

Annual Groundwater Monitoring Report

Cardinal Operating Company

Cardinal Plant

FAR 1 RSW Landfill

Brilliant, OH

January 2018

Prepared by:

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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 FAR 1 RSW Landfill 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.

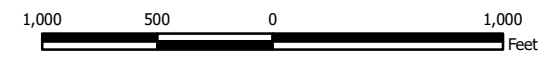


Monitoring Well Network

- ◆ Background Sampling Location
- ◆ Compliance Sampling Location
- Residual Solid Waste (RSW) Landfill

Notes

- Monitoring well coordinates provided by AEP.
 -Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Former Fly Ash Reservoir I - Residual Solid Waste Landfill (Geosyntec, 2016) provided by AEP.



**Site Layout
Residual Solid Waste Landfill**

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* (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 - Landfill**

Parameter	Unit	CA-0623A								
		10/13/2016	11/15/2016	12/14/2016	1/10/2017	4/18/2017	5/25/2017	6/21/2017	7/27/2017	9/27/2017
		Background								
Antimony	µg/L	0.0200 J	0.0100 J	0.0100 J	<0.01 U	0.0200 J	<0.01 U	<0.01 U	0.0100 J	-
Arsenic	µg/L	0.540	0.340	0.360	0.270	0.400	0.260	0.240	0.260	-
Barium	µg/L	20.1	21.1	21.5	21.2	23.0	22.5	20.6	21.0	-
Beryllium	µg/L	0.00900 J	0.00600 J	<0.005 U	<0.005 U	<0.004 U	<0.004 U	<0.004 U	<0.004 U	-
Boron	mg/L	0.442	0.487	0.388	0.434	0.418	0.474	0.454	0.422	0.488
Cadmium	µg/L	<0.004 U	<0.004 U	<0.004 U	<0.004 U	<0.005 U	<0.005 U	<0.005 U	0.0300	-
Calcium	mg/L	1.55	1.37	1.22	1.16	1.12	1.15	1.14	1.14	1.11
Chloride	mg/L	24.8	25.4	25.7	24.0	16.4	14.6	16.2	23.1	24.5
Chromium	µg/L	4.10	0.548	0.829	0.120	0.112	0.515	0.0620	0.143	-
Cobalt	µg/L	0.116	0.0450	0.0470	0.0260	0.0220	0.0200	0.0220	0.0200 J	-
Combined Radium	pCi/L	0.587	0.587	0.600	0.344	0.656	0.855	1.03	0.359	-
Fluoride	mg/L	2.12	1.98	1.93	1.88	2.02	2.04	2.09	2.03	1.98
Lead	µg/L	0.164	0.0560	0.0640	0.0310	0.0470	0.0240	0.0320	0.118	-
Lithium	mg/L	0.0200	0.0200	0.0200	0.0240	0.0200	0.0250	0.0260	0.0210	-
Mercury	µg/L	<0.002 U	<0.002 U	<0.002 U	<0.002 U	<0.002 U	<0.002 U	<0.002 U	<0.002 U	-
Molybdenum	µg/L	0.990	0.730	0.600	1.61	0.720	0.810	0.430	0.530	-
Selenium	µg/L	0.0600 J	<0.03 U	0.0300 J	<0.03 U	<0.03 U	<0.03 U	<0.03 U	<0.03 U	-
Total Dissolved Solids	mg/L	600	666	642	658	666	651	657	644	669
Sulfate	mg/L	37.7	44.3	47.9	51.7	43.4	40.3	41.6	36.3	35.6
Thallium	µg/L	<0.01 U	<0.01 U	<0.01 U	<0.01 U	<0.01 U	<0.01 U	<0.01 U	0.0200 J	-
pH	SU	8.92	8.70	8.71	8.72	8.93	7.89	8.31	8.50	8.55

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. 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 - Landfill**

Parameter	Unit	OAE-2005-10-C									
		6/29/2016	8/9/2016	12/14/2016	1/12/2017	2/9/2017	4/17/2017	5/31/2017	6/22/2017	7/27/2017	10/3/2017
		Background									
Antimony	µg/L	0.290	-	0.360	0.0700	0.0300 J	0.0400 J	0.0300 J	0.0500 J	0.280	-
Arsenic	µg/L	0.920	-	7.87	0.970	0.850	0.670	0.520	0.630	0.960	-
Barium	µg/L	26.6	-	209	45.3	29.5	31.9	32.0	27.6	41.1	-
Beryllium	µg/L	<0.005 U	-	0.588	0.0410	0.00800 J	0.00700 J	0.0100 J	<0.004 U	0.0400 J	-
Boron	mg/L	0.332	-	0.343	0.389	0.451	0.422	0.438	0.437	0.486	0.425
Cadmium	µg/L	0.0400	-	0.500	0.0400	0.0100 J	0.0200 J	0.0100 J	0.00700 J	0.0400 J	-
Calcium	mg/L	8.18	-	142	12.4	7.55	7.16	6.19	5.99	10.5	5.52
Chloride	mg/L	35.9	-	12.2	10.5	10.5	11.4	11.1	11.2	12.3	12.3
Chromium	µg/L	0.600	-	36.3	3.86	0.824	0.860	0.737	0.244	2.95	-
Cobalt	µg/L	0.162	-	12.8	0.852	0.167	0.207	0.151	0.0600	0.801	-
Combined Radium	pCi/L	0.225	-	2.40	0.678	0.168	0.227	1.18	2.71	0.0950	-
Fluoride	mg/L	1.01	-	0.720	0.820	0.840	0.880	0.870	0.890	0.900	0.960
Lead	µg/L	0.412	-	475	20.3	4.87	6.84	6.50	3.96	29.3	-
Lithium	mg/L	0.0420	-	0.0520	0.0390	0.0360	0.0290	0.0250	0.0320	0.0350	-
Mercury	µg/L	<0.002 U	-	0.00600	0.00400 J	<0.002 U	0.00300 J	<0.002 U	<0.002 U	<0.002 U	-
Molybdenum	µg/L	10.9	-	3.05	1.27	1.06	1.97	3.99	1.79	2.72	-
Selenium	µg/L	0.100	-	3.10	0.100	0.0400 J	0.0400 J	<0.03 U	<0.03 U	0.0600 J	-
Total Dissolved Solids	mg/L	1660	-	1780	1490	1650	1470	1500	1430	1540	1350
Sulfate	mg/L	681	-	482	248	421	442	437	430	403	393
Thallium	µg/L	0.0300 J	-	0.124	0.0200 J	0.0100 J	<0.01 U	0.0100 J	<0.01 U	0.0200 J	-
pH	SU	8.15	8.12	8.49	8.07	7.66	8.21	8.21	8.01	7.93	8.35

Notes:

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mg/L: milligrams per liter

pCi/L: picocuries 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 - Landfill**

Parameter	Unit	S-1									
		6/30/2016	8/4/2016	10/11/2016	1/11/2017	4/11/2017	4/20/2017	5/24/2017	6/21/2017	7/26/2017	10/4/2017
		Background									
Antimony	µg/L	0.0200 J	0.0200 J	0.0400 J	0.0200 J	0.0400 J	-	0.0300 J	0.0300 J	<0.02 U	-
Arsenic	µg/L	0.440	0.350	0.460	0.480	0.400	-	0.420	0.420	0.410	-
Barium	µg/L	24.8	24.6	23.1	23.6	23.2	-	23.4	22.9	22.6	-
Beryllium	µg/L	<0.005 U	<0.005 U	<0.005 U	<0.005 U	<0.004 U	-	<0.004 U	<0.008 U	<0.008 U	-
Boron	mg/L	0.924	0.937	0.921	0.856	0.874	-	0.897	0.895	0.855	0.834
Cadmium	µg/L	0.0100 J	0.0400	0.0400	0.0400	0.100	-	0.0600	0.0600	0.0500	-
Calcium	mg/L	335	291	296	293	279	-	314	320	319	305
Chloride	mg/L	6.36	6.10	6.13	6.03	5.69	-	5.77	5.73	5.65	5.39
Chromium	µg/L	0.300	0.100	0.300	0.193	0.0200 J	-	0.0500 J	0.100 J	0.405	-
Cobalt	µg/L	0.824	0.771	0.623	0.811	0.919	-	0.622	1.17	1.04	-
Combined Radium	pCi/L	1.42	1.35	0.562	1.96	0.244	-	1.35	0.680	1.92	-
Fluoride	mg/L	0.200	0.190	0.240	0.170	0.160	-	0.170	0.140	0.140	0.160
Lead	µg/L	0.101	0.162	0.0890	0.229	0.383	-	0.154	0.145	0.110	-
Lithium	mg/L	0.0500	0.0330	0.0330	0.0390	0.0360	-	0.0470	0.0390	0.0420	-
Mercury	µg/L	<0.002 U	<0.002 U	<0.002 U	<0.002 U	<0.002 U	-	<0.002 U	<0.002 U	<0.002 U	-
Molybdenum	µg/L	2.92	2.23	3.70	2.69	2.25	-	3.06	2.78	3.10	-
Selenium	µg/L	0.100	<0.03 U	0.0500 J	<0.03 U	<0.03 U	-	0.0500 J	<0.06 U	<0.06 U	-
Total Dissolved Solids	mg/L	1750	1760	1670	1820	-	1860	1830	1880	1840	1820
Sulfate	mg/L	947	928	885	996	-	970	954	1050	1080	1000
Thallium	µg/L	0.0540	0.0200 J	0.0100 J	0.0300 J	0.0100 J	-	0.0100 J	<0.02 U	0.0200 J	-
pH	SU	7.10	7.10	7.26	7.23	6.81	6.98	6.82	7.05	6.79	7.08

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. 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 - Landfill**

Parameter	Unit	S-2									
		6/24/2016	8/4/2016	10/6/2016	10/27/2016	1/17/2017	4/19/2017	5/24/2017	6/21/2017	7/26/2017	10/4/2017
		Background									
Antimony	µg/L	4.23	3.60	1.01	-	0.660	0.530	0.230	0.290	3.57	-
Arsenic	µg/L	13.6	10.9	5.57	-	5.78	5.99	2.70	3.93	5.87	-
Barium	µg/L	19.5	18.4	18.1	-	20.3	17.3	16.8	17.4	16.8	-
Beryllium	µg/L	0.0400 J	0.0200 J	0.0300 J	-	0.0440	0.0300 J	0.0200 J	0.0300 J	0.0200 J	-
Boron	mg/L	1.66	1.91	2.74	-	2.32	1.80	1.90	1.77	2.09	2.73
Cadmium	µg/L	0.620	1.04	0.290	-	0.270	0.0400 J	<0.01 U	0.0300 J	0.240	-
Calcium	mg/L	424	386	421	-	463	403	420	353	391	395
Chloride	mg/L	7.91	6.70	5.76	-	7.56	6.88	7.62	6.82	6.35	4.98
Chromium	µg/L	1.10	0.300	0.900	-	1.03	0.200 J	0.0500 J	0.385	0.526	-
Cobalt	µg/L	3.87	4.97	4.21	-	5.29	4.80	3.67	3.96	5.21	-
Combined Radium	pCi/L	0.627	1.24	1.15	-	2.96	0.166	0.696	2.42	0.982	-
Fluoride	mg/L	0.400	0.360	0.350	-	0.320	0.280	0.300	0.290	0.280	0.310
Lead	µg/L	10.1	8.64	7.53	-	3.77	0.546	0.200	1.02	5.00	-
Lithium	mg/L	0.0740	0.0670	0.0660	-	0.0920	0.0880	0.0900	0.0790	0.0830	-
Mercury	µg/L	<0.002 U	<0.002 U	0.00600	-	<0.002 U	0.00500	<0.002 U	<0.002 U	<0.002 U	-
Molybdenum	µg/L	20.4	21.2	27.2	-	24.3	22.4	17.3	19.0	26.4	-
Selenium	µg/L	1.30	3.00	0.0900 J	-	0.100	0.100 J	<0.06 U	<0.09 U	0.700	-
Total Dissolved Solids	mg/L	3000	2870	2920	-	3260	3060	2970	2820	2890	2990
Sulfate	mg/L	1880	1800	1820	-	2020	1880	1820	1800	1910	1880
Thallium	µg/L	1.06	1.72	0.254	-	0.505	0.100 J	0.199	0.303	1.22	-
pH	SU	7.55	7.91	-	7.33	6.92	6.89	6.82	7.05	6.90	7.89

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. 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 - Landfill**

Parameter	Unit	S-4									
		6/28/2016	8/5/2016	10/12/2016	1/11/2017	4/11/2017	4/26/2017	5/24/2017	6/21/2017	7/26/2017	10/4/2017
		Background									
Antimony	µg/L	0.410	0.170	0.430	0.310	0.250	-	0.200 J	0.160	0.170	-
Arsenic	µg/L	15.7	6.82	4.84	9.10	5.37	-	12.1	5.90	6.76	-
Barium	µg/L	116	63.3	175	466	255	-	595	521	620	-
Beryllium	µg/L	3.13	1.24	0.217	0.506	0.192	-	0.691	0.276	0.334	-
Boron	mg/L	0.405	0.301	0.196	0.276	0.329	-	0.450	0.381	0.308	0.242
Cadmium	µg/L	15.1	3.61	4.99	4.05	2.55	-	0.910	0.530	0.470	-
Calcium	mg/L	709	508	353	423	383	-	437	471	473	406
Chloride	mg/L	8.13	7.73	6.62	5.34	-	5.71	5.91	6.38	6.66	5.98
Chromium	µg/L	71.1	28.7	8.00	19.9	9.49	-	22.2	10.8	13.2	-
Cobalt	µg/L	116	37.1	34.9	26.0	18.7	-	18.1	14.1	14.2	-
Combined Radium	pCi/L	2.59	1.46	1.90	14.1	4.02	-	0.957	1.80	1.33	-
Fluoride	mg/L	0.260	0.230	0.220	0.230	-	0.260	0.240	0.210	0.210	0.200
Lead	µg/L	128	29.8	5.64	13.5	7.85	-	19.1	7.70	10.2	-
Lithium	mg/L	0.140	0.0720	0.0470	0.0760	0.0640	-	0.0880	0.0770	0.0780	-
Mercury	µg/L	0.0300	1.01	0.0220	0.0590	0.0300	-	0.00300 J	0.0230	0.00600	-
Molybdenum	µg/L	9.15	3.65	6.29	5.06	3.85	-	4.04	3.62	3.72	-
Selenium	µg/L	10.0	4.80	1.00	2.10	1.10	-	2.70	1.10	0.500	-
Total Dissolved Solids	mg/L	2870	3010	2280	2930	-	2690	3390	2780	2710	2310
Sulfate	mg/L	1680	1580	1210	1400	-	1510	1500	1700	1640	1380
Thallium	µg/L	2.02	0.692	0.505	0.658	0.431	-	0.360	0.208	0.224	-
pH	SU	7.19	6.96	6.71	7.19	7.31	7.02	6.92	6.75	6.70	7.71

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. 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 - Landfill**

Parameter	Unit	S-5									
		6/29/2016	10/12/2016	11/15/2016	1/11/2017	4/11/2017	4/26/2017	5/24/2017	6/21/2017	7/26/2017	10/4/2017
		Background									
Antimony	µg/L	0.210	0.140	0.130	0.0200 J	0.0300 J	-	0.0500 J	0.130	0.0200 J	-
Arsenic	µg/L	11.6	11.8	15.8	0.680	0.600	-	1.04	4.29	0.640	-
Barium	µg/L	97.9	74.1	101	19.5	19.7	-	26.7	50.4	20.1	-
Beryllium	µg/L	0.771	0.700	1.19	0.0100 J	0.0100 J	-	0.0510	0.221	0.0210	-
Boron	mg/L	0.00900 J	0.0310	0.0260	0.0190	0.0340	-	0.0870	0.0320	0.0300	0.0200
Cadmium	µg/L	0.840	1.18	1.82	0.0300	0.0300	-	0.100	0.300	0.0300	-
Calcium	mg/L	297	271	292	251	250	-	273	259	272	243
Chloride	mg/L	6.99	6.87	6.95	6.60	-	6.80	6.85	6.82	6.85	6.66
Chromium	µg/L	6.10	4.80	7.04	0.298	0.166	-	0.444	1.95	0.298	-
Cobalt	µg/L	7.77	6.76	9.50	0.270	0.229	-	0.718	2.76	0.296	-
Combined Radium	pCi/L	2.47	0.780	1.14	0.629	0.941	-	0.924	0.640	0.961	-
Fluoride	mg/L	0.110	0.100 J	0.100	0.100	-	0.100	0.100	0.0800	0.0800	0.0900 J
Lead	µg/L	24.8	28.9	39.8	0.444	0.499	-	1.91	8.38	0.769	-
Lithium	mg/L	0.0140	0.0110	0.0230	0.0140	0.0110	-	0.0130	0.0100	0.0170	-
Mercury	µg/L	<0.002 U	<0.002 U	0.172	<0.002 U	<0.002 U	-	<0.002 U	0.00200 J	<0.002 U	-
Molybdenum	µg/L	1.22	0.970	1.23	0.430	0.180	-	0.320	0.670	0.310	-
Selenium	µg/L	4.70	4.80	7.60	0.0600 J	0.0800 J	-	0.300	1.60	0.0800 J	-
Total Dissolved Solids	mg/L	1250	1250	1270	1240	-	1280	1310	1330	1300	1280
Sulfate	mg/L	697	662	678	670	-	685	675	726	713	691
Thallium	µg/L	0.247	0.216	0.325	0.0200 J	<0.01 U	-	0.0200 J	0.0960	0.0200 J	-
pH	SU	7.10	7.39	7.28	7.54	7.15	7.63	7.12	7.20	7.20	8.11

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. 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 - Landfill**

Parameter	Unit	S-6									
		6/28/2016	8/5/2016	10/12/2016	1/11/2017	4/11/2017	4/20/2017	5/24/2017	6/21/2017	7/26/2017	10/4/2017
		Background									
Antimony	µg/L	0.0700	0.0800 J	0.0500 J	0.0500 J	<0.02 U	-	<0.3 U	0.0100 J	<0.02 U	-
Arsenic	µg/L	0.540	0.720	0.750	0.810	0.600	-	0.800 J	0.590	0.510	-
Barium	µg/L	15.4	23.7	26.5	15.0	13.6	-	14.3	12.7	15.1	-
Beryllium	µg/L	0.00500 J	<0.01 U	0.0100 J	<0.01 U	<0.008 U	-	0.300 J	<0.004 U	<0.008 U	-
Boron	mg/L	1.65	1.97	2.06	2.15	1.69	-	1.72	1.54	1.44	1.67
Cadmium	µg/L	0.600	0.400	0.520	0.140	0.130	-	<0.2 U	0.0800	0.140	-
Calcium	mg/L	241	308	352	393	254	-	263	219	203	251
Chloride	mg/L	32.0	37.4	41.1	39.0	-	40.6	35.7	32.2	29.3	37.0
Chromium	µg/L	0.100	0.400	0.300	0.226	0.0300 J	-	0.300 J	0.0650	0.318	-
Cobalt	µg/L	0.268	0.383	0.437	0.404	0.279	-	0.300 J	0.226	0.208	-
Combined Radium	pCi/L	0.752	2.33	0.936	0.981	0.0753	-	0.811	1.42	1.56	-
Fluoride	mg/L	0.280	0.220	0.210	0.140	-	0.160	0.230	0.230	0.230	0.200
Lead	µg/L	0.737	0.862	0.717	1.40	0.211	-	0.200 J	0.158	0.344	-
Lithium	mg/L	0.0420	0.0290	0.0300	0.0330	0.0300	-	0.0320	0.0270	0.0310	-
Mercury	µg/L	0.00300 J	<0.002 U	0.00200 J	<0.002 U	<0.002 U	-	<0.002 U	<0.002 U	<0.002 U	-
Molybdenum	µg/L	0.500	0.530	0.320	1.04	0.540	-	3.08	0.620	1.08	-
Selenium	µg/L	<0.03 U	<0.06 U	<0.06 U	0.0600 J	<0.06 U	-	<0.9 U	<0.03 U	<0.06 U	-
Total Dissolved Solids	mg/L	1040	2270	2260	2520	-	2470	22100	766	1890	2200
Sulfate	mg/L	1110	1340	1350	1440	-	1420	1200	1220	1070	1250
Thallium	µg/L	0.0400 J	0.0400 J	0.0400 J	0.0400 J	<0.02 U	-	<0.3 U	<0.01 U	0.0300 J	-
pH	SU	7.44	7.19	7.69	7.08	7.38	7.55	6.95	7.46	7.20	7.89

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. 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 - Landfill**

Parameter	Unit	S-7									
		6/30/2016	8/4/2016	10/11/2016	1/11/2017	4/11/2017	4/20/2017	5/24/2017	6/21/2017	7/26/2017	10/4/2017
		Background									
Antimony	µg/L	0.0700	0.100	0.0900	0.0800	0.100	-	0.0600 J	0.0600 J	0.0600 J	-
Arsenic	µg/L	0.520	0.490	0.710	0.560	0.590	-	0.500	0.760	0.510	-
Barium	µg/L	13.7	13.2	14.0	13.3	13.3	-	14.1	12.8	13.5	-
Beryllium	µg/L	0.0100 J	0.00800 J	0.0100 J	0.00700 J	0.0100 J	-	0.00800 J	<0.008 U	0.00900 J	-
Boron	mg/L	1.77	1.78	1.81	1.75	1.84	-	1.82	1.74	1.79	1.88
Cadmium	µg/L	0.0300	0.0700	0.0900	1.16	0.430	-	0.0300 J	0.0200 J	0.0200 J	-
Calcium	mg/L	271	247	255	245	240	-	251	239	259	244
Chloride	mg/L	34.1	33.9	35.7	33.7	-	32.6	34.7	35.2	35.2	36.5
Chromium	µg/L	0.300	0.100	0.100	0.0860	0.0690	-	0.132	0.0500 J	0.329	-
Cobalt	µg/L	0.132	0.142	0.140	0.144	0.147	-	0.140	0.149	0.159	-
Combined Radium	pCi/L	0.996	1.15	0.235	0.824	0.437	-	1.05	0.710	1.07	-
Fluoride	mg/L	0.180	0.160	0.170	0.160	-	0.160	0.160	0.140	0.130	0.100 J
Lead	µg/L	1.36	3.58	4.23	5.03	6.17	-	1.34	0.617	0.928	-
Lithium	mg/L	0.0900	0.0810	0.0870	0.0930	0.0840	-	0.0900	0.0870	0.0920	-
Mercury	µg/L	<0.002 U	<0.002 U	<0.002 U	0.00500	<0.002 U	-	<0.002 U	<0.002 U	<0.002 U	-
Molybdenum	µg/L	5.45	7.53	7.95	8.10	6.19	-	7.60	7.70	7.61	-
Selenium	µg/L	0.300	0.100	0.200	0.100	0.300	-	0.200	0.200 J	0.100 J	-
Total Dissolved Solids	mg/L	1850	1820	1760	1820	-	1850	1900	1890	1900	1860
Sulfate	mg/L	1040	1020	988	1060	-	961	1010	1140	1090	1020
Thallium	µg/L	0.0200 J	0.0200 J	0.0200 J	0.0300 J	0.0200 J	-	0.0200 J	0.0200 J	0.0300 J	-
pH	SU	7.25	7.69	7.22	7.23	7.51	7.44	7.00	6.98	6.93	7.41

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. 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 - Landfill**

Parameter	Unit	S-10								
		6/23/2016	8/3/2016	10/20/2016	1/17/2017	5/2/2017	5/25/2017	6/27/2017	7/26/2017	9/26/2017
		Background								
Antimony	µg/L	0.0500	0.0500 J	0.0600	0.0500 J	0.0500 J	0.0600	0.0700 J	0.0600 J	-
Arsenic	µg/L	0.650	0.400	0.660	0.740	0.720	0.880	1.11	0.940	-
Barium	µg/L	20.2	13.1	12.9	20.6	19.9	25.6	19.4	20.0	-
Beryllium	µg/L	0.0200 J	<0.01 U	0.0100 J	0.0100 J	0.0100 J	0.0200 J	0.0200 J	0.0200 J	-
Boron	mg/L	1.27	0.853	0.896	1.22	1.33	1.50	1.40	1.29	0.825
Cadmium	µg/L	0.0200 J	0.0100 J	0.0100 J	0.0100 J	<0.01 U	0.0300	<0.01 U	0.0600	-
Calcium	mg/L	246	303	285	252	251	238	264	249	295
Chloride	mg/L	25.7	25.0	24.3	26.4	29.3	27.8	25.3	25.1	24.6
Chromium	µg/L	0.200	0.0200 J	0.0770	0.106	0.0600 J	0.0400 J	0.0900 J	0.372	-
Cobalt	µg/L	0.111	0.0430	0.0790	0.0770	0.0680	0.311	0.292	0.260	-
Combined Radium	pCi/L	0.996	0.573	1.82	1.76	0.729	1.27	1.81	1.05	-
Fluoride	mg/L	0.170	0.210	0.230	0.160	0.160	0.150	0.150	0.130	0.170
Lead	µg/L	0.0600	0.0100 J	0.0340	0.0670	0.0480	0.0560	0.0470	0.0570	-
Lithium	mg/L	0.0930	0.0610	0.0650	0.0890	0.102	0.110	0.0840	0.0950	-
Mercury	µg/L	0.00400 J	<0.002 U	<0.002 U	<0.002 U	<0.002 U	<0.002 U	<0.002 U	<0.002 U	-
Molybdenum	µg/L	15.2	6.91	5.12	14.5	18.9	21.6	18.1	20.7	-
Selenium	µg/L	0.400	0.300	0.500	0.500	0.700	0.600	0.600	0.400	-
Total Dissolved Solids	mg/L	1670	1700	1690	1600	1640	1570	1660	1640	1730
Sulfate	mg/L	967	998	970	897	889	867	979	989	1060
Thallium	µg/L	<0.01 U	<0.02 U	0.116	0.0200 J	<0.02 U	<0.01 U	<0.02 U	0.0300 J	-
pH	SU	6.88	6.88	6.99	6.97	7.00	7.12	7.13	6.92	7.74

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. 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 - Landfill**

Parameter	Unit	S-17									
		6/29/2016	8/9/2016	10/12/2016	2/9/2017	3/9/2017	4/17/2017	5/31/2017	6/22/2017	8/1/2017	10/3/2017
		Background									
Antimony	µg/L	0.0200 J	0.120	-	0.0700	0.0200 J	0.0200 J	0.0600	0.0100 J	0.0700	-
Arsenic	µg/L	5.23	9.37	-	10.1	9.28	9.41	11.6	9.62	10.7	-
Barium	µg/L	37.7	41.2	-	31.3	31.0	33.7	43.3	23.7	43.0	-
Beryllium	µg/L	0.0100 J	0.157	-	0.0420	0.0100 J	0.00600 J	0.0430	0.00600 J	0.0570	-
Boron	mg/L	0.127	0.151	-	0.173	0.157	0.153	0.175	0.221	0.165	0.168
Cadmium	µg/L	0.0700	0.910	-	0.0900	0.0200	<0.005 U	0.110	0.0200	0.120	-
Calcium	mg/L	235	237	-	254	203	201	195	138	190	212
Chloride	mg/L	3.52	3.98	-	3.02	2.55	2.98	3.22	2.36	2.68	4.71
Chromium	µg/L	0.600	4.30	-	1.17	0.479	0.0300 J	1.00	0.139	1.55	-
Cobalt	µg/L	0.518	1.69	-	3.43	1.27	0.769	1.17	1.10	1.11	-
Combined Radium	pCi/L	0.568	1.19	-	1.27	0.691	2.75	1.09	1.16	0.807	-
Fluoride	mg/L	0.240	0.220	-	0.160	0.190	0.190	0.200	0.200	0.220	0.220
Lead	µg/L	0.393	6.43	-	1.79	0.471	0.00800 J	1.96	0.182	2.88	-
Lithium	mg/L	0.0400	0.0330	-	0.0440	0.0330	0.0320	0.0320	0.0340	0.0320	-
Mercury	µg/L	<0.002 U	0.0150	-	0.00600	<0.002 U	0.00300 J	0.00200 J	<0.002 U	<0.002 U	-
Molybdenum	µg/L	0.810	0.960	-	2.40	1.86	1.84	1.91	1.60	2.01	-
Selenium	µg/L	0.100	0.800	-	0.400	0.100	0.0500 J	0.300	0.0400 J	0.400	-
Total Dissolved Solids	mg/L	1460	1410	-	1720	1370	1470	1440	1170	1420	1460
Sulfate	mg/L	813	797	-	1180	740	823	821	643	850	784
Thallium	µg/L	0.0940	0.369	-	0.131	0.0500 J	0.0300 J	0.0910	0.0100 J	0.116	-
pH	SU	7.04	6.97	8.00	6.39	-	6.80	6.73	6.84	8.08	7.14

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. 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 - Landfill**

Parameter	Unit	S-18								
		6/29/2016	8/9/2016	10/6/2016	1/12/2017	4/17/2017	5/31/2017	6/22/2017	7/27/2017	10/3/2017
		Background								
Antimony	µg/L	0.0300 J	0.0500	0.0600	0.0300 J	0.0900 J	0.0300 J	0.0200 J	<0.02 U	-
Arsenic	µg/L	1.40	2.29	2.24	0.900	0.980	1.41	0.800	0.740	-
Barium	µg/L	20.9	68.9	64.5	22.1	21.7	25.9	18.3	18.3	-
Beryllium	µg/L	0.00900 J	0.0920	0.103	0.00800 J	0.0100 J	0.0200	<0.008 U	<0.008 U	-
Boron	mg/L	0.611	0.658	0.568	0.561	0.558	0.538	0.573	0.517	0.556
Cadmium	µg/L	0.0600	0.0400	0.0400	0.0200 J	0.0100 J	0.140	0.0200 J	0.0500	-
Calcium	mg/L	218	207	179	202	142	189	154	156	178
Chloride	mg/L	2.20	1.77	1.82	1.23	2.36	1.36	1.50	1.55	1.18
Chromium	µg/L	0.500	1.90	1.80	0.184	0.143	0.371	0.0900 J	0.421	-
Cobalt	µg/L	0.248	0.606	0.834	0.350	0.334	0.215	0.151	0.227	-
Combined Radium	pCi/L	1.04	2.05	2.11	1.17	0.522	1.35	2.58	0.434	-
Fluoride	mg/L	0.360	0.330	0.350	0.360	0.350	0.320	0.310	0.300	0.290
Lead	µg/L	0.329	1.87	2.48	0.236	0.175	0.877	0.0700	0.116	-
Lithium	mg/L	0.0740	0.0630	0.0570	0.0730	0.0570	0.0560	0.0600	0.0570	-
Mercury	µg/L	0.00200 J	0.00900	<0.002 U	0.00200 J	0.00300 J	0.00600	<0.002 U	<0.002 U	-
Molybdenum	µg/L	11.5	12.1	13.7	10.7	7.63	10.9	7.92	8.40	-
Selenium	µg/L	0.100	0.300	0.400	0.0600 J	0.300	0.0700 J	<0.06 U	<0.06 U	-
Total Dissolved Solids	mg/L	1540	1520	1600	1760	1610	1490	1530	1510	1520
Sulfate	mg/L	910	859	928	1040	908	872	899	842	799
Thallium	µg/L	0.0950	0.0200 J	0.0300 J	0.0690	0.0200 J	0.0300 J	<0.02 U	0.0200 J	-
pH	SU	6.98	7.01	7.35	6.87	6.97	6.76	6.93	6.98	7.12

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. 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 - Landfill**

Parameter	Unit	S-19A								
		6/24/2016	8/8/2016	10/5/2016	1/12/2017	4/17/2017	5/31/2017	6/22/2017	7/27/2017	10/3/2017
		Background								
Antimony	µg/L	<0.02 U	<0.02 U	<0.02 U	<0.02 U	0.0500 J	<0.05 U	<0.03 U	<0.03 U	-
Arsenic	µg/L	1.84	2.46	2.78	2.30	2.15	2.63	2.07	2.19	-
Barium	µg/L	18.2	18.6	15.2	15.7	20.7	19.6	18.7	19.6	-
Beryllium	µg/L	0.0100 J	0.0100 J	0.0100 J	<0.01 U	0.0300 J	0.0200 J	<0.01 U	0.0200 J	-
Boron	mg/L	0.330	0.340	0.378	0.335	0.364	0.331	0.348	0.311	0.388
Cadmium	µg/L	0.0100 J	<0.008 U	<0.008 U	<0.008 U	0.0200 J	<0.02 U	<0.02 U	<0.02 U	-
Calcium	mg/L	419	405	338	373	413	401	407	388	388
Chloride	mg/L	3.64	4.01	6.90	6.32	4.68	4.02	3.97	3.84	3.47
Chromium	µg/L	0.100	0.100	0.100 J	0.162	0.0600 J	0.200 J	0.502	0.485	-
Cobalt	µg/L	0.0950	0.0870	0.463	0.182	0.0990	0.127	0.0500 J	0.0710	-
Combined Radium	pCi/L	1.77	1.24	1.76	1.82	0.572	1.57	0.948	2.26	-
Fluoride	mg/L	0.350	0.360	0.390	0.320	0.330	0.320	0.360	0.290	0.320
Lead	µg/L	0.0410	0.0100 J	0.0890	0.0300 J	0.0600 J	0.106	0.0660	0.0500 J	-
Lithium	mg/L	0.0610	0.0580	0.0610	0.0650	0.0620	0.0600	0.0660	0.0610	-
Mercury	µg/L	<0.002 U	<0.002 U	<0.002 U	<0.002 U	0.00300 J	<0.002 U	<0.002 U	<0.002 U	-
Molybdenum	µg/L	3.49	4.83	7.80	6.77	5.12	6.89	5.35	5.31	-
Selenium	µg/L	<0.06 U	0.0900 J	0.100 J	<0.06 U	<0.1 U	<0.2 U	<0.09 U	<0.09 U	-
Total Dissolved Solids	mg/L	3290	3190	2780	2910	3230	6730	3330	3080	3050
Sulfate	mg/L	2070	1980	1700	1730	2040	2090	2130	2120	1930
Thallium	µg/L	<0.02 U	<0.02 U	<0.02 U	<0.02 U	0.0500 J	<0.05 U	<0.03 U	0.0300 J	-
pH	SU	6.83	6.85	6.85	6.83	6.89	6.64	6.80	6.96	6.97

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. 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 - Landfill**

Parameter	Unit	S-20										
		6/29/2016	8/3/2016	10/6/2016	1/17/2017	4/12/2017	4/19/2017	5/2/2017	5/30/2017	6/21/2017	8/1/2017	9/26/2017
Background											Detection	
Antimony	µg/L	0.130	0.0900 J	0.0600 J	0.0400 J	0.220	-	-	0.0500 J	0.0400 J	<0.02 U	-
Arsenic	µg/L	4.91	4.55	3.11	2.67	2.35	-	-	2.42	2.16	2.06	-
Barium	µg/L	16.5	16.3	16.6	16.1	16.4	-	-	16.1	15.4	14.6	-
Beryllium	µg/L	0.0300	0.0300 J	0.0100 J	0.0100 J	0.0100 J	-	-	0.0100 J	0.0100 J	0.0100 J	-
Boron	mg/L	0.172	0.200	0.220	0.220	0.254	-	-	0.214	0.273	0.294	0.293
Cadmium	µg/L	<0.004 U	<0.008 U	0.0500	<0.004 U	<0.005 U	-	-	<0.01 U	<0.01 U	<0.01 U	-
Calcium	mg/L	345	342	386	344	323	-	-	305	326	322	339
Chloride	mg/L	3.04	2.62	2.72	2.59	-	2.76	2.81	2.84	2.72	2.59	2.53
Chromium	µg/L	5.50	1.00	0.300	0.212	3.50	-	-	2.32	0.508	0.384	-
Cobalt	µg/L	4.51	5.58	6.70	5.77	5.14	-	-	5.40	5.17	5.21	-
Combined Radium	pCi/L	0.504	1.89	1.01	2.05	0.430	-	-	0.861	1.32	4.99	-
Fluoride	mg/L	0.220	0.260	0.250	0.250	-	0.250	0.260	0.230	0.240	0.260	0.260
Lead	µg/L	0.462	0.348	0.375	0.164	0.128	-	-	0.145	0.0890	0.0200 J	-
Lithium	mg/L	0.0540	0.0330	0.0340	0.0360	0.0380	-	-	0.0300	0.0370	0.0390	-
Mercury	µg/L	<0.002 U	<0.002 U	<0.002 U	<0.002 U	0.00300 J	-	-	<0.002 U	<0.002 U	<0.002 U	-
Molybdenum	µg/L	0.910	0.470	1.67	0.500	0.720	-	-	0.900	4.00	1.92	-
Selenium	µg/L	0.200	<0.06 U	0.0600 J	0.0400 J	0.0800 J	-	-	0.200 J	<0.06 U	<0.06 U	-
Total Dissolved Solids	mg/L	1740	2030	2060	2010	-	1920	1940	1840	1960	1900	1950
Sulfate	mg/L	1030	1140	1170	1070	-	1040	1030	1030	1070	1230	1180
Thallium	µg/L	0.0300 J	<0.02 U	<0.02 U	0.0200 J	0.0100 J	-	-	<0.02 U	0.0400 J	<0.02 U	-
pH	SU	6.57	6.58	-	6.64	6.70	7.26	6.64	6.57	6.30	7.94	7.74

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. 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 - Landfill**

Parameter	Unit	SGS-1								
		6/23/2016	8/5/2016	10/20/2016	1/16/2017	5/2/2017	5/24/2017	6/22/2017	7/27/2017	10/4/2017
		Background								
Antimony	µg/L	0.0500 J	0.0400 J	0.0300 J	0.0700 J	0.0300 J	0.0200 J	0.0300 J	0.0200 J	-
Arsenic	µg/L	1.42	1.71	2.47	3.17	2.22	2.16	2.18	2.73	-
Barium	µg/L	34.0	32.3	31.7	38.4	32.9	34.7	33.1	35.1	-
Beryllium	µg/L	<0.01 U	<0.005 U	<0.005 U	<0.02 U	<0.008 U	<0.008 U	<0.008 U	<0.008 U	-
Boron	mg/L	0.989	0.948	1.12	0.853	0.831	0.912	0.877	0.866	0.934
Cadmium	µg/L	<0.008 U	0.00500 J	<0.004 U	0.0200 J	<0.01 U	<0.01 U	<0.01 U	<0.01 U	-
Calcium	mg/L	189	170	156	129	118	126	119	115	110
Chloride	mg/L	28.6	25.5	24.1	23.6	24.3	24.0	24.0	23.8	23.4
Chromium	µg/L	0.200	0.100	0.245	0.200 J	0.100 J	0.223	0.130	0.355	-
Cobalt	µg/L	1.91	1.04	0.885	0.872	0.610	0.516	0.544	0.555	-
Combined Radium	pCi/L	0.778	1.89	1.79	4.04	0.259	1.21	1.04	1.27	-
Fluoride	mg/L	0.420	0.470	0.510	0.570	0.590	0.580	0.570	0.560	0.550
Lead	µg/L	0.0410	0.0200 J	0.00900 J	0.0500 J	0.0100 J	0.0300 J	0.0200 J	0.0200 J	-
Lithium	mg/L	0.0260	0.0270	0.0310	0.0270	0.0260	0.0310	0.0240	0.0290	-
Mercury	µg/L	<0.002 U	<0.002 U	<0.002 U	<0.002 U	<0.002 U	<0.002 U	<0.002 U	<0.002 U	-
Molybdenum	µg/L	10.2	3.16	30.1	15.5	2.07	1.93	2.18	2.11	-
Selenium	µg/L	0.0900 J	0.0700 J	0.0500 J	0.200 J	<0.06 U	0.0600 J	<0.06 U	<0.06 U	-
Total Dissolved Solids	mg/L	1970	1890	1920	1820	1820	1810	1810	1810	1800
Sulfate	mg/L	1030	1010	947	918	916	891	947	959	922
Thallium	µg/L	<0.02 U	0.0400 J	0.0300 J	0.585	0.0200 J	<0.02 U	<0.02 U	<0.02 U	-
pH	SU	6.86	6.98	6.72	7.08	7.44	7.05	7.62	8.86	7.99

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. 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 - Landfill**

Parameter	Unit	SGS-2								
		6/23/2016	8/4/2016	10/20/2016	1/16/2017	5/2/2017	5/24/2017	6/21/2017	7/27/2017	10/4/2017
		Background								
Antimony	µg/L	0.740	0.310	0.130	0.200 J	0.230	0.220	0.150	0.110	-
Arsenic	µg/L	2.65	4.36	8.13	16.5	16.7	26.8	17.1	17.8	-
Barium	µg/L	50.5	49.3	50.9	67.5	63.7	82.7	71.6	78.4	-
Beryllium	µg/L	<0.01 U	<0.005 U	0.00600 J	<0.02 U	<0.008 U	<0.008 U	<0.008 U	<0.008 U	-
Boron	mg/L	0.870	0.869	0.851	0.612	0.655	0.590	0.587	0.612	0.670
Cadmium	µg/L	0.140	0.0400	0.00900 J	<0.02 U	<0.01 U	<0.01 U	<0.01 U	<0.01 U	-
Calcium	mg/L	104	70.3	44.8	23.2	26.0	12.1	16.1	15.1	13.0
Chloride	mg/L	80.9	77.5	63.3	102	70.5	97.7	68.0	111	62.2
Chromium	µg/L	0.300	0.600	0.544	0.423	0.281	0.279	0.264	0.505	-
Cobalt	µg/L	1.04	0.788	0.218	0.155	0.142	0.0970	0.105	0.110	-
Combined Radium	pCi/L	0.799	1.32	1.09	1.34	0.988	1.12	0.563	0.552	-
Fluoride	mg/L	1.60	1.74	2.10	2.01	2.24	2.36	2.42	2.61	2.33
Lead	µg/L	0.131	0.192	0.130	0.164	0.266	0.190	0.184	0.150	-
Lithium	mg/L	0.0440	0.0350	0.0390	0.0340	0.0320	0.0340	0.0300	0.0340	-
Mercury	µg/L	<0.002 U	<0.002 U	<0.002 U	<0.002 U	0.00200 J	0.00400 J	0.00300 J	0.00300 J	-
Molybdenum	µg/L	31.1	22.8	15.5	3.82	5.31	1.82	7.18	7.28	-
Selenium	µg/L	0.800	0.200	0.0900 J	<0.1 U	0.100 J	0.100 J	0.0800 J	0.0900 J	-
Total Dissolved Solids	mg/L	2050	1980	1790	1960	1830	1820	1740	1750	1700
Sulfate	mg/L	832	799	491	365	344	127	201	73.2	131
Thallium	µg/L	0.0300 J	0.0550	0.0200 J	<0.04 U	<0.02 U	<0.02 U	<0.02 U	<0.02 U	-
pH	SU	7.41	7.91	7.87	7.91	7.89	8.17	8.15	8.84	8.28

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. 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 - Landfill**

Parameter	Unit	SGS-3								
		6/27/2016	8/3/2016	10/7/2016	1/10/2017	4/17/2017	5/30/2017	6/22/2017	7/27/2017	10/3/2017
		Background								
Antimony	µg/L	0.630	0.320	0.310	0.530	0.240	0.740	0.100 J	0.110	-
Arsenic	µg/L	1.11	1.27	2.04	3.61	2.69	3.48	3.14	3.11	-
Barium	µg/L	74.3	104	189	253	156	208	155	152	-
Beryllium	µg/L	0.0200 J	0.0100 J	0.0720	0.204	0.00800 J	0.0900	<0.01 U	<0.008 U	-
Boron	mg/L	0.209	0.236	0.452	0.290	0.283	0.299	0.306	0.283	0.302
Cadmium	µg/L	0.00800 J	0.00800 J	0.00700 J	0.0400	0.00600 J	0.110	<0.02 U	0.0100 J	-
Calcium	mg/L	16.4	15.0	9.98	24.6	6.04	12.2	4.98	4.96	4.82
Chloride	mg/L	149	248	279	297	313	346	311	298	314
Chromium	µg/L	0.800	1.50	1.00	6.64	0.293	3.23	0.223	0.400	-
Cobalt	µg/L	0.702	1.09	0.644	3.06	0.400	1.95	0.325	0.335	-
Combined Radium	pCi/L	0.237	1.66	1.67	0.448	0.506	1.29	0.637	0.672	-
Fluoride	mg/L	1.18	0.730	2.02	1.74	1.81	1.92	2.04	1.91	2.04
Lead	µg/L	0.358	0.382	0.710	5.13	0.279	3.43	0.150	0.184	-
Lithium	mg/L	0.0470	0.0220	1.96	0.0320	0.0200	0.0200	0.0270	0.0250	-
Mercury	µg/L	<0.002 U	<0.002 U	<0.002 U	<0.002 U	0.00200 J	<0.002 U	<0.002 U	<0.002 U	-
Molybdenum	µg/L	24.2	30.2	12.6	11.6	12.2	13.4	12.6	10.6	-
Selenium	µg/L	0.300	0.200	0.300	0.700	<0.03 U	0.200	<0.09 U	<0.06 U	-
Total Dissolved Solids	mg/L	1570	1550	1600	1690	-	1730	3390	1700	1630
Sulfate	mg/L	494	56.2	100	93.2	63.6	83.4	103	126	118
Thallium	µg/L	0.0200 J	0.0660	0.0100 J	0.0600	<0.01 U	0.0500 J	<0.03 U	0.0500 J	-
pH	SU	7.90	8.21	8.22	8.06	7.94	7.83	7.90	7.86	8.09

Notes:

µg/L: micrograms per liter

mg/L: milligrams per liter

pCi/L: picocuries per liter

SU: standard unit

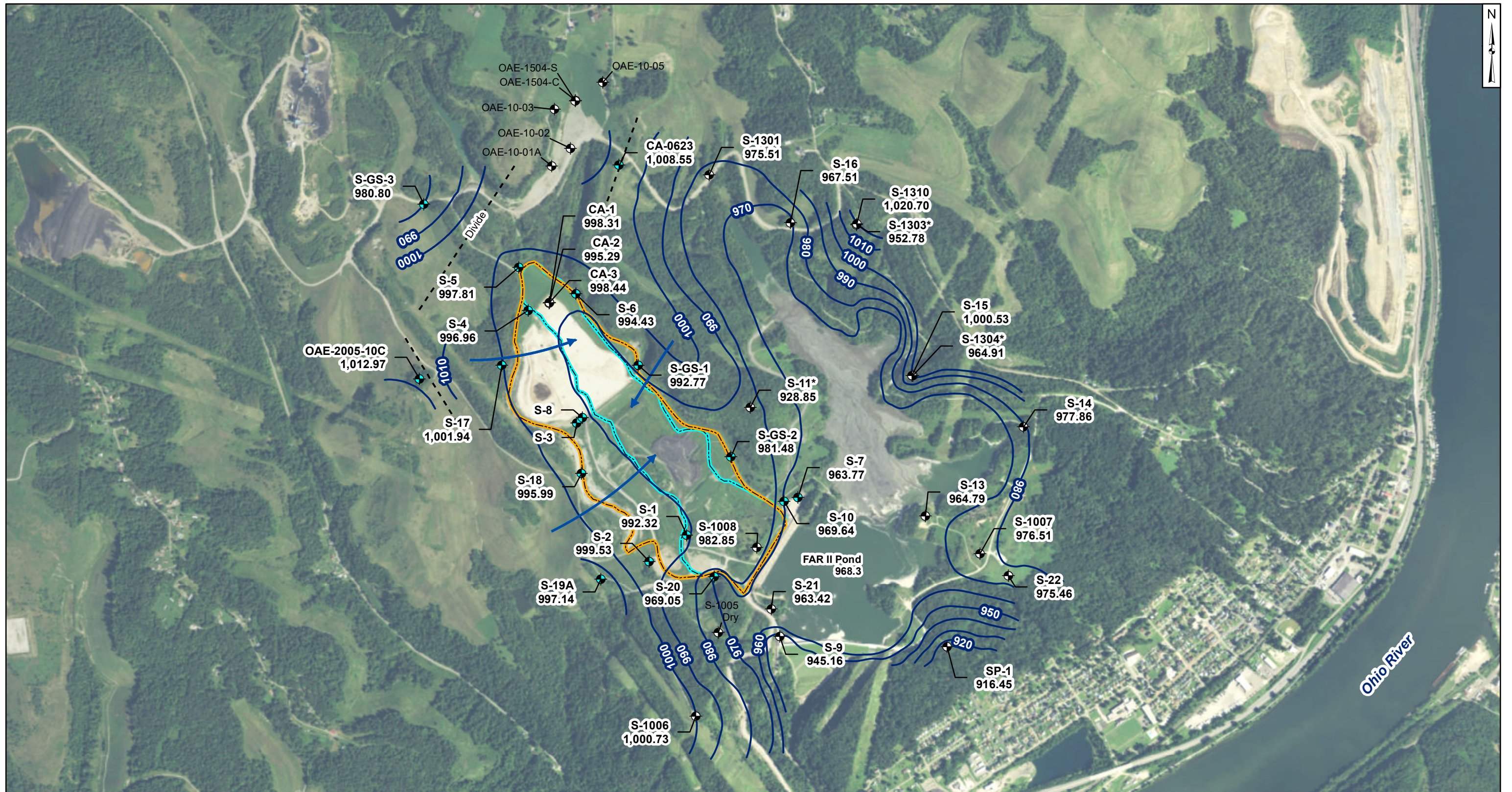
U: Non-detect value. Parameters which were not detected are shown as less than the method detection limit (MDL).

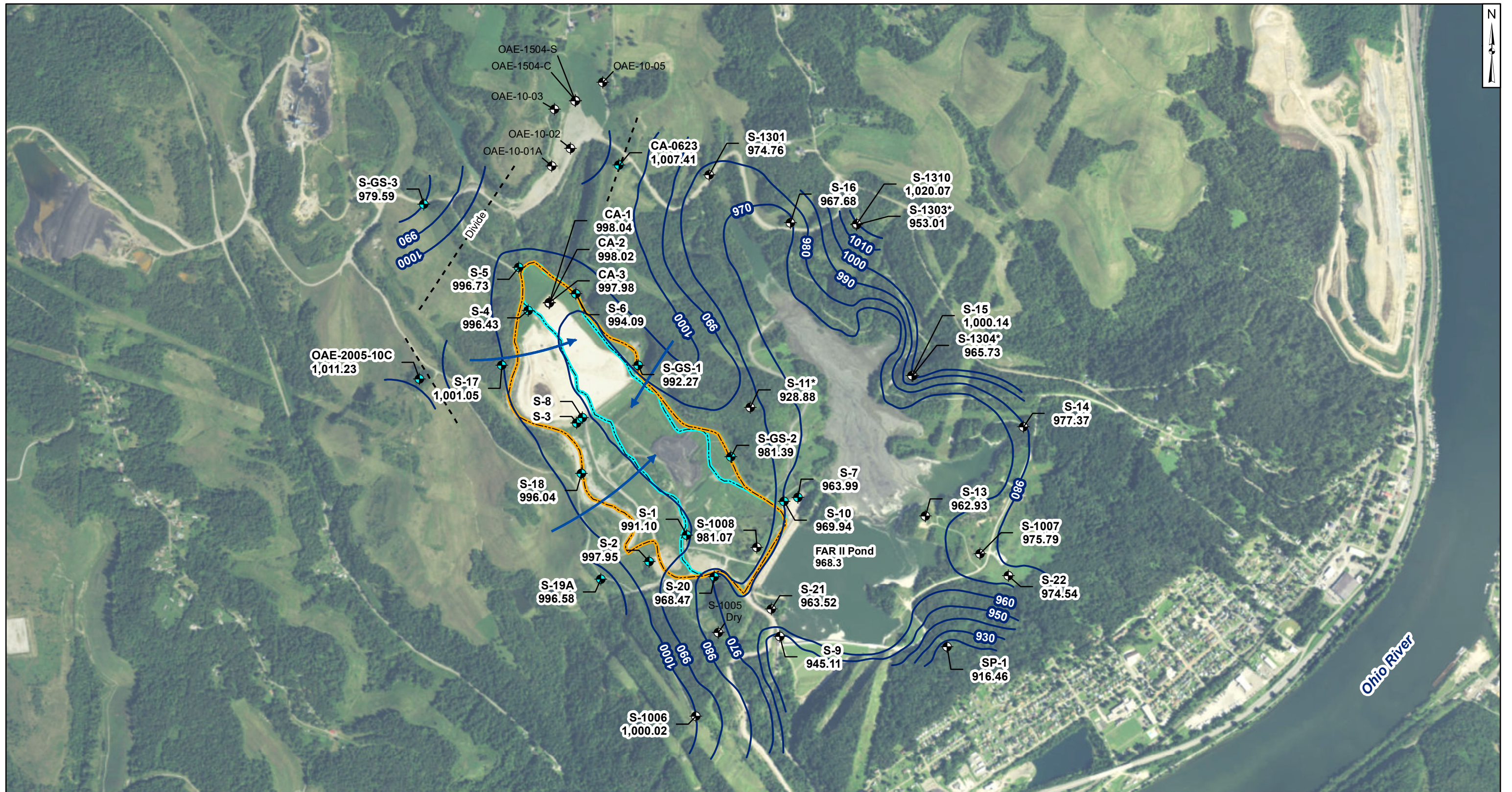
J: Estimated value. Parameter was detected in concentrations below the reporting limit.

-: Not sampled

For statistical analysis, parameters which were not detected were replaced with the reporting limit.

Groundwater Flow Direction Maps

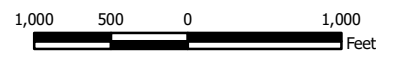




- Legend**
- FAR I Network Monitoring Well
 - State/Other Program Monitoring Well
 - Approximate Groundwater Flow Direction
 - Groundwater Elevation Contour
 - Residual Solid Waste (RSW) Landfill
 - Former Fly Ash Reservoir (FAR) I

Notes

- Monitoring well coordinates and water level data (collected between August 1 and August 2, 2016) provided by AEP.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Former Fly Ash Reservoir I - Residual Solid Waste Landfill (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.
- CA-1, CA-2, CA-3, and S-1008 are screened in CCR material.
- * Wells not used for contouring due to inconsistent and/or anomalous readings.



**Potentiometric Surface Map - Shallow Water Table
Former FAR I & RSW Landfill
August 2016**

AEP Cardinal Generating Plant
Brilliant, Ohio

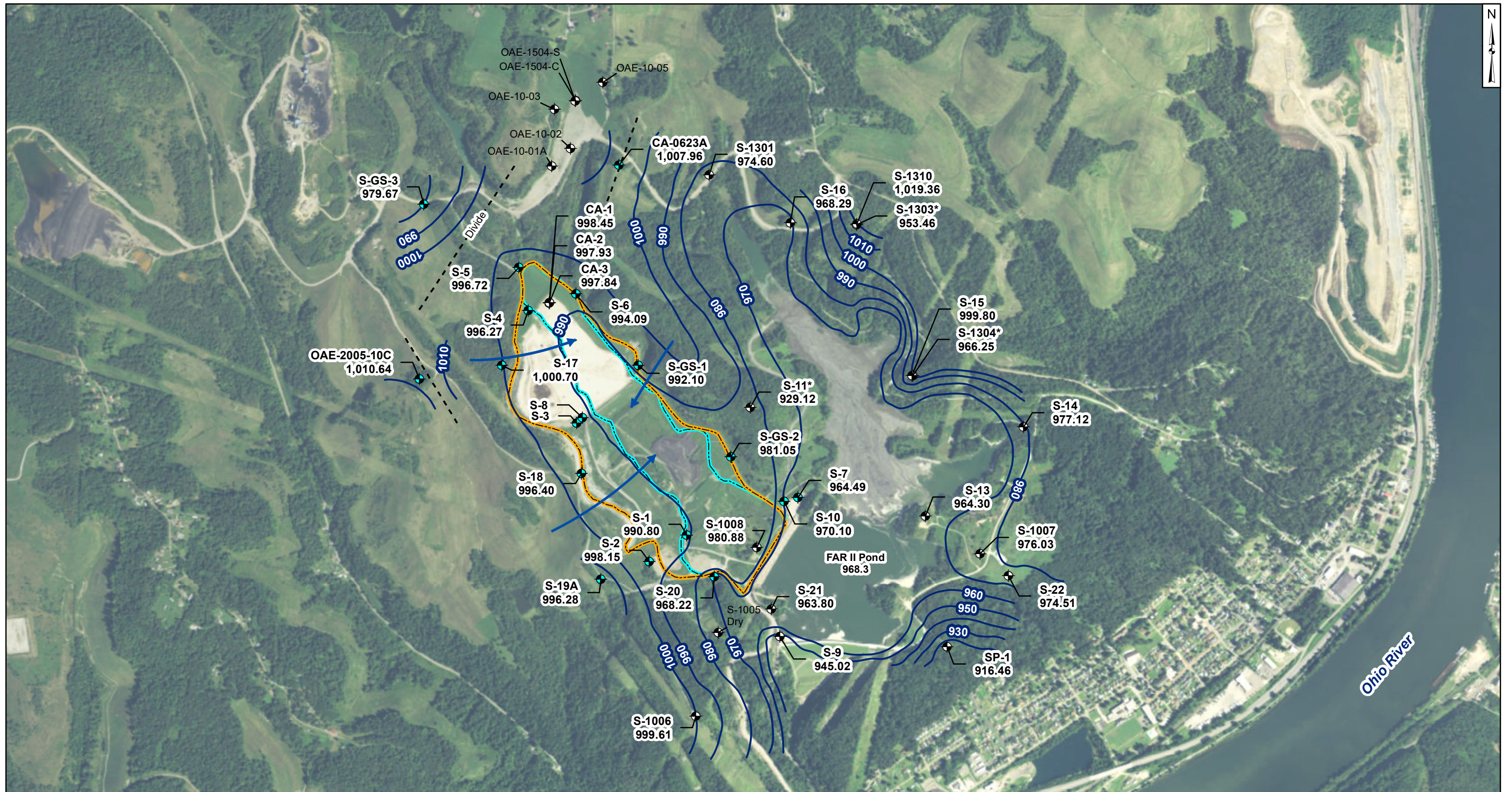
Geosyntec
consultants

Columbus, Ohio

2017/08/18

Figure

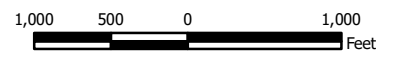
2



- Legend**
- FAR I Network Monitoring Well
 - State/Other Program Monitoring Well
 - Approximate Groundwater Flow Direction
 - Groundwater Elevation Contour
 - Residual Solid Waste (RSW) Landfill
 - Former Fly Ash Reservoir (FAR) I

Notes

- Monitoring well coordinates and water level data (collected between October 3 and October 4, 2016) provided by AEP.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Former Fly Ash Reservoir I - Residual Solid Waste Landfill (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.
- CA-1, CA-2, CA-3, and S-1008 are screened in CCR material.
- * Wells not used for contouring due to inconsistent and/or anomalous readings.
- CA-0623 was replaced by CA-0623A on 8/16/2016



**Potentiometric Surface Map - Shallow Water Table
Former FAR I & RSW Landfill
October 2016**

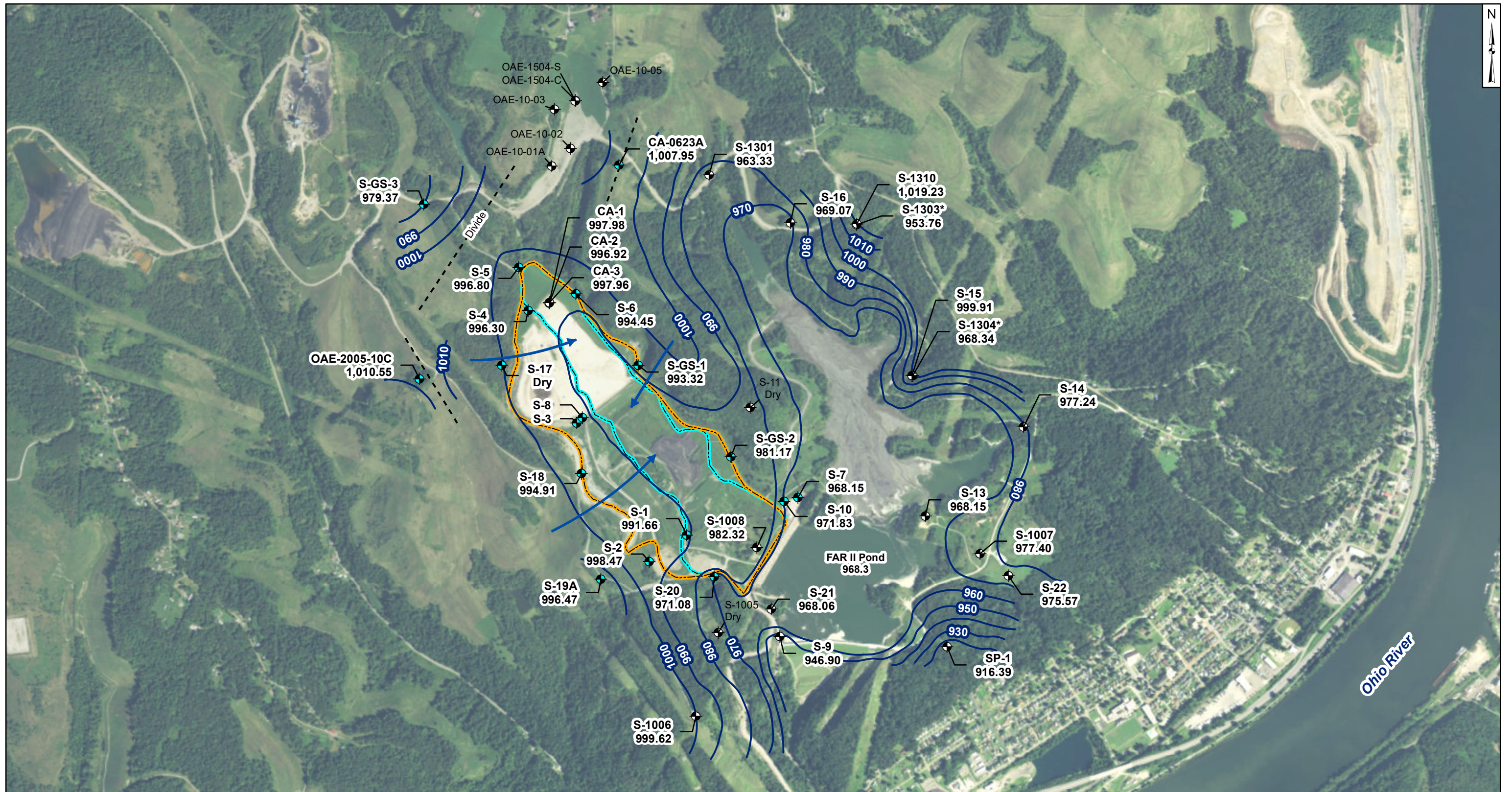
AEP Cardinal Generating Plant
Brilliant, Ohio



Columbus, Ohio

2017/08/24

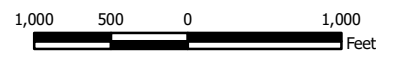
Figure
3



- Legend**
- FAR I Network Monitoring Well
 - State/Other Program Monitoring Well
 - Approximate Groundwater Flow Direction
 - Groundwater Elevation Contour
 - Residual Solid Waste (RSW) Landfill
 - Former Fly Ash Reservoir (FAR) I

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 - Former Fly Ash Reservoir I - Residual Solid Waste Landfill (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.
- CA-1, CA-2, CA-3, and S-1008 are screened in CCR material.
- * Wells not used for contouring due to inconsistent and/or anomalous readings.



**Potentiometric Surface Map - Shallow Water Table
Former FAR I & RSW Landfill
November 2016**

AEP Cardinal Generating Plant
Brilliant, Ohio

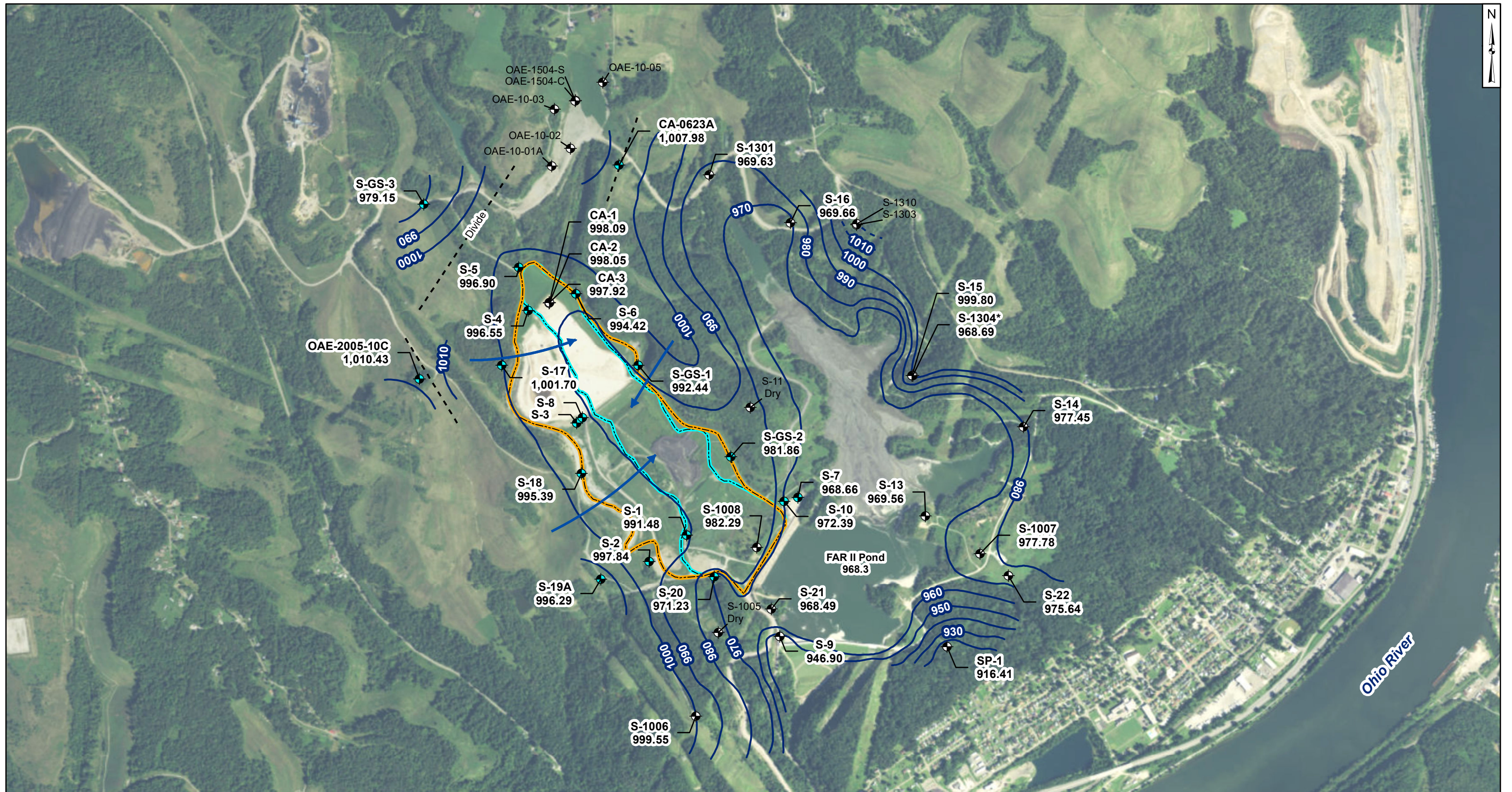


Columbus, Ohio

2017/08/24

Figure

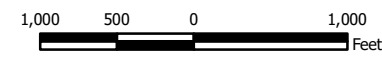
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- Legend**
- FAR I Network Monitoring Well
 - State/Other Program Monitoring Well
 - Groundwater Elevation Contour
 - Inferred Groundwater Elevation Contour
 - Approximate Groundwater Flow Direction
 - Residual Solid Waste (RSW) Landfill
 - Former Fly Ash Reservoir (FAR) I

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 - Former Fly Ash Reservoir I - Residual Solid Waste Landfill (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.
- CA-1, CA-2, CA-3, and S-1008 are screened in CCR material.
- * Wells not used for contouring due to inconsistent and/or anomalous readings.
- S-1310 not measured; contours inferred from previous events.



**Potentiometric Surface Map - Shallow Water Table
Former FAR I & RSW Landfill
December 2016**

AEP Cardinal Generating Plant
Brilliant, Ohio

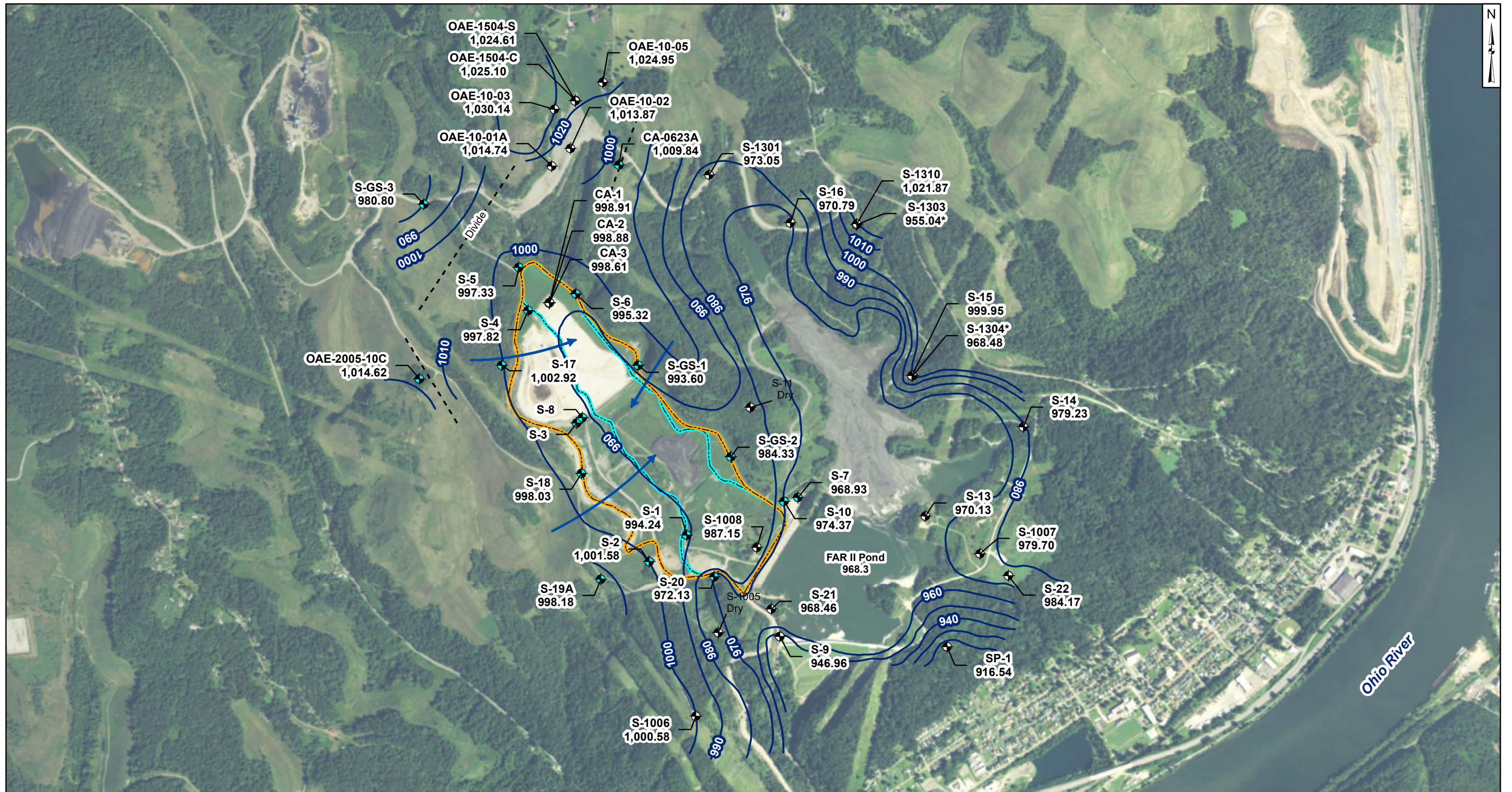
Geosyntec
consultants

Columbus, Ohio

2017/08/24

Figure

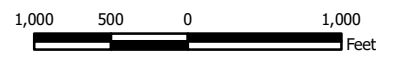
5



- Legend**
- FAR I Network Monitoring Well
 - State/Other Program Monitoring Well
 - Groundwater Elevation Contour
 - Inferred Groundwater Elevation Contour
 - Approximate Groundwater Flow Direction
 - Residual Solid Waste (RSW) Landfill
 - Former Fly Ash Reservoir (FAR) I

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 - Former Fly Ash Reservoir I - Residual Solid Waste Landfill (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.
- CA-1, CA-2, CA-3, and S-1008 are screened in CCR material.
- * Wells not used for contouring due to inconsistent and/or anomalous readings.



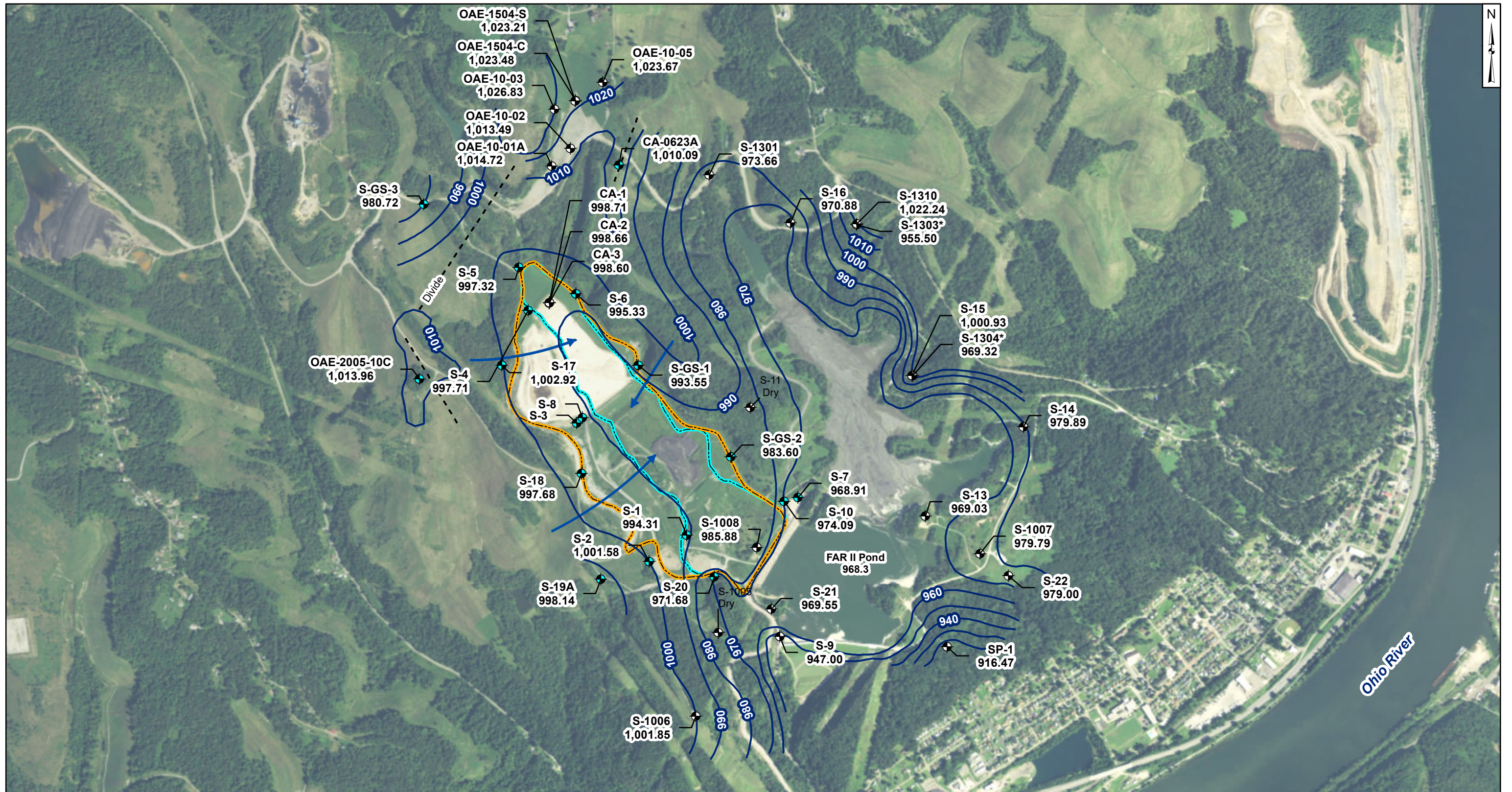
**Potentiometric Surface Map - Shallow Water Table
Former FAR I & RSW Landfill
April 2017**

AEP Cardinal Generating Plant
Brilliant, Ohio



Columbus, Ohio 2017/08/24

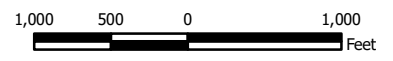
Figure
7



- Legend**
- FAR I Network Monitoring Well
 - State/Other Program Monitoring Well
 - Groundwater Elevation Contour
 - Inferred Groundwater Elevation Contour
 - Approximate Groundwater Flow Direction
 - Residual Solid Waste (RSW) Landfill
 - Former Fly Ash Reservoir (FAR) I

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 - Former Fly Ash Reservoir I - Residual Solid Waste Landfill (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.
- CA-1, CA-2, CA-3, and S-1008 are screened in CCR material.
- * Wells not used for contouring due to inconsistent and/or anomalous readings.



**Potentiometric Surface Map - Shallow Water Table
Former FAR I & RSW Landfill
May 2017**

AEP Cardinal Generating Plant
Brilliant, Ohio

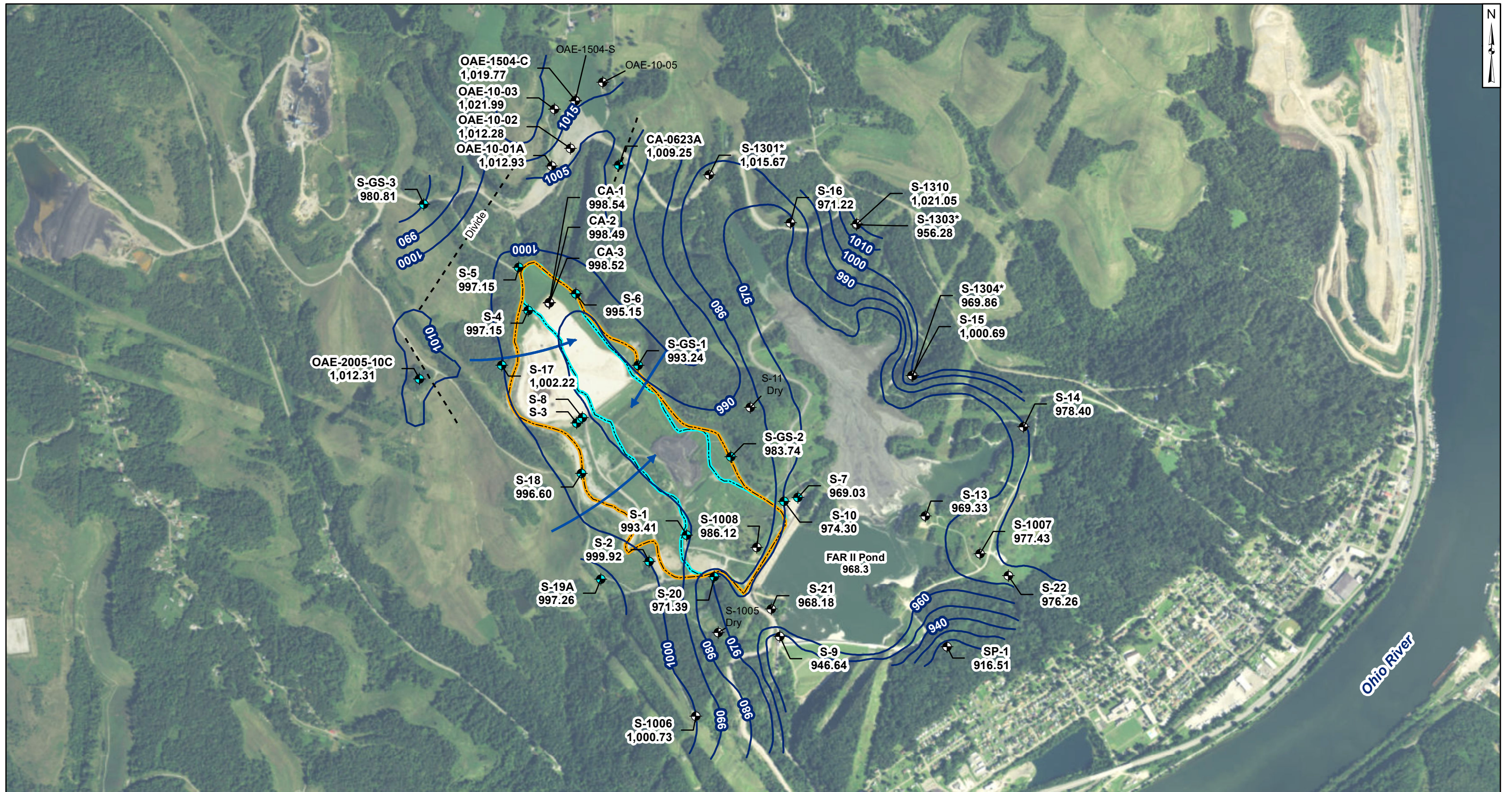


Columbus, Ohio

2017/08/24

Figure

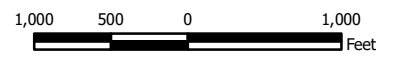
8



- Legend**
- FAR I Network Monitoring Well
 - State/Other Program Monitoring Well
 - Groundwater Elevation Contour
 - Inferred Groundwater Elevation Contour
 - Approximate Groundwater Flow Direction
 - Residual Solid Waste (RSW) Landfill
 - Former Fly Ash Reservoir (FAR) I

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 - Former Fly Ash Reservoir I - Residual Solid Waste Landfill (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.
- CA-1, CA-2, CA-3, and S-1008 are screened in CCR material.
- * Wells not used for contouring due to inconsistent and/or anomalous readings.



**Potentiometric Surface Map - Shallow Water Table
Former FAR I & RSW Landfill
June 2017**

AEP Cardinal Generating Plant
Brilliant, Ohio

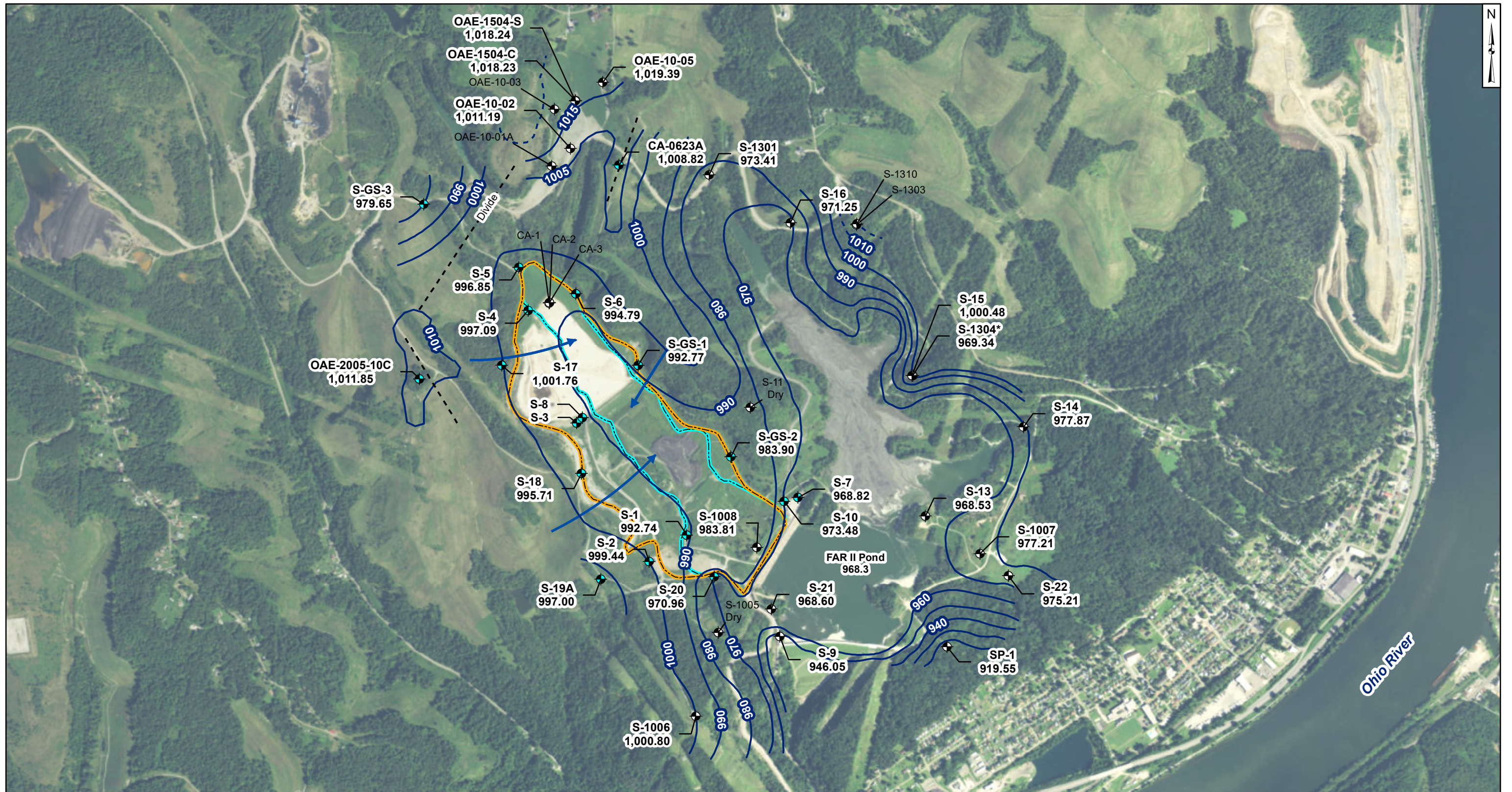


Columbus, Ohio

2017/08/24

Figure

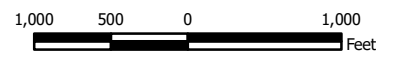
9



- Legend**
- FAR I Network Monitoring Well
 - State/Other Program Monitoring Well
 - Groundwater Elevation Contour
 - Inferred Groundwater Elevation Contour
 - Approximate Groundwater Flow Direction
 - Residual Solid Waste (RSW) Landfill
 - Former Fly Ash Reservoir (FAR) I

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 - Former Fly Ash Reservoir I - Residual Solid Waste Landfill (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.
- CA-1, CA-2, CA-3, and S-1008 are screened in CCR material.
- * Wells not used for contouring due to inconsistent and/or anomolous readings.
- S-1310 and OAE-10-3 not measured; contours inferred from previous events.



**Potentiometric Surface Map - Shallow Water Table
Former FAR I & RSW Landfill
July 2017**

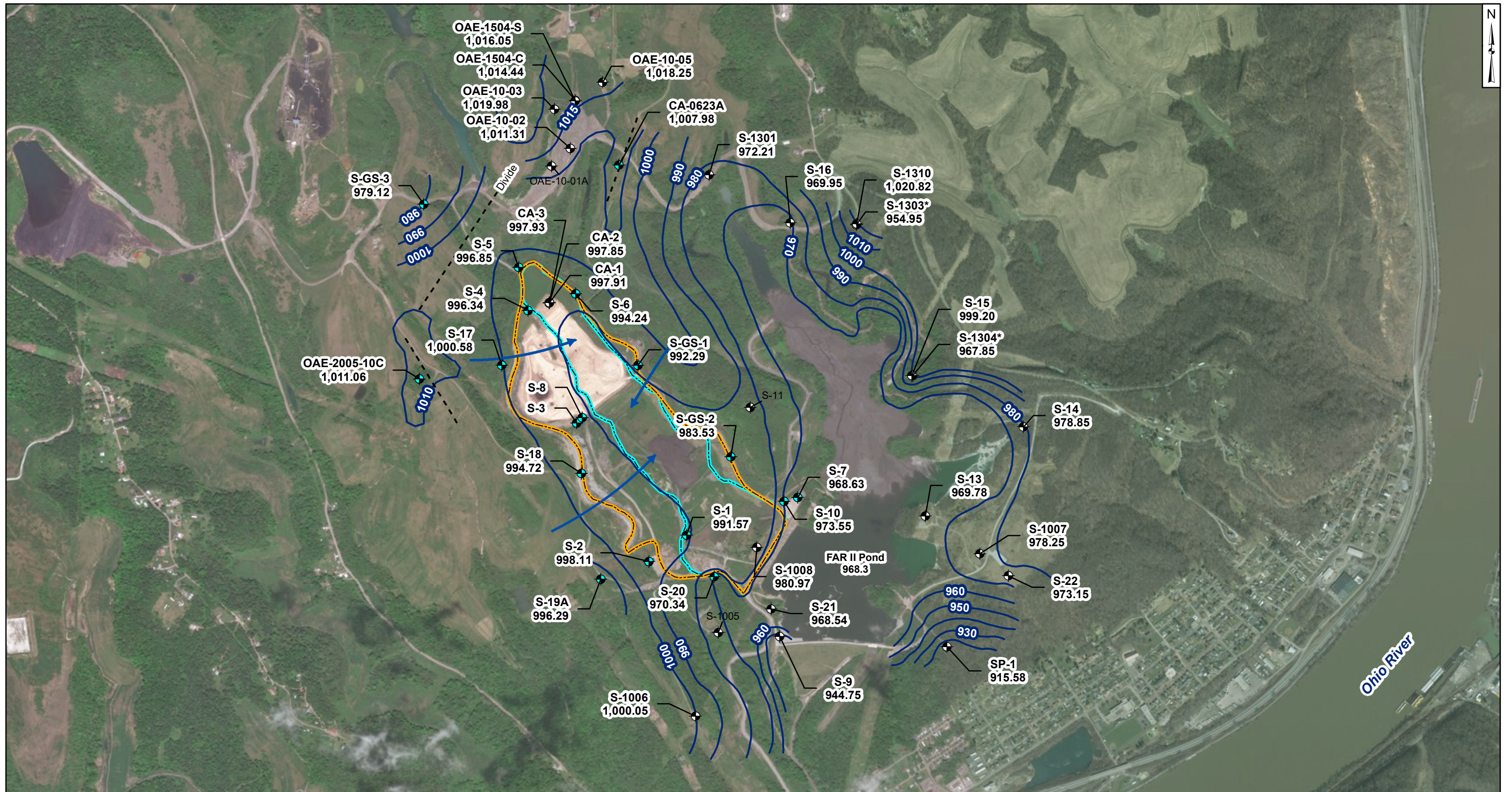
AEP Cardinal Generating Plant
Brilliant, Ohio



Columbus, Ohio

2017/08/24

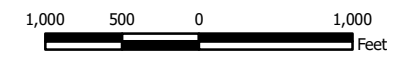
Figure
10



- Legend**
- FAR I Network Monitoring Well
 - State/Other Program Monitoring Well
 - Groundwater Elevation Contour
 - Inferred Groundwater Elevation Contour
 - Approximate Groundwater Flow Direction
 - Residual Solid Waste (RSW) Landfill
 - Former Fly Ash Reservoir (FAR) I

Notes

- Monitoring well coordinates and water level data (collected on October 1, 2017) provided by AEP.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Former Fly Ash Reservoir I - Residual Solid Waste Landfill (Geosyntec, 2016) provided by AEP.
- Groundwater elevation units are feet above mean sea level.
- * Wells not used for contouring due to inconsistent/anomalous readings.



**Potentiometric Surface Map - Shallow Water Table
Former FAR I & RSW Landfill
October 2017**

AEP Cardinal Generating Plant
Brilliant, Ohio

Geosyntec
consultants

Columbus, Ohio

2018/01/29

Figure

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Groundwater Flow Velocity Calculations

**Table 1: Residence Time Calculation Summary
Cardinal Plant - Landfill**

CCR Management Unit	Monitoring Well	Well Diameter (inches)	2016-06		2016-08		2016-10		2016-11		2016-12	
			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)
Residual Solid Waste Landfill	OAE-2005-10C ^[1]	2.0	7.3	8.3	3.0	20.0	1.6	38.5	1.4	44.8	1.1	57.3
	CA-0623A ^[1]	2.0	8.5	7.1	7.4	8.2	7.9	7.7	7.9	7.7	7.9	7.7
	S-1 ^[2]	1.25	10.2	3.7	4.8	7.9	3.5	10.9	7.3	5.2	6.5	5.9
	S-10 ^[2]	2.0	28.4	2.1	27.5	2.2	27.1	2.2	22.4	2.7	20.8	2.9
	S-17 ^[1]	2.0	4.9	12.5	4.5	13.5	4.4	14.0	NC	NC	4.8	12.8
	S-18 ^[2]	2.0	3.5	17.5	3.5	17.3	3.7	16.4	2.9	21.3	3.1	19.4
	S-19 ^[2]	2.0	7.0	8.7	8.4	7.3	9.1	6.7	8.7	7.0	9.1	6.7
	S-2 ^[2]	1.25	11.4	3.3	9.5	4.0	9.8	3.9	10.2	3.7	9.4	4.0
	S-20 ^[2]	2.0	21.2	2.9	19.9	3.1	19.3	3.2	26.0	2.3	26.3	2.3
	S-4 ^[1]	1.0	4.9	6.2	4.5	6.7	4.4	6.9	4.4	6.9	4.6	6.6
	S-5 ^[1]	1.0	19.0	1.6	16.4	1.9	16.3	1.9	16.5	1.8	16.8	1.8
	S-6 ^[1]	1.0	5.7	5.4	5.2	5.8	5.2	5.8	5.7	5.3	5.7	5.4
	S-7 ^[2]	1.0	10.3	3.0	9.9	3.1	9.1	3.3	3.1	10.0	2.2	13.8
	S-GS-1 ^[2]	2.0	6.4	9.5	6.9	8.9	7.0	8.7	5.9	10.3	6.7	9.1
S-GS-2 ^[2]	2.0	4.4	14.0	4.4	13.8	4.6	13.3	4.5	13.5	4.2	14.6	
S-GS-3 ^[1]	2.0	12.4	4.9	14.1	4.3	14.0	4.4	14.4	4.2	14.7	4.1	

CCR Management Unit	Monitoring Well	Well Diameter (inches)	2017-01		2017-04		2017-05		2017-06		2017-07		2017-10	
			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)
Residual Solid Waste Landfill	OAE-2005-10C ^[1]	2.0	5.4	11.3	11.9	5.1	7.9	7.7	4.6	13.2	3.7	16.5	2.0	30.4
	CA-0623A ^[1]	2.0	8.6	7.1	9.6	6.3	9.6	6.3	8.8	6.9	8.4	7.2	7.8	7.8
	S-1 ^[2]	1.25	4.2	9.2	4.6	8.2	4.4	8.6	4.1	9.2	3.9	9.7	3.6	10.5
	S-10 ^[2]	2.0	17.6	3.5	15.4	3.9	16.2	3.8	15.6	3.9	17.8	3.4	15.7	3.9
	S-17 ^[1]	2.0	4.9	12.5	5.1	11.9	5.3	11.4	5.0	12.1	4.8	12.6	4.3	14.2
	S-18 ^[2]	2.0	3.7	16.7	4.5	13.4	4.5	13.6	3.8	15.9	3.3	18.3	2.8	21.7
	S-19 ^[2]	2.0	6.7	9.1	4.3	14.0	3.8	15.8	5.7	10.7	6.2	9.8	9.4	6.5
	S-2 ^[2]	1.25	7.3	5.2	8.2	4.7	8.7	4.4	7.4	5.1	7.1	5.4	10.1	3.8
	S-20 ^[2]	2.0	4.0	15.0	4.2	14.6	4.1	14.8	4.0	15.2	3.9	15.8	3.4	17.7
	S-4 ^[1]	1.0	4.6	6.6	5.0	6.0	5.5	5.5	5.1	6.0	5.0	6.0	1.3	23.2
	S-5 ^[1]	1.0	2.4	12.6	2.5	12.2	2.7	11.1	2.7	11.4	2.6	11.9	2.4	12.7
	S-6 ^[1]	1.0	5.3	5.8	7.8	3.9	8.3	3.7	8.0	3.8	7.5	4.1	5.5	5.5
	S-7 ^[2]	1.0	1.6	19.6	1.6	19.4	1.5	20.3	1.5	20.1	1.5	20.5	16.5	1.8
	S-GS-1 ^[2]	2.0	6.1	9.9	5.7	10.7	5.3	11.5	5.5	11.0	5.9	10.3	6.5	9.4
S-GS-2 ^[2]	2.0	3.7	16.4	2.8	21.6	3.2	19.1	3.1	19.5	3.0	20.0	3.2	18.7	
S-GS-3 ^[1]	2.0	14.6	4.2	13.0	4.7	12.0	5.1	11.8	5.1	13.3	4.6	14.3	4.3	

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

APPENDIX II

Not applicable at this time.