0.54	158	0.39	62.7	1.0	28.3	1.0
	MW-BAP-2 <sup>[2]</sup>	2.0	26.5	2.3	7.8	7.8	190	0.32	52	1.2	6.4	9.5	6.4	9.5
	MW-BAP-3 <sup>[2]</sup>	2.0	14.4	4.2	20.3	3.0	127	0.48	59	1.0	18.7	3.3	18.7	3.3
	MW-BAP-4 <sup>[1]</sup>	2.0	34	1.8	26.8	2.3	43	1.4	165	0.4	56.9	1.1	57	1.1
	MW-BAP-5 <sup>[1]</sup>	2.0	36	1.7	18.2	3.3	14	4.3	57	1.1	17.2	3.5	57	1.1

Notes:  
[1] - Upgradient Well  
[2] - Compliance Well



<b>APPENDIX II</b>
--------------------

Not applicable at this time.