Luminant

Dynegy Midwest Generation, LLC
1500 Eastport Plaza Dr.
Collinsville, IL 62234

August 28, 2023

Illinois Environmental Protection Agency
DWPC – Permits MC #15
Attn: Part 845 Coal Combustion Residual Rule Submittal
1021 North Grand Avenue East
P.O. Box 19276
Springfield, IL 62794-9276

Re: Baldwin Power Plant Fly Ash Pond System; IEPA ID W1578510001-01,02,03

Dear Mr. LeCrone:

In accordance with 35 I.A.C. § 845.200, Dynegy Midwest Generation, LLC (DMG) is submitting an amendment to the operating permit application for the Baldwin Power Plant Fly Ash Pond System (IEPA ID W1578510001-01,02,03).

DMG is hereby providing updates to the groundwater monitoring program originally submitted with the operating permit application on October 25, 2021. The modifications include updates to the following documents submitted with the operating permit application:

- Groundwater Monitoring Plan (Replaces Operating Permit Application Attachment I)

Sincerely,

Phil Morris
Sr. Director – Environmental Compliance

Enclosures

Intended for
Dynegy Midwest Generation, LLC

Date
August 25, 2023

Project No.
1940103649-002

GROUNDWATER MONITORING PLAN REVISION 1

FLY ASH POND SYSTEM
BALDWIN POWER PLANT
BALDWIN, ILLINOIS

Bright ideas. Sustainable change.

GROUNDWATER MONITORING PLAN REVISION 1
BALDWIN POWER PLANT FLY ASH POND SYSTEM

Project name	**Baldwin Power Plant Fly Ash Pond System**
Project no.	**1940103649-002**
Recipient	**Dynegy Midwest Generation, LLC**
Document type	**Groundwater Monitoring Plan**
Revision	**DRAFT Revision 1**
Date	**August 25, 2023**

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Senior Managing Engineer

Evvan G. Plank
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LICENSED PROFESSIONAL CERTIFICATIONS

35 I.A.C. § 845.630 Groundwater Monitoring Systems (PE)

I, Eric J. Tlachac, a qualified professional engineer in good standing in the State of Illinois, certify that the groundwater monitoring system described in this document (Groundwater Monitoring Plan Revision 1, Baldwin Power Plant Fly Ash Pond System), meets the intent of 35 I.A.C. § 845.630. The monitoring system was developed based on information included in the Illinois Environmental Protection Agency (IEPA)-approved Hydrogeologic Site Characterization Report submitted with the IEPA-approved Closure and Post-Closure Care Plan and the Hydrogeologic Site Characterization Report Revision 1 for the Baldwin Bottom Ash Pond (Ramboll, 2023).

Eric J. Tlachac
Qualified Professional Engineer
062-063091
Illinois
Date: August 25, 2023

35 I.A.C. § 845.630 Groundwater Monitoring Systems (PG)

I, Brian G. Hennings, a qualified professional geologist in good standing in the State of Illinois, certify that the groundwater monitoring system described in this document (Groundwater Monitoring Plan Revision 1, Baldwin Power Plant Fly Ash Pond System), meets the intent of 35 I.A.C. § 845.630. The monitoring system was developed based on information included in the IEPA-approved Hydrogeologic Site Characterization Report submitted with the IEPA-approved Closure and Post Closure Care Plan and the Hydrogeologic Site Characterization Report Revision 1 for the Baldwin Bottom Ash Pond (Ramboll, 2023).

Brian G. Hennings
Professional Geologist
196.001482
Illinois
Date: August 25, 2023

CONTENTS

TABLES (IN TEXT)

TABLES (ATTACHED)

FIGURES (ATTACHED)

APPENDICES

ACRONYMS AND ABBREVIATIONS

35 I.A.C.	Title 35 of the Illinois Administrative Code
40 C.F.R.	Title 40 of the Code of Federal Regulations
ASD	Alternate Source Demonstration
BAP	Bottom Ash Pond
bgs	below ground surface
BPP	Baldwin Power Plant
CCA	compliance commitment agreement
CCR	coal combustion residuals
Closure Plan	*Baldwin Fly Ash Pond System Closure Plan, Post-Closure Plan* (AECOM, 2016)
cm/s	centimeters per second
DMG	Dynegy Midwest Generation, LLC
FAPS	Fly Ash Pond System
GMP	Groundwater Monitoring Plan Revision 1
GWPS	groundwater protection standard
HCR	Hydrogeologic Site Characterization Report Revision 1
ID	identification
IEPA	Illinois Environmental Protection Agency
LCL	lower confidence limit
mp	measuring point
NID	National Inventory of Dams
No.	number
NPDES	National Pollution Discharge Elimination System
NRT	Natural Resource Technology, Inc.
PMP	potential migration pathway
QAPP	Multi-Site Quality Assurance Project Plan
QA/QC	quality assurance/quality control
Ramboll	Ramboll Americas Engineering Solutions, Inc.
RL	reporting limit
SAP	Multi-Site Sampling and Analysis Plan
SI	Surface Impoundment
TDS	total dissolved solids
UA	uppermost aquifer
UGU	Upper Groundwater Unit
UU	upper unit
USEPA	United States Environmental Protection Agency

REVISION SUMMARY

Revision Date	Description of Changes (Section title or number – description)
08/25/2023	The 35 I.A.C. § 845 groundwater monitoring network was revised and expanded concurrent with revisions to the 40 C.F.R. § 257 monitoring system.

1. INTRODUCTION

1.1 Overview

In accordance with requirements of Title 35 of the Illinois Administrative Code (35 I.A.C.) § 845, Standards for the Disposal of Coal Combustion Residuals in Surface Impoundments (SI), Ramboll Americas Engineering Solutions, Inc. (Ramboll) has prepared this Groundwater Monitoring Plan Revision 1 (GMP) on behalf of Baldwin Power Plant (BPP) (**Figure 1-1**), operated by Dynegy Midwest Generation, LLC (DMG). This report applies specifically to the coal combustion residuals (CCR) Multi-Unit referred to as the Fly Ash Pond System (FAPS; CCR unit identification [ID] number [No.] 605 and National Inventory of Dams [NID] No. IL50723). The FAPS consists of three CCR SIs including the Old East Fly Ash Pond System (Illinois Environmental Protection Agency [IEPA] ID No. W1578510001-01), the East Fly Ash Pond (IEPA ID No. W1578510001-02), and the West Fly Ash Pond (IEPA ID No. W1578510001-03) (**Figure 1-2**). The FAPS is a closed, unlined CCR Multi-Unit that was previously used to manage CCR and non-CCR waste streams at the BPP. This GMP includes 35 I.A.C. § 845 content requirements specific to 35 I.A.C. § 845.630 (Groundwater Monitoring System), 35 I.A.C. § 845.640 (Groundwater Sampling and Analysis), and 35 I.A.C. § 845.650 (Groundwater Monitoring Program) for the FAPS at BPP.

AECOM submitted the *Closure and Post-Closure Care Plan for the Baldwin Fly Ash Pond System* (Closure Plan) dated March 2016, which was approved by the IEPA on August 16, 2016. The Closure Plan included the Groundwater Monitoring Plan (Natural Resource Technology, Inc. [NRT], 2016) which defined groundwater monitoring for the FAPS following approval of the Closure Plan. Closure of the FAPS was completed on November 17, 2020.

A checklist which identifies the specific requirements of 35 I.A.C. § 845.630, 35 I.A.C. § 845.640, and 35 I.A.C. § 845.650 is included in **Table 1-1**. The table provides references to sections, tables, and figures included in this document to locate the information that meets specific requirements of 35 I.A.C. § 845.630, 35 I.A.C. § 845.640, and 35 I.A.C. § 845.650.

1.2 Site Location and Background

The BPP is located in southwest Illinois in Randolph and St. Clair Counties. The Randolph County portion of the BPP is located within Sections 2, 3, 4, 9, 10, 11, 14, 15, and 16 of Township 4 South and Range 7 West. The St. Clair County portion of the property is located within Sections 33, 34, and 35 of Township 3 South and Range 7 West. The FAPS is approximately one-half mile west-northwest of the Village of Baldwin (**Figure 1-1**).

The BPP property is bordered to the west by the Kaskaskia River; to the east by Baldwin Road, farmland, and strip-mining areas; to the southeast by the village of Baldwin; to the south by the Illinois Central Gulf railroad tracks, scattered residences, and State Route 154; and to the north by farmland. The St. Clair/Randolph County Line crosses east-west at approximately the midpoint of Baldwin Lake (*i.e.,* Cooling Pond). **Figure 1-1** shows the location of the BPP; **Figure 1-2** is a site map showing the location of the FAPS (a 35 I.A.C. § 845 regulated CCR Unit and the subject of this GMP), Bottom Ash Pond (BAP), Secondary Pond, Tertiary Pond, and Cooling Pond. Information regarding the BAP, Secondary Pond, Tertiary Pond, and Cooling Pond is solely for background information, as this GMP applies specifically to the FAPS CCR unit, which will hereinafter be referred to as the Site.

1.3 Conceptual Model

Multiple site investigations have been completed at the BPP to characterize the geology, hydrogeology, and groundwater quality as required by Title 40 of the Code of Federal Regulations (40 C.F.R.) § 257.91 (Groundwater Monitoring Systems). The FAPS has been well characterized, as detailed in the Hydrogeologic Site Characterization Report submitted with the IEPA approved Closure and Post Closure Care Plan and Hydrogeologic Site Characterization Report Revision 1 (HCR [Ramboll, 2023]) that was included with the 35 I.A.C. § 845 Construction Permit application for closure of the BAP. Revision 1 of the HCR was prepared to comply with the requirements specified in 35 I.A.C. § 845.620 and expands upon a similar document included with the Operating Permit application for the BAP submitted to the IEPA in 2021 as well as the Hydrogeologic Monitoring Plan (Natural Resource Technology, an OBG Company [NRT/OBG], 2017). A refined conceptual site model has been developed and is discussed below.

Three hydrostratigraphic units are present at the Site:

- **CCR:** CCR, consisting primarily of fly ash, bottom ash, and boiler slag. Also includes earthen fill deposits of predominantly clay and silt materials from on-site excavations that were used to construct berms and roads surrounding the various impoundments across the Site.
- **Upper Unit (UU):** Predominantly clay with some silt and minor sand, silt layers, and occasional sand lenses. Includes the lithologic layers identified as the Cahokia Alluvium, Peoria Loess, Equality Formation, and Vandalia Till Member. This unit is composed of unlithified natural geologic materials and extends from the upper saturated materials to the bedrock. Thin sand seams and the interface (contact) between the UU and bedrock have been identified as potential migration pathways (PMPs). No continuous sand seams were observed within or immediately adjacent to the FAPS; however, the sand seams may act as a PMP due to relatively higher hydraulic conductivities. The acronym UU and the materials it contains is synonymous with Upper Groundwater Unit (UGU) used in previous documents.
- **Bedrock Unit:** This unit is considered the Uppermost Aquifer (UA) and is composed of interbedded shale and limestone bedrock, which underlies and is continuous across the entire Site.

Lateral groundwater flow in the shallow unlithified materials (**Figure 1-3**) and bedrock (**Figure 1-4**) is generally to the west and southwest across the Site toward the Kaskaskia River. Groundwater flow in bedrock is toward the northwest in the east and central areas of the BAP, and southwest to northwest on the east area of the FAPS until groundwater reaches the bedrock valley feature underlying the Secondary and Tertiary Ponds west of the BAP and FAPS, at which point the flow direction veers towards this bedrock surface low.

Immediately upgradient and downgradient of the BPP property boundaries, both the shallow glacial deposits and the shallow bedrock have served as a source of water supply. The shallow unlithified deposits off-site have yielded water through intermittent, discontinuous sand lenses and, in the bedrock, through fractured sandstone and limestone. However, within the area of the Site, investigations have indicated only thin and intermittent sand lenses are present within predominantly clay deposits; thus, the unlithified materials do not represent a continuous aquifer unit. Based on these details, the Bedrock Unit was designated as the UA in the *Supplemental Hydrogeologic Site Characterization and Groundwater Monitoring Plan* (NRT, 2016), consistent with the United States Environmental Protection Agency (USEPA) definition in 40 C.F.R. § 257.53.

The shallow bedrock is the only water-bearing unit that is continuous across the Site. Shallow sandstone and creviced limestone may yield small supplies in some areas, but water quality becomes poorer (*i.e.,* highly mineralized) with increasing depth. The Pennsylvanian and Mississippian rocks generally have low porosities and permeabilities, are not a reliable source of groundwater, and the quality varies considerably (Pryor, 1956). Therefore, the lower limit of the UA is the depth at which either the groundwater is mineralized to a point that it is no longer a useable water source, or the secondary porosities do not yield a sufficient volume of groundwater to produce a useable water supply.

Additional monitoring wells were installed and groundwater samples were collected from wells placed in both the UA and UU in 2022. The additional monitoring wells were installed for further hydrogeologic investigation and water quality evaluation of the BAP. Following these investigation activities and refinement of background groundwater quality, an additional background well was selected for inclusion within the groundwater monitoring systems for the FAPS and BAP.

Evaluation of background groundwater quality has been completed as part of this GMP, and compliance with 35 I.A.C. § 845 will be determined following the first round of groundwater sampling. The first round of groundwater sampling for compliance was completed in the second quarter of 2023 in accordance with the Compliance Commitment Agreement (CCA) entered on December 28, 2022, for the BPP.

2. GROUNDWATER MONITORING SYSTEMS

2.1 Existing Monitoring Well Network and Analysis

This GMP is being provided to propose an updated groundwater monitoring network and monitoring program specific to the FAPS that will comply with 35 I.A.C. § 845. The remaining discussion in this document will include only these networks and monitoring programs that are applicable and specific to the FAPS, specifically National Pollutant Discharge Elimination System (NPDES) monitoring network, the IEPA Operating Permit monitoring program, the Closure Plan monitoring program, the 40 C.F.R. § 257 monitoring network, and the proposed 35 I.A.C. § 845 monitoring network. DMG entered into a CCA with the IEPA on December 28, 2022. Groundwater monitoring in accordance with the CCA and the 35 I.A.C. § 845 proposed GMP and sampling methodologies provided in the operating permit application for the FAPS commenced in the second quarter of 2023. Dynegy may cease groundwater monitoring under the post-closure plans once it commences with quarterly monitoring. After the FAPS has been issued an approved operating permit, groundwater monitoring shall be conducted in accordance with that operating permit. As specified in the CCA, groundwater sampling requirements that apply to the CCR SI under other existing state permit programs will become void upon issuance of an approved operating permit pursuant to 35 I.A.C § 845.

2.1.1 NPDES Permit Monitoring Network

Effective November 1, 2022, Special Condition No. 17 requiring groundwater monitoring and reporting was removed from NPDES Permit IL0000043.

2.1.2 IEPA Operating Permit 2020-EA-65016 Monitoring Program

The IEPA Operating Permit 2020-EA-65016 monitoring well network includes eighteen monitoring wells, including two background monitoring wells (MW-304 and MW-306) installed in bedrock, three compliance wells (MW-350, MW352, and MW-355) installed in bedrock, ten compliance wells (MW-104SR, MW-104DR, MW-150, MW-151, MW-152, MW-252, MW-153, MW-253, MW-154, and MW-155) installed in unlithified materials, and two supplemental monitoring wells (OW-156[1] and OW-157S[1]) installed in the unlithified materials. These wells are monitored in accordance with Special Condition No. 5 of IEPA Operating Permit 2020-EA-65016, issued on March 31, 2020. The IEPA Operating Permit 2020-EA-65016 monitoring network well locations are shown on **Figure 2-1**.

The IEPA Operating Permit 2020-EA-65016 monitoring network wells are sampled quarterly for the laboratory and field parameters listed in **Table A** on the following page, as required in the permit. Monitoring wells OW-156 and OW-157 are monitored for field parameters only. Results are submitted to IEPA by February 28 of the following year as required by the permit.

[1] OW-156 and OW-157 are identified in NPDES Permit IL0000043 as MW-156 and MW-157S, respectively.

Table A. IEPA Operating Permit Groundwater Monitoring Program Parameters

Field Parameters [1]		
pH	Depth to Water (bgs; feet)	Groundwater Elevation (feet)
Specific Conductance	Depth to Water (below mp; feet)	
Temperature	Elevation of mp; feet	
Inorganics		
Chloride (dissolved)	Sulfate (dissolved)	
Nitrate	TDS	
Metals		
Boron (dissolved)	Iron (total)	Manganese (total)

[1] Dissolved oxygen, oxidation/reduction potential, and turbidity are recorded during sample collection.
bgs = below ground surface
mp = measuring point
TDS = total dissolved solids

2.1.3 IEPA Closure Plan Monitoring Program

Quarterly groundwater monitoring pursuant to 35 I.A.C § 845 was initiated May 16, 2023. In accordance with the CCA, groundwater monitoring performed under Section 6.8 of the approved Closure Plan ceased with initiation of the 35 I.A.C. § 845 monitoring program in the second quarter of 2023.

2.1.4 40 C.F.R. § 257 Monitoring Program

The 40 C.F.R. § 257 monitoring well network was revised and expanded in July 2023 concurrent with revisions to the 35 I.A.C. § 845 monitoring network detailed in this document. The monitoring well network consists of twelve bedrock groundwater monitoring wells used to monitor the UA, including three background wells (MW-304, MW-306, and MW-358) and nine compliance wells (MW-350, MW-352, MW-366, MW-375, MW-377, MW-383, MW-384, MW-390, and MW-391), and six wells to monitor the unlithified materials considered to be the PMP (MW-150, MW-151, MW 152, MW-153, MW-252, and MW-253). The 40 C.F.R. § 257 monitoring well network locations are shown on **Figure 2-1**.

Assessment monitoring in accordance with 40 C.F.R. § 257.95 was initiated on April 9, 2018. Details on the procedures and techniques used to fulfill the groundwater sampling and analysis program requirements are found in Multi-Site Sampling and Analysis Plan (SAP) (Ramboll, 2022a).

Groundwater samples are collected semi-annually and analyzed for the following laboratory and field parameters from Appendix III and Appendix IV of 40 C.F.R. § 257, summarized in **Table B** on the following page.

Table B. 40 C.F.R. § 257 Groundwater Monitoring Program Parameters

Field Parameters[1]			
Groundwater Elevation	pH		
Appendix III Parameters (Total, except TDS)			
Boron	Chloride	Sulfate	
Calcium	Fluoride	TDS	
Appendix IV Parameters (Total)			
Antimony	Cadmium	Lithium	Selenium
Arsenic	Chromium	Mercury	Thallium
Barium	Cobalt	Molybdenum	Radium 226 and 228 combined
Beryllium	Lead		

[1] Dissolved oxygen, temperature, specific conductance, oxidation/reduction potential, and turbidity are recorded during sample collection.

Results and analysis of groundwater sampling are reported annually by January 31 of the following year and made available on the CCR public website as required by 40 C.F.R. § 257.

2.2 Proposed 35 I.A.C. § 845 Monitoring Well Network

The groundwater monitoring well network proposed in this GMP consists of 18 wells, including three background monitoring wells (MW-304, MW-306, and MW-358) installed in bedrock, nine compliance wells (MW-350, MW-352, MW-366, MW-375, MW-377, MW-383, MW-384, MW-390, and MW-391) installed in bedrock, and six compliance wells (MW-150, MW-151, MW-152, MW-153, MW-252, and MW-253) installed within the unlithified materials, considered to be the PMP. The proposed network is summarized in **Table C** on the following page and displayed on **Figure 2-2**.

The groundwater samples collected from the 18 wells will be used to monitor and evaluate groundwater quality within the hydrostratigraphic units and demonstrate compliance with the groundwater quality standards listed in 35 I.A.C. § 845.600(a). The proposed monitoring wells will yield groundwater samples that represent the quality of downgradient groundwater at the CCR boundary (as required in 35 I.A.C. § 845.630(a)(2)). Monitoring well depths and construction details are listed in **Table 2-1** and summarized in **Table C** on the following page.

Table C. Proposed 35 I.A.C. § 845 Monitoring Well Network

Well ID	Monitored Unit	Well Screen Interval (feet bgs)	Well Type[1]
MW-150	PMP	15.0 – 24.7	Compliance
MW-151	PMP	6.1 – 15.8	Compliance
MW-152	PMP	7.5 – 16.7	Compliance
MW-153	PMP	10.4 – 20.0	Compliance
MW-252	PMP	44.4 – 49.0	Compliance
MW-253	PMP	29.9 – 34.5	Compliance
MW-304	UA	45.0 – 55.0	Background
MW-306	UA	72.7 – 87.7	Background
MW-350	UA	41.6 – 46.2	Compliance
MW-358	UA	80.0 – 90.0	Background
MW-352	UA	67.9 – 72.5	Compliance
MW-366	UA	42.0 – 52.0	Compliance
MW-375	UA	57.0 – 67.0	Compliance
MW-377	UA	46.0 – 56.0	Compliance
MW-383	UA	58.0 – 68.0	Compliance
MW-384	UA	60.5 – 70.5	Compliance
MW-390	UA	50.0 – 65.0	Compliance
MW-391	UA	55.0 – 70.0	Compliance

[1] Well Type refers to the role of the well in the monitoring network.
bgs = below ground surface
PMP = potential migration pathway
UA = uppermost aquifer

2.3 Well Abandonment

No wells are currently proposed for abandonment.

3. APPLICABLE GROUNDWATER QUALITY STANDARDS

3.1 Groundwater Classification

The classification of groundwater at the Site was addressed in the Phase II investigation (NRT, 2014). Field hydraulic conductivity tests performed on the UU materials (*i.e.,* Cahokia Formation, Equality Formation, and Vandalia Till) and Bedrock Unit materials (*i.e.,* Mississippian and Pennsylvanian bedrock) as part of the Phase II and 2022 Hydrogeologic Site Investigation (Ramboll, 2023) had geometric mean hydraulic conductivities of 2.9 x 10^{-5} centimeters per second (cm/s) and 1.9 x 10^{-6} cm/s, respectively.

Geologic material with a hydraulic conductivity of less than 1 x 10^{-4} cm/s which does not meet the provisions of 35 I.A.C. § 620.210 (Class I), 35 I.A.C. § 620.230 (Class III), or 35 I.A.C. § 620.240 (Class IV), meets the definition of a Class II – General Resource Groundwater (35 I.A.C. § 620.220). Based on the detailed geologic information provided for the unlithified materials and bedrock at BPP, along with the hydrogeologic data, the groundwater in both the unlithified deposits and underlying bedrock at the Site is classified as Class II - General Resource Groundwater.

3.2 Statistical Evaluation of Background Groundwater Data

A statistical analysis plan (**Appendix A**) has been developed to describe procedures that will be used to establish background conditions and implement compliance and corrective action monitoring as necessary and required by 35 I.A.C. §§ 845.640, 845.650, and 845.680. The statistical analysis plan was prepared in accordance with the requirements of 35 I.A.C. § 845.640(f), with reference to the acceptable statistical procedures provided in USEPA's *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (USEPA, 2009), and is intended to provide a logical process and framework for conducting the statistical analysis of the data obtained during groundwater monitoring.

In accordance with 35 I.A.C. § 845.640(f)(1), the statistical method chosen for analysis of background groundwater quality is the tolerance interval procedure for each constituent listed in 35 I.A.C. § 845.600(a)(1) at this CCR multi-unit per 35 I.A.C. § 845.640(f)(1)(C). Background statistical calculations consider concentrations from all sampling events from 2015 through May 2023. Resulting background concentrations are provided in **Table 3-1**.

3.3 Applicable Groundwater Protection Standards

The applicable GWPS has been established in accordance with 35 I.A.C. § 845.600(a) (greater of the background concentration or numerical limit specified in 35 I.A.C. § 845.600(a)(1)). A comparison of the statistical background concentrations and groundwater quality standards listed in 35 I.A.C. § 845.600(a)(1) and a summary of the resulting Groundwater Protection Standards (GWPSs) are provided in **Table 3-1**. Most of the background concentrations in the UA are less than the groundwater quality standards listed in 35 I.A.C. § 845.600(a)(1). Therefore, for these parameters, the groundwater quality standards listed in 35 I.A.C. § 845.600(a)(1) will be applied to the results from the proposed groundwater monitoring network. The exceptions include boron, chloride, lithium, pH, sulfate, and TDS, where the background concentration or measurement are greater than the 35 I.A.C. 35 I.A.C. § 845.600(a)(1) standard. In these instances, the GWPS will be the background concentration or measurement.

Under most circumstances, the GWPS will be compared to the lower confidence limit (LCL) for the observed concentrations for each constituent in each compliance well in accordance with the statistical analysis plan (**Appendix A**). Consistent with the *Unified Guidance*, the same general statistical method of confidence interval testing against a fixed GWPS is recommended in compliance and corrective action programs. Confidence intervals provide a flexible and statistically accurate method to test how a parameter estimated from a single sample compares to a fixed numerical limit. Confidence intervals explicitly account for variation and uncertainty in the sample data used to construct them.

Evaluation of the applicable standards will occur in conjunction with the analysis of groundwater quality results. Background calculations and the resulting concentrations may be updated as appropriate, in accordance with the statistical analysis plan included in **Appendix A**.

4. GROUNDWATER MONITORING PLAN

The GMP will monitor and evaluate groundwater quality to demonstrate compliance with the groundwater quality standards included in 40 C.F.R. § 257.94(e), 40 C.F.R. § 257.95(h), and 35 I.A.C. § 845.600(a)(1). The groundwater monitoring program will include sampling and analysis procedures that are consistent and provide an accurate representation of groundwater quality at the background and compliance wells as required by 35 I.A.C. § 845.630.

As discussed in **Section 2**, three active monitoring programs specific to the FAPS exist, the IEPA Operating Permit monitoring program, the 40 C.F.R. § 257 monitoring program, and the proposed 35 I.A.C. § 845 monitoring program. It is expected that upon USEPA approval of 35 I.A.C. § 845, the 40 C.F.R. § 257 network monitoring and reporting will be eliminated, and the proposed 35 I.A.C. § 845 monitoring and reporting included in this GMP will continue until requirements of 35 I.A.C. § 845 have been achieved. As specified in the CCA, groundwater sampling requirements that apply to the CCR SI under other existing IEPA permit programs will become void upon issuance of an approved operating permit pursuant to 35 I.A.C § 845.

4.1 Monitoring Networks and Parameters

4.1.1 NPDES Permit Monitoring

As discussed in **Section 2.1.1**, the NPDES Permit was reissued on November 1, 2022, to remove groundwater monitoring and reporting specific to the BAP.

4.1.2 IEPA Operating Permit 2020-EA-65016 Monitoring

The existing IEPA Operating Permit monitoring program was discussed in detail in **Section 2.1.2**. Well locations and parameters will continue to be monitored and reported as required by Special Condition No. 5 of IEPA Operating Permit 2020-EA-65016 until IEPA approves an alternate schedule or removes Special Condition No. 5 from the IEPA Operating Permit.

4.1.3 IEPA Closure Plan Monitoring

The existing IEPA-approved Closure Plan monitoring program was discussed in **Section 2.1.3.** In accordance with the CCA, groundwater monitoring performed under Section 6.8 of the approved Closure Plan ceased with initiation of the 35 I.A.C. § 845 monitoring program in the second quarter of 2023.

4.1.4 40 C.F.R. § 257 Monitoring

The existing 40 C.F.R. § 257 monitoring program was discussed in detail in **Section 2.1.4**. Well locations and parameters will continue to be monitored and reported as required by 40 C.F.R. § 257 until USEPA approves 35 I.A.C. § 845. Any future changes to the groundwater monitoring well network as approved by the IEPA under 35 I.A.C. § 845 will also be incorporated into the 40 C.F.R. § 257 monitoring system.

4.1.5 35 I.A.C. § 845 Groundwater Monitoring

The proposed 35 I.A.C. § 845 Monitoring Network will consist of eighteen wells, including three background monitoring wells (MW-304, MW-306, and MW-358) installed in bedrock, nine compliance wells (MW-350, MW-352, MW-366, MW-375, MW-377, MW-383, MW-384, MW-390, and MW-391) installed in bedrock, and six compliance wells (MW-150, MW-151, MW-152, MW-153, MW-252 and MW-253) installed within the unlithified materials PMP to monitor potential impacts from the FAPS (**Figure 2-2**). Groundwater samples will be collected and analyzed for the laboratory and field parameters shown on **Table 4-1** and summarized in **Table D** below.

Table D. 35 I.A.C. § 845 Groundwater Monitoring Program Parameters

Field Parameters[1]			
Groundwater Elevation	pH	Turbidity	
Metals (Total)			
Antimony	Boron	Cobalt	Molybdenum
Arsenic	Cadmium	Lead	Selenium
Barium	Calcium	Lithium	Thallium
Beryllium	Chromium	Mercury	
Inorganics (Total, except TDS)			
Chloride	Fluoride	Sulfate	TDS
Other (Total)			
Radium 226 and 228 combined			

[1] Dissolved oxygen, temperature, specific conductance, and oxidation/reduction potential will be recorded during sample collection.

4.2 35 I.A.C. § 845 Sampling Schedule

Groundwater sampling for the 35 I.A.C. § 845 monitoring well network will initially be performed quarterly according to the schedule in **Table E** on the following page.

Table E. 35 I.A.C. § 845 Sampling Schedule

Frequency	Duration
Monthly (groundwater elevations only)	Began: Second quarter of 2023.
	Ends: Following the 30-year post closure care period and following IEPA approval of documentation that groundwater concentrations are below standards in 35 I.A.C. § 845.600 and concentrations exceeding background are not increasing and meet requirements in 35 I.A.C. § 845.780 (c)(2)(B)(i) and (ii).
Quarterly (groundwater quality)	Begins: the quarter following approval of this plan and issuance of the Operating Permit.
	Ends: Following the 30-year post closure care period and following IEPA approval of documentation that groundwater concentrations are below standards in 35 I.A.C. § 845.600 and concentrations exceeding background are not increasing and meet requirements in 35 I.A.C. § 845.780 (c)(2)(B)(i) and (ii), or upon IEPA approval of an alternate schedule as allowed by 35 I.A.C. § 845.650(b)(4).
Semi-annual (groundwater quality)	Begins: Following 5 years of quarterly groundwater monitoring and IEPA approval of a demonstration that groundwater concentrations are below standards in 35 I.A.C. § 845.600 and not exhibiting statistically significant increasing trends, monitoring effectiveness is not compromised by a semi-annual schedule, and sufficient data has been collected to characterize groundwater.
	Ends: Following detection of a statistically-significant increasing trend in groundwater concentrations or an exceedance of the standards in 35 I.A.C. § 845.600 (quarterly monitoring shall be resumed in these circumstances), or following the 30-year post closure care period and following IEPA approval of documentation that groundwater concentrations are below standards in 35 I.A.C. § 845.600 and concentrations exceeding background are not increasing and meet requirements in 35 I.A.C. § 845.780 (c)(2)(B)(i) and (ii).

4.3 Groundwater Sample Collection

Groundwater sampling procedures have been developed in the SAP (Ramboll, 2022a) and the collection of groundwater samples is being implemented to meet the requirements of 35 I.A.C. § 845.640. In addition to groundwater well samples, quality assurance samples will be collected as described in the Multi-Site Quality Assurance Project Plan (QAPP) (Ramboll, 2022c).

4.4 Laboratory Analysis

Laboratory analysis will be performed consistent with the requirements of 35 I.A.C. § 845.640(j)by a state-certified laboratory using methods approved by IEPA and USEPA. Laboratory methods may be modified based on laboratory equipment availability or procedures, but the Reporting Limit (RL) for all parameters analyzed, regardless of method, will be lower than the applicable groundwater quality standard. RLs for the applicable parameters are summarized in **Table 4-2**. Concentrations lower than the RL will be reported as less than the RL. Data reporting requirements and workflow are provided in the Multi-Site Data Management Plan (Ramboll, 2022d).

4.5 Quality Assurance Program

Consistent with the requirements of 35 I.A.C. § 845.640(a)(5), the QAPP includes procedures and techniques for laboratory quality assurance/quality control (QA/QC) and the SAP includes requirements for field data collection QA/QC.

4.6 Groundwater Monitoring System Maintenance Plan

Consistent with the requirements of 35 I.A.C. § 845.630(e)(2), the SAP includes procedures for maintenance to be performed as needed to assure that the monitoring wells provide representative groundwater samples.

4.7 Statistical Analysis

Statistical analysis will be consistent with procedures listed in 35 I.A.C. § 845.640(f). A statistical analysis plan, provided in **Appendix A**, has been developed to summarize the statistical procedures that will be used to evaluate the groundwater results.

4.8 Data Reporting

Data reporting for the 40 C.F.R. § 257 monitoring program will be consistent with recordkeeping, notification, and internet posting requirements described in 40 C.F.R. § 257.105 through 40 C.F.R. § 257.107.

Groundwater monitoring and analysis completed in accordance with the 35 I.A.C. § 845 monitoring under an approved monitoring program will be reported to IEPA within 60 days after completion of sampling and place the data in the facility's operating record as required by 35 I.A.C. § 845.610(b)(3)(D). Within 14 days of posting to the operating record, information will be posted to the publicly accessible internet site "Illinois CCR Rule Compliance Data and Information" as required by 35 I.A.C. § 845.810(d). Information will also be submitted to IEPA annually by January 31 as required by 35 I.A.C. § 845.550, for data collected the preceding year. The report will include the status of the groundwater monitoring and corrective action plan for the BPP FPAS in addition to other requirements detailed in 35 I.A.C. § 845.610(e).

4.9 Compliance with Applicable On-site Groundwater Quality Standards

In accordance with 35 I.A.C. § 845.600(a)(1), the GWPS at the waste boundary will be the higher of either the 35 I.A.C. § 845.600 standard or the concentration determined by background groundwater monitoring.

As provided in 35 I.A.C. § 845.780(c)(2), at the end of the 30-year post-closure care period, groundwater monitoring will continue to be conducted in post-closure care until the groundwater results show the concentrations are:

- Below the GWPS in 35 I.A.C. § 845.600; and
- Not increasing for those constituents over background, using the statistical procedures and performance standards in 35 I.A.C. § 845.640(f) and (g), provided that:
  - Concentrations have been reduced to the maximum extent feasible; and
  - Concentrations are protective of human health and the environment.

If one or more constituents are detected and confirmed by an immediate resample, to greater than the GWPS in any sampling event, an Alternate Source Demonstration (ASD) will be evaluated as described in **Section 4.10**.

4.10 Alternate Source Demonstrations

As allowed in 35 I.A.C. § 845.650(e), following detection of an exceedance of the GWPS, an ASD will be evaluated and, if completed, submitted to IEPA within 60 days. The ASD will provide lines of evidence that a source other than the FAPS caused the contamination and the FAPS did not contribute to the contamination, or that the exceedance of the GWPS resulted from error in sampling, analysis, statistical evaluation, natural variation in groundwater quality, or a change in the potentiometric surface and groundwater flow direction.

The ASD will include information and analysis that supports the conclusions and a certification of accuracy by a qualified professional engineer. Once the ASD is approved by IEPA, the 35 I.A.C. § 845 groundwater monitoring will continue as defined in **Section 4.1.5**.

If an ASD is not completed and submitted, or IEPA does not approve the ASD, a notification of the exceedance will be provided to IEPA and placed in the operating record. Additional actions will also be completed as required by 35 I.A.C § 845.650(d)(1) through (3), including initiation of an assessment of corrective measures under 35 I.A.C § 845.660. As allowed in 35 I.A.C § 845.650(e)(7), a petition for review of IEPA's non-concurrence under 35 I.A.C. § 105 may also be filed.

4.11 Assessment of Corrective Measures and Corrective Action

As described in 35 I.A.C. § 845.660, if the ASD summarized in **Section 4.10** has not been approved by IEPA, an assessment of corrective measures will be initiated within 90 days of the detection of a result exceeding 35 I.A.C. § 845.600 standards (*i.e.,* receipt of laboratory data). The assessment of corrective measures will include at least the following (35 I.A.C. § 845.660 (c)):

- The performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to any residual contamination.
- The time required to begin and complete the corrective action plan; and
- The institutional requirements, such as State or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the corrective action plan.

Within one year of completing the assessment of corrective measures, a corrective action plan will be developed to identify the selected remedy in accordance with 35 I.A.C. § 845.670. If closure of the CCR unit is required, a closure alternatives analysis will be completed as specified in 35 I.A.C. § 845.710. The analysis and selected alternative will be submitted to IEPA in a Closure Plan as specified by 35 I.A.C. § 845.720. Groundwater monitoring proposed in this GMP will continue as specified until the post closure care period has expired and IEPA has approved termination of post-closure care.

5. REFERENCES

AECOM, 2016. *Closure and Post-Closure Care Plan for the Baldwin Fly Ash Pond System. Baldwin Energy Complex. Baldwin, Illinois.* March 31, 2016.

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TABLES

TABLE 1-1. 35 I.A.C. § 845 REQUIREMENTS CHECKLIST

GROUNDWATER MONITORING PLAN REVISION 1

BALDWIN POWER PLANT

FLY ASH POND SYSTEM

BALDWIN, ILLINOIS

35 I.A.C. § 845 Reference	35 I.A.C. § 845 Components	Location of Information in GMP
845.630	**Groundwater Monitoring Systems**	
845.630(a)(2)	Potential contaminant pathways must be monitored.	Sections 2.2, 3.3 & 4.1.5 Table 2-1
845.630(a) 845.630(b) 845.630(c)	At least two upgradient wells and four downgradient wells (min. 1 and 3, but requires additional documentation)	Sections 2.2 & 4.1.5 Table 2-1 Figure 2-1
845.630(a) 845.630(b) 845.630(c)	Downgradient Well Density	Figure 2-1
845.630(a)(2)	Downgradient wells at waste boundary	Figure 2-1
845.640	**Groundwater Sampling and Analysis Requirements**	
845.640(a)	Consistent sampling and analysis procedures	Section 4 Tables 4-1 & 4-2
845.640(b)	Methods are appropriate	Section 4 Tables 4-1 & 4-2
845.640(c)	Groundwater elevations must be measured in each well prior to purging, each time groundwater is sampled.	Section 4.3
845.640 (d)(e)(f)(g)(h)	Establishment of background and application of statistical methods	Sections 3 & 4.7 Appendix A
845.640(i)	Analyze total recoverable metals	Section 4.2 Table 4-1
845.640(j)	Analyze groundwater samples using a certified laboratory	Section 4.4

TABLE 1-1. 35 I.A.C. § 845 REQUIREMENTS CHECKLIST
GROUNDWATER MONITORING PLAN REVISION 1
BALDWIN POWER PLANT
FLY ASH POND SYSTEM
BALDWIN, ILLINOIS

35 I.A.C. § 845 Reference	35 I.A.C. § 845 Components	Location of Information in GMP
845.650	**Groundwater Monitoring Program**	
845.650(a)	Must include monitoring for all constituents with a groundwater protection standard in Section 845.600(a), calcium, and turbidity	Section 4.1.5
845.650(b)(c)	Groundwater Monitoring Frequency	Sections 4.2
845.650(d)(e)	Exceedances of the groundwater protection standard	Sections 4.9, 4.10 & 4.11
845.650(b)(2) and (3)	Staff gauge/ piezometer to monitor head in impoundment	NA
NA	Staff gauge/ piezometer to monitor head of neighboring surface water body	NA

[O: CJC 10/11/21; U: EGP 07/31/23; C: LDC 08/07/23]

Notes:
GMP = Groundwater Monitoring Plan
NA = Not Applicable

RAMBOLL

TABLE 2-1. MONITORING WELL LOCATIONS AND CONSTRUCTION DETAILS
GROUNDWATER MONITORING PLAN REVISION 1
BALDWIN POWER PLANT
FLY ASH POND SYSTEM
BALDWIN, ILLINOIS

Well Number	Type	HSU	Date Constructed	Top of PVC Elevation (ft)	Measuring Point Elevation (ft)	Measuring Point Description	Ground Elevation (ft)	Screen Top Depth (ft BGS)	Screen Bottom Depth (ft BGS)	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Well Depth (ft BGS)	Bottom of Boring Elevation (ft)	Screen Length (ft)	Screen Diameter (inches)	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
MW-150	C	PMP	09/01/2010	396.54	396.54	Top of PVC	393.84	15.00	24.70	378.80	369.20	25.20	368.70	9.6	2	38.189401	-89.878468
MW-151	C	PMP	09/01/2010	399.96	399.96	Top of PVC	397.22	6.10	15.80	391.10	381.40	16.30	380.90	9.6	2	38.188449	-89.872354
MW-152	C	PMP	09/01/2010	424.99	424.99	Top of PVC	422.18	7.50	16.70	414.70	405.50	17.20	405.00	9.3	2	38.187569	-89.866764
MW-153	C	PMP	09/01/2010	445.67	445.67	Top of PVC	442.77	10.40	20.00	432.40	422.80	20.50	422.30	9.6	2	38.185884	-89.86101
MW-252	C	PMP	09/01/2010	425.07	425.07	Top of PVC	422.27	44.40	49.00	377.90	373.20	49.50	372.70	4.6	2	38.187563	-89.866745
MW-253	C	PMP	09/01/2010	445.84	445.84	Top of PVC	442.70	29.90	34.50	412.80	408.20	35.00	407.70	4.6	2	38.185885	-89.861026
MW-304	B	UA	10/20/2015	455.49	455.49	Top of PVC	453.03	45.00	55.00	408.00	398.00	55.00	317.60	10	2	38.188332	-89.853441
MW-306	B	UA	09/25/1991	453.17	453.17	Top of PVC	450.91	72.70	87.70	378.20	363.20	87.70	361.20	15	2	38.20114	-89.846756
MW-350	C	UA	09/01/2010	396.80	396.80	Top of PVC	394.11	41.60	46.20	352.50	347.90	46.60	347.40	4.6	2	38.189416	-89.878477
MW-352	C	UA	09/01/2010	425.04	425.04	Top of PVC	422.36	67.90	72.50	354.50	349.80	73.00	348.60	4.6	2	38.187554	-89.866729
MW-358	B	UA	10/08/2022	455.73	455.73	Top of PVC	453.59	80.00	90.00	373.73	363.73	90.00	363.59	10	2	38.195275	-89.849417
MW-366	C	UA	12/04/2015	425.08	425.08	Top of PVC	422.54	42.00	52.00	380.50	370.50	52.00	368.20	10	2	38.192191	-89.872345
MW-375	C	UA	11/06/2015	423.05	423.05	Top of PVC	420.50	57.00	67.00	363.50	353.50	67.00	335.80	10	2	38.189045	-89.873514
MW-377	C	UA	11/02/2015	421.36	421.36	Top of PVC	418.75	46.00	56.00	372.80	362.80	56.00	360.50	10	2	38.188386	-89.869742
MW-383	C	UA	12/21/2015	459.49	459.49	Top of PVC	457.18	58.00	68.00	399.20	389.20	68.00	384.20	10	2	38.194913	-89.858286
MW-384	C	UA	12/18/2015	458.95	458.95	Top of PVC	456.70	60.50	70.50	396.20	386.20	70.50	362.60	10	2	38.191789	-89.860699
MW-390	C	UA	03/04/2016	428.06	428.06	Top of PVC	425.98	50.00	65.00	376.00	361.00	65.00	358.00	15	2	38.192956	-89.869793
MW-391	C	UA	03/10/2016	426.63	426.63	Top of PVC	424.24	55.00	70.00	369.20	354.20	70.00	349.80	15	2	38.190869	-89.874759

TABLE 2-1. MONITORING WELL LOCATIONS AND CONSTRUCTION DETAILS
GROUNDWATER MONITORING PLAN REVISION 1
BALDWIN POWER PLANT
FLY ASH POND SYSTEM
BALDWIN, ILLINOIS

Notes:
All elevation data are presented relative to the North American Vertical Datum 1988 (NAVD88), GEOID 12A
Type refers to the role of the well in the monitoring network: background (B), compliance (C), or water level measurements only (WLO)
WLO wells are temporary pending implementation of impoundment closure per an approved Construction Permit application
BGS = below ground surface
ft = foot or feet
HSU = Hydrostratigraphic Unit
PMP = potential migration pathway
PVC = polyvinyl chloride
UA = uppermost aquifer
generated 07/18/2023, 9:47:33 AM CDT

TABLE 3-1. BACKGROUND GROUNDWATER QUALITY AND STANDARDS
GROUNDWATER MONITORING PLAN REVISION 1
BALDWIN POWER PLANT
FLY ASH POND SYSTEM
BALDWIN, ILLINOIS

Parameter	Background Concentration	845 Limit	Groundwater Protection Standard	Unit
Antimony, total	0.0023	0.006	0.006	mg/L
Arsenic, total	0.0104	0.010	0.010	mg/L
Barium, total	0.261	2.0	2.0	mg/L
Beryllium, total	0.0005	0.004	0.004	mg/L
Boron, total	2.16	2	2.16	mg/L
Cadmium, total	0.002	0.005	0.005	mg/L
Chloride, total	1370	200	1370	mg/L
Chromium, total	0.0125	0.1	0.1	mg/L
Cobalt, total	0.0022	0.006	0.006	mg/L
Fluoride, total	3.84	4.0	4.0	mg/L
Lead, total	0.0022	0.0075	0.0075	mg/L
Lithium, total	0.14	0.04	0.14	mg/L
Mercury, total	0.0002	0.002	0.002	mg/L
Molybdenum, total	0.0782	0.1	0.1	mg/L
pH (field)	11.1 / 7.5	9.0 / 6.5	11.1 / 6.5	SU
Radium 226 and 228 combined	3.76	5	5	pCi/L
Selenium, total	0.0032	0.05	0.05	mg/L
Sulfate, total	762	400	762	mg/L
Thallium, total	0.002	0.002	0.002	mg/L
Total Dissolved Solids	3260	1200	3260	mg/L

Notes:
For pH, the values presented are the upper / lower limits
Groundwater protection standards for calcium and turbidity do not apply per 35 I.A.C. § 845.600(b)
mg/L = milligrams per liter
SU = standard units
pCi/L = picocuries per liter

TABLE 4-1. SAMPLING AND ANALYSIS SUMMARY
GROUNDWATER MONITORING PLAN REVISION 1
BALDWIN POWER PLANT
FLY ASH POND SYSTEM
BALDWIN, ILLINOIS

Parameter	Analytical Method [1]	Number of Samples	Field Duplicates [2]	Field Blanks [3]	Equipment Blanks [3]	MS/MSD [4]	Total	Container Type	Minimum Volume [5]	Preservation (Cool to 4 °C for all samples)	Sample Hold Time from Collection Date
Metals											
Metals [6]	6020, Li - EPA 200.7	10	1	0	0	1	12	plastic	600 mL	HNO_3 to pH<2	6 months
Mercury	7470A or 6020	10	1	0	0	1	12	plastic	400 mL	HNO_3 to pH<2	28 days
Inorganic Parameters											
Fluoride	9214 or EPA 300	10	1	0	0	1	12	plastic	300 mL	Cool to 4 °C	28 days
Chloride	9251 or EPA 300	10	1	0	0	1	12	plastic	100 mL	Cool to 4 °C	28 days
Sulfate	9036 or EPA 300	10	1	0	0	1	12	plastic	50 mL	Cool to 4 °C	28 days
Total Dissolved Solids	SM 2540 C	10	1	0	0	1	12	plastic	200 mL	Cool to 4 °C	7 days
Radium											
Radium 226	9315 or EPA 903	10	0	0	0	0	10	plastic	1000 mL	HNO_3 to pH<2	6 months
Radium 228	9320 or EPA 904	10	0	0	0	0	10	plastic	1000 mL	HNO_3 to pH<2	6 months
Field Parameters											
pH	SM 4500-H+ B	10	NA	NA	NA	NA	10	flow-through cell	NA	none	immediately
Dissolved Oxygen [8]	SM 4500-O/405.1	10	NA	NA	NA	NA	10	flow-through cell	NA	none	immediately
Temperature [8]	SM 2550	10	NA	NA	NA	NA	10	flow-through cell	NA	none	immediately
Oxidation/Reduction Potential [8]	SM 2580 B	10	NA	NA	NA	NA	10	flow-through cell	NA	none	immediately
Specific Conductance [8]	SM 2510 B	10	NA	NA	NA	NA	10	flow-through cell	NA	none	immediately
Turbidity [7]	SM 2130 B	10	NA	NA	NA	NA	10	flow-through cell or hand-held turbidity meter	NA	none	immediately

[O: CJC 10/11/21; U: EGP 06/01/23; C: CJC 06/14/23]

Notes:
[1] Analytical method numbers are from SW-846 unless otherwise indicated. Analytical methods may be updated with more recent versions as appropriate.
[2] Field duplicates will be collected at a frequency of one per group of 10 or fewer investigative water samples. Field duplicates will not be collected for radium analysis.
[3] Field blanks will be collected at the discretion of the project manager; Equipment blanks will be collected at a rate of 1 per sampling event if non-dedicated equipment is used.
[4] Matrix Spike/Matrix Spike Duplicate (MS/MSD) samples will be collected at a frequency of one per group of 20 or fewer investigative water samples per CCR unit/multi-unit. Additional volume to be determined by laboratory.
[5] Sample volume is estimated and will be determined by the laboratory.
[6] Metals = antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, lead, lithium, molybdenum, selenium, thallium. Metals may be analyzed via ICP/ ICP-MS USEPA methods 6010 or 6020 depending on laboratory instrument availability.
[7] If turbidity exceeds 10 NTUs, a duplicate sample filtered through a .45 micron filter may be collected for metals analysis in addition to the unfiltered sample. Both samples would be submitted for analysis.
[8] Parameter collected for quality assurance and quality control for field sampling purposes only; not required to be collected or reported under Part 845; collection of parameter may be discontinued without notification.
< = less than
°C = degrees Celsius
HNO_3 = nitric acid
mL = milliliter
NA = not applicable
NTU = nephelometric turbidity unit

TABLE 4-2. DETECTION AND REPORTING LIMITS FOR 35 I.A.C. § 845 PARAMETERS

GROUNDWATER MONITORING PLAN REVISION 1

BALDWIN POWER PLANT

FLY ASH POND SYSTEM

BALDWIN, ILLINOIS

Constituent	CAS	Unit	Analytical Methods [1]	USEPA MCL [2]	35 I.A.C. § 845.600	RL [4, 5]	MDL [5]
Metals							
Antimony	7440-36-0	mg/L	6020	0.006	0.006	0.003	0.00036
Arsenic	7440-38-2	mg/L	6020	0.01	0.01	0.001	0.00013
Barium	7440-39-3	mg/L	6020	2	2	0.001	0.00028
Beryllium	7440-41-7	mg/L	6020	0.004	0.004	0.001	0.000017
Boron	7440-42-8	mg/L	6020	NS	2	0.01	0.0023
Cadmium	7440-43-9	mg/L	6020	0.005	0.005	0.001	0.000042
Calcium	7440-70-2	mg/L	6020	NS	NS	0.15	0.15
Chromium	7440-47-3	mg/L	6020	0.1	0.1	0.004	0.00027
Cobalt	7440-48-4	mg/L	6020	0.006	0.006	0.002	0.000017
Lead	7439-92-1	mg/L	6020	0.015	0.0075	0.001	0.000025
Lithium	7439-93-2	mg/L	6020 or EPA 200.7	0.04	0.04	0.02	0.0001
Mercury	7439-97-6	mg/L	6020 or 7470A	0.002	0.002	0.0002	0.000078
Molybdenum	7439-98-7	mg/L	6020	0.1	0.1	0.001	0.000063
Selenium	7782-49-2	mg/L	6020	0.05	0.05	0.001	0.00032
Thallium	7440-28-0	mg/L	6020	0.002	0.002	0.001	0.000062
Inorganics							
Fluoride	7681	mg/L	9214 or EPA 300	4	4	0.25	0.065
Chloride	16887-00-6	mg/L	9251 or EPA 300	250 [3]	200	1	0.15
Sulfate	18785-72-3	mg/L	9036 or EPA 300	250 [3]	400	1	0.24
Total Dissolved Solids	10052	mg/L	SM 2540C	500 [3]	1200	17	--
Other							
Radium 226 and 226 combined	7440-14-4	pCi/L	9315/9320 or EPA 903/904	5	5	-- [6]	-- [7]

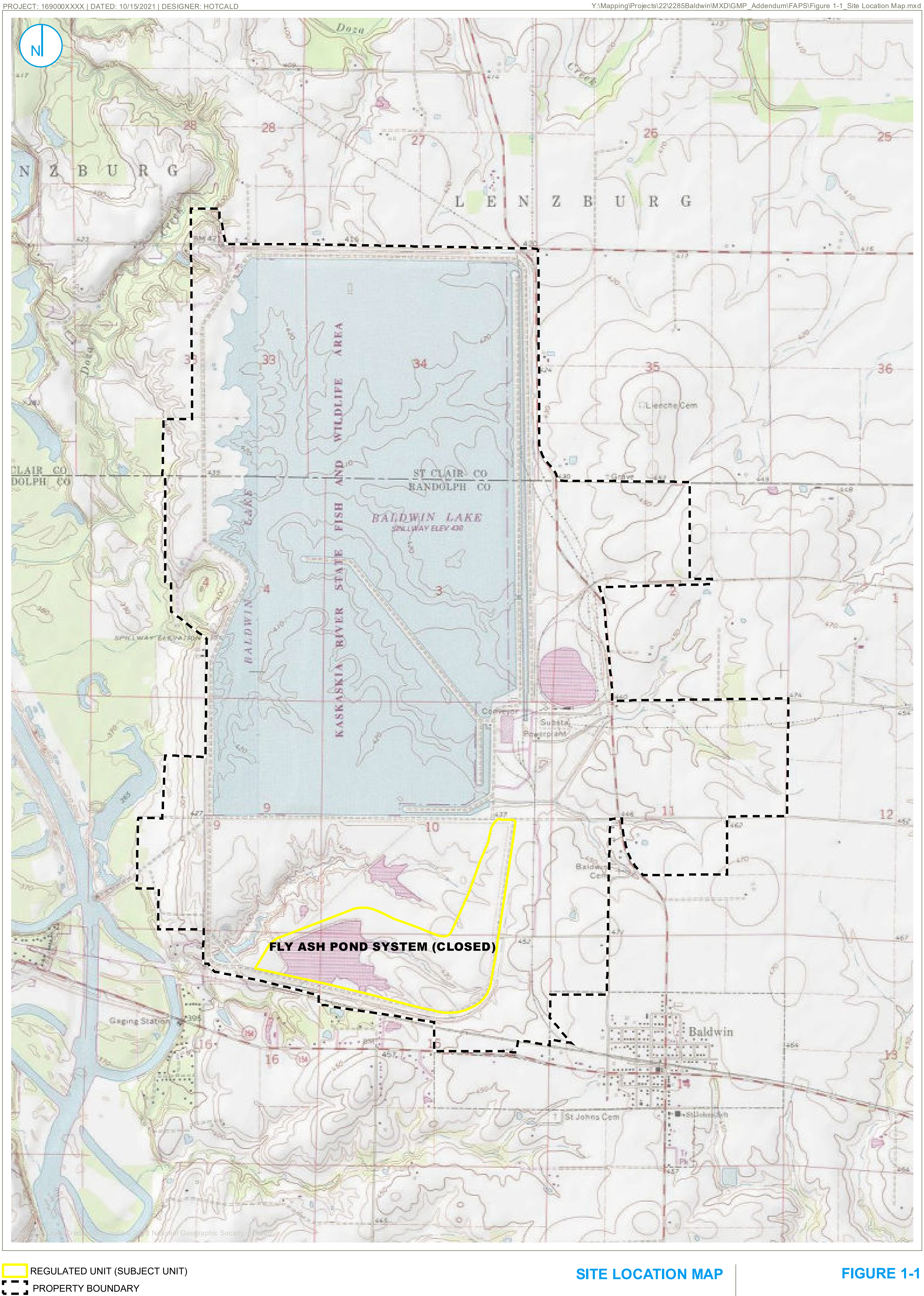
TABLE 4-2. DETECTION AND REPORTING LIMITS FOR 35 I.A.C. § 845 PARAMETERS
GROUNDWATER MONITORING PLAN REVISION 1
BALDWIN POWER PLANT
FLY ASH POND SYSTEM
BALDWIN, ILLINOIS

Constituent	CAS	Unit	Analytical Methods [1]	USEPA MCL [2]	35 I.A.C. § 845.600	RL [4, 5]	MDL [5]
Field							
pH	NA	SU	SM 4500-H+ B	NS	6.5-9.0	NA	NA
Oxidation/Reduction Potential	NA	mV	SM 2580 B	NS	NS	NA	NA
Dissolved Oxygen	NA	mg/L	SM 4500-O/405.1	NS	NS	NA	NA
Temperature	NA	°C	SM 2550	NS	NS	NA	NA
Specific Conductance	NA	µS/cm	SM 2510 B	NS	NS	NA	NA
Turbidity	NA	NTU	SM 2130 B	NS	NS	NA	NA

[O: CJC 10/11/21; U: EGP 06/01/23 C: CJC 06/14/23]

Notes:
[1] Analytical method numbers are from SW-846 unless otherwise indicated. Metals will be analyzed via Method 6020 or 6010 depending on laboratory equipment availability. Selected method will ensure reporting limits (RL) are below Title 35 of the Illinois Administrative Code (35 I.A.C.) § 845.600 groundwater protection standards.
[2] USEPA MCL = United States Environmental Protection Agency Maximum Contaminant Level.
[3] USEPA SMCL = United States Environmental Protection Agency Secondary Maximum Contaminant Level.
[4] RLs will be less than the 35 I.A.C. § 845.600 groundwater protection standards.
[5] RLs and method detection limits (MDL) will vary depending on the laboratory performing the work.
[6] All radium results will be reported (values may be positive or negative) and will include uncertainty and the calculated MDC.
[7] Laboratories calculate a minimum detectable concentration (MDC) based on the sample.
°C = degrees Celsius
µS/cm = microSiemens per centimeter
CAS = Chemical Abstract Number
MDL = Method detection limit as established by the laboratory
mg/L = milligrams per liter
mV = millivolts
NA = Not applicable
NS = No standard
NTU = nephelometric turbidity unit
pCi/L = picoCuries per liter
RL = Reporting limit as established by the laboratory
SM = Standard Methods for the Examination of Water and Wastewater
SU = standard units

FIGURES



SITE LOCATION MAP

FIGURE 1-1

35 I.A.C. § 845 GROUNDWATER MONITORING PLAN REVISION 1
FLY ASH POND SYSTEM
BALDWIN POWER PLANT
BALDWIN, ILLINOIS

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

Y:\Mapping\Projects\22\2285\Baldwin\MXD\GMP_Addendum\FAPS\Figure 1-2_Site Map.mxd

PROJECT: 169000XXXX | DATED: 10/15/2021 | DESIGNER: HOTCALD

REGULATED UNIT (SUBJECT UNIT) FLY ASH POND SYSTEM (CLOSED)

SITE FEATURE

LIMITS OF FINAL COVER

PROPERTY BOUNDARY

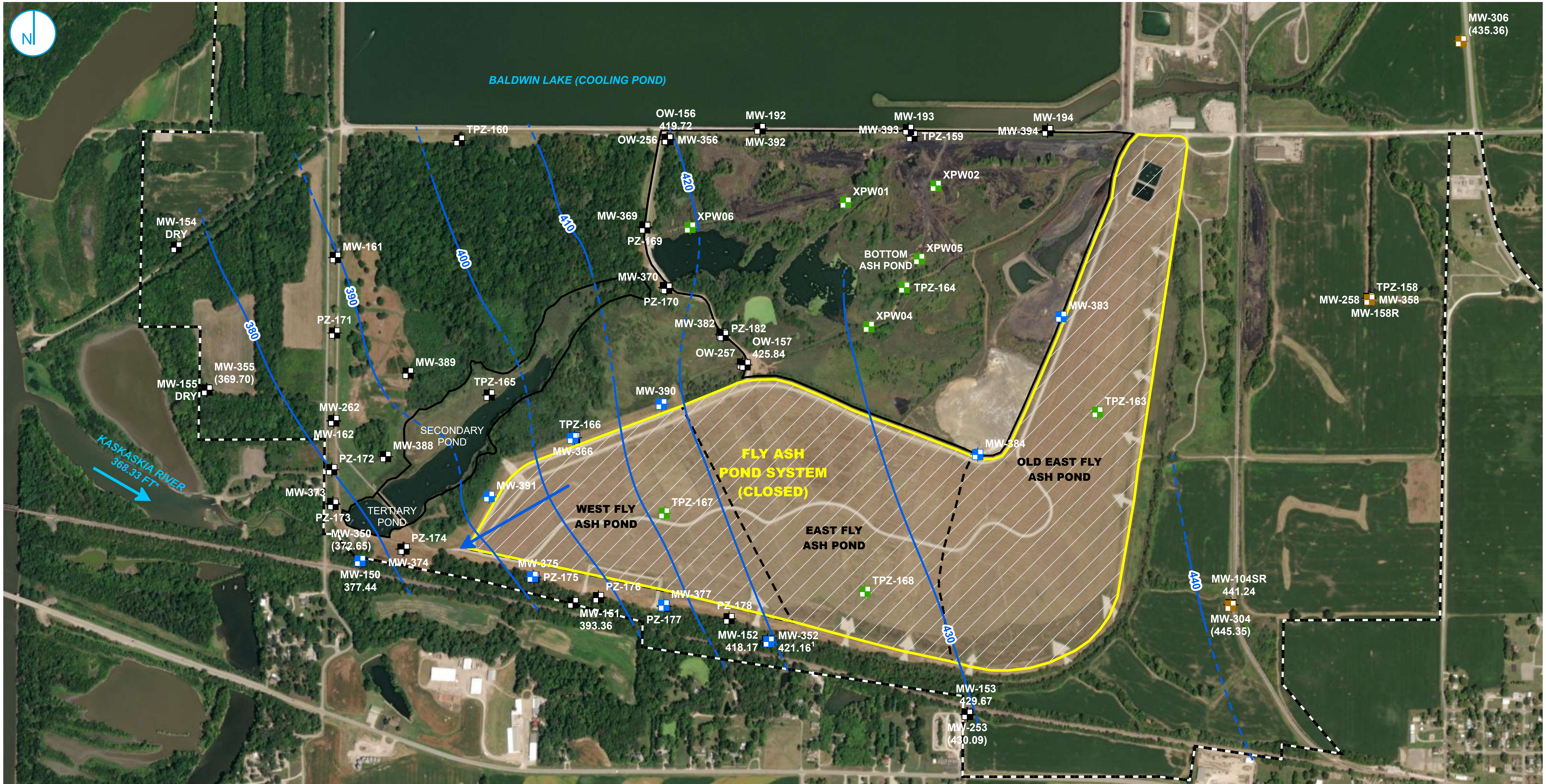
0 400 800 Feet

SITE MAP

35 I.A.C. § 845 GROUNDWATER MONITORING PLAN REVISION 1
FLY ASH POND SYSTEM
BALDWIN POWER PLANT
BALDWIN, ILLINOIS

FIGURE 1-2

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.



NOTE:
ELEVATIONS IN PARENTHESIS NOT USED FOR CONTOURING
[1] = GROUNDWATER ELEVATION ABOVE GROUND SURFACE; ELEVATION NOT USED FOR CONTOURING
*RIVER ELEVATION OBTAINED FROM UNITED STATES GEOLOGICAL SURVEY KASKASKIA RIVER NEAR RED BUD, IL GAUGING STATION (05595240). ELEVATION WAS REPORTED IN NGVD29 THEN CONVERTED TO NAVD88.

PROJECT: 169000XXXX | DATED: 7/19/2023 | DESIGNER: GALARNMC

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COMPLIANCE MONITORING WELL
BACKGROUND MONITORING WELL
MONITORING WELL
PORE WATER WELL
GROUNDWATER ELEVATION CONTOUR (10-FT CONTOUR INTERVAL, NAVD88)
INFERRED GROUNDWATER ELEVATION CONTOUR
GROUNDWATER FLOW DIRECTION
REGULATED UNIT (SUBJECT UNIT)
SITE FEATURE
LIMITS OF FINAL COVER
PROPERTY BOUNDARY

0 400 800 Feet

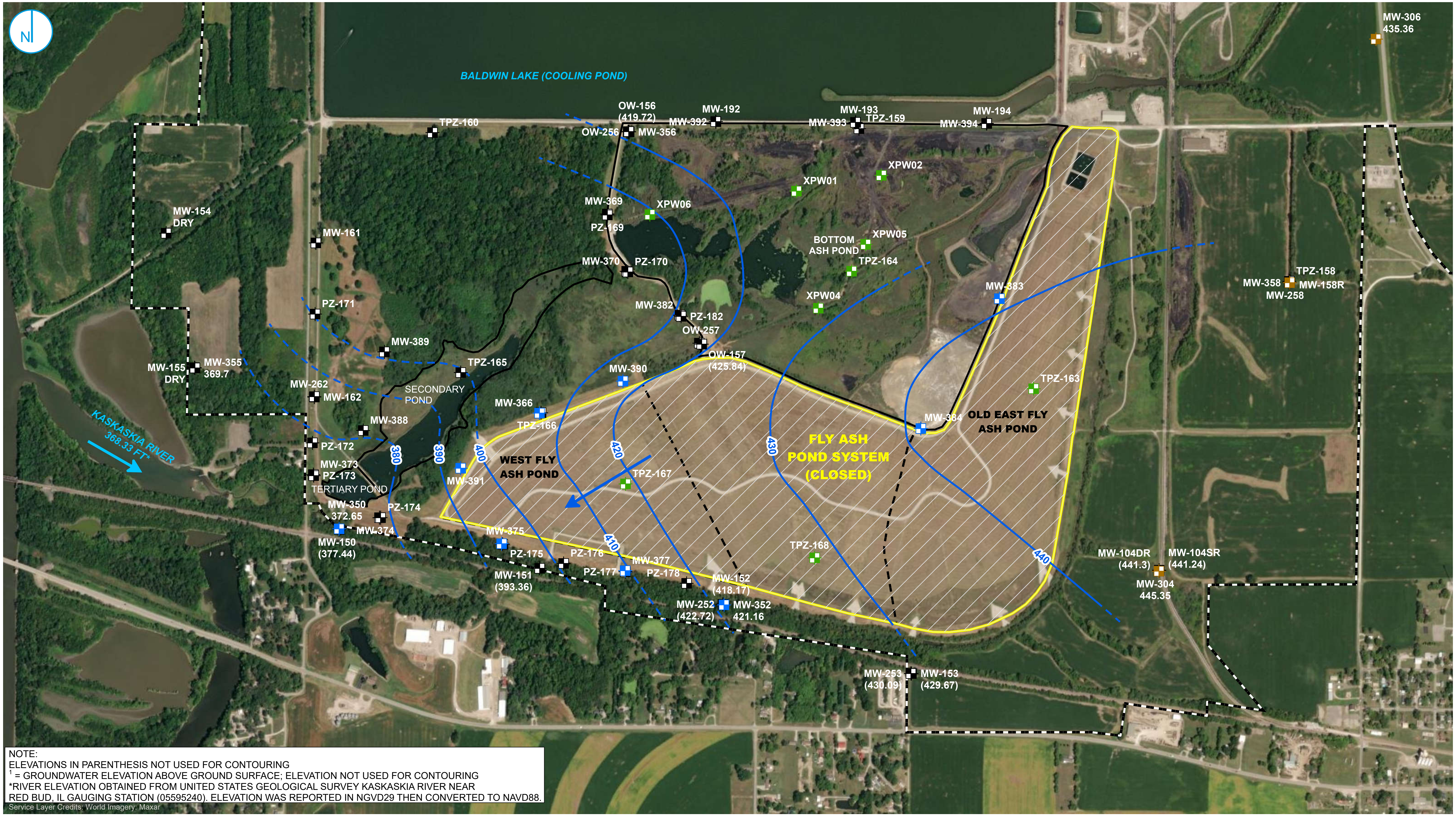
UPPER UNIT POTENTIOMETRIC SURFACE MAP
DECEMBER 5-6, 2022

35 I.A.C. § 845 GROUNDWATER MONITORING PLAN REVISION 1
FLY ASH POND SYSTEM
BALDWIN POWER PLANT
BALDWIN, ILLINOIS

FIGURE 1-3

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.

RAMBOLL



NOTE:
ELEVATIONS IN PARENTHESIS NOT USED FOR CONTOURING
[1] = GROUNDWATER ELEVATION ABOVE GROUND SURFACE; ELEVATION NOT USED FOR CONTOURING
*RIVER ELEVATION OBTAINED FROM UNITED STATES GEOLOGICAL SURVEY KASKASKIA RIVER NEAR RED BUD, IL GAUGING STATION (05595240). ELEVATION WAS REPORTED IN NGVD29 THEN CONVERTED TO NAVD88.

COMPLIANCE MONITORING WELL
BACKGROUND MONITORING WELL
MONITORING WELL
PORE WATER WELL

GROUNDWATER ELEVATION CONTOUR (10-FT CONTOUR INTERVAL, NAVD88)
INFERRED GROUNDWATER ELEVATION CONTOUR
GROUNDWATER FLOW DIRECTION

REGULATED UNIT (SUBJECT UNIT)
SITE FEATURE
LIMITS OF FINAL COVER
PROPERTY BOUNDARY

0 400 800 Feet

BEDROCK POTENTIOMETRIC SURFACE MAP
DECEMBER 5-6, 2022

35 I.A.C. § 845 GROUNDWATER MONITORING PLAN REVISION 1
FLY ASH POND SYSTEM
BALDWIN POWER PLANT
BALDWIN, ILLINOIS

FIGURE 1-4

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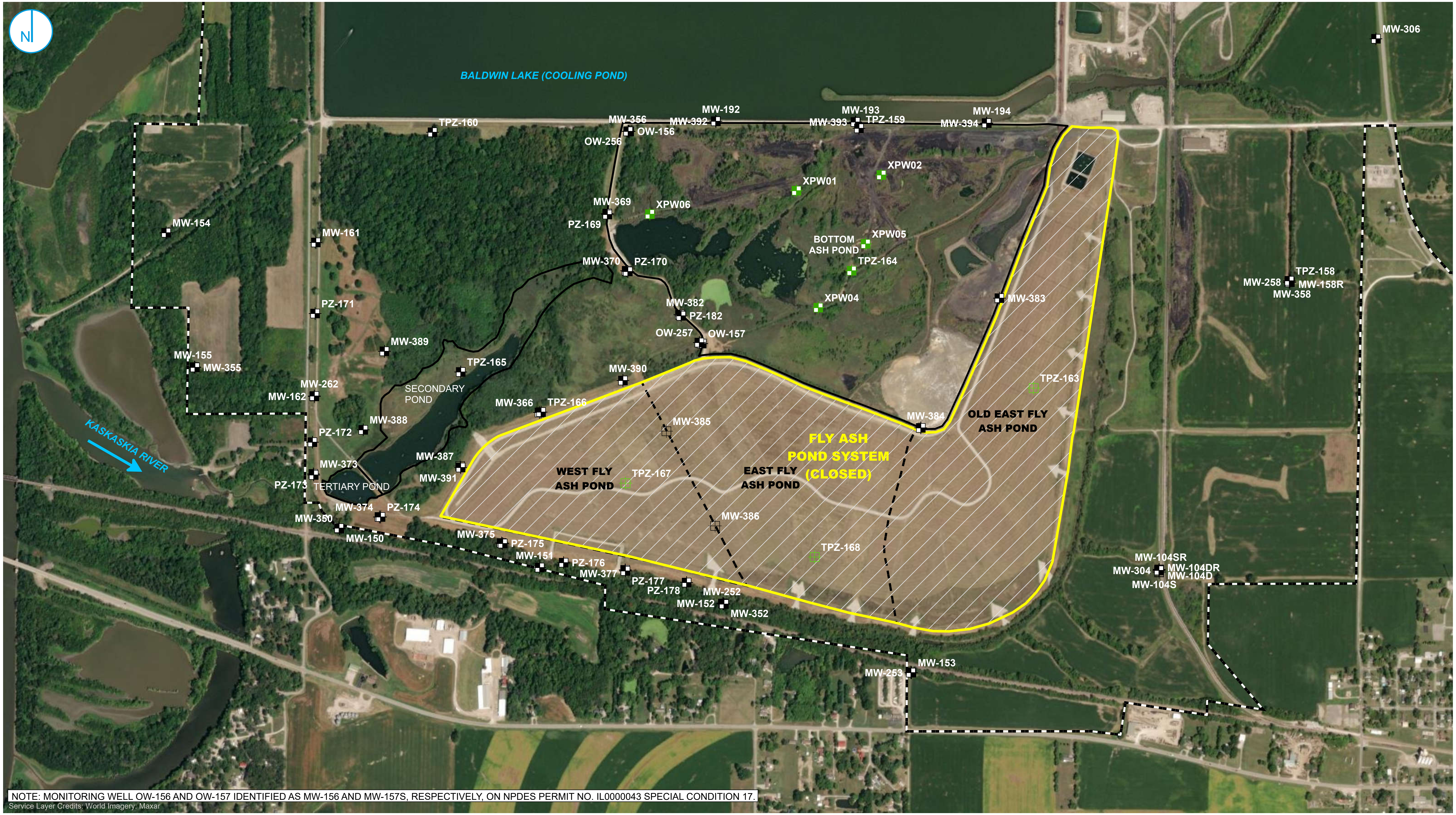
PROJECT: 169000XXXX | DATED: 7/19/2023 | DESIGNER: GALARNMC



PROJECT: 169000XXXX | DATED: 7/18/2023 | DESIGNER: GALARNMC

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MONITORING WELL AND PIEZOMETER LOCATION
PORE WATER WELL
CLOSED MONITORING WELL
CLOSED PORE WATER WELL
REGULATED UNIT (SUBJECT UNIT)
SITE FEATURE
CAPPED AREA
PROPERTY BOUNDARY

0 400 800 Feet

MONITORING WELL LOCATION MAP

35 I.A.C. § 845 GROUNDWATER MONITORING PLAN REVISION 1
FLY ASH POND SYSTEM
BALDWIN POWER PLANT
BALDWIN, ILLINOIS

FIGURE 2-1

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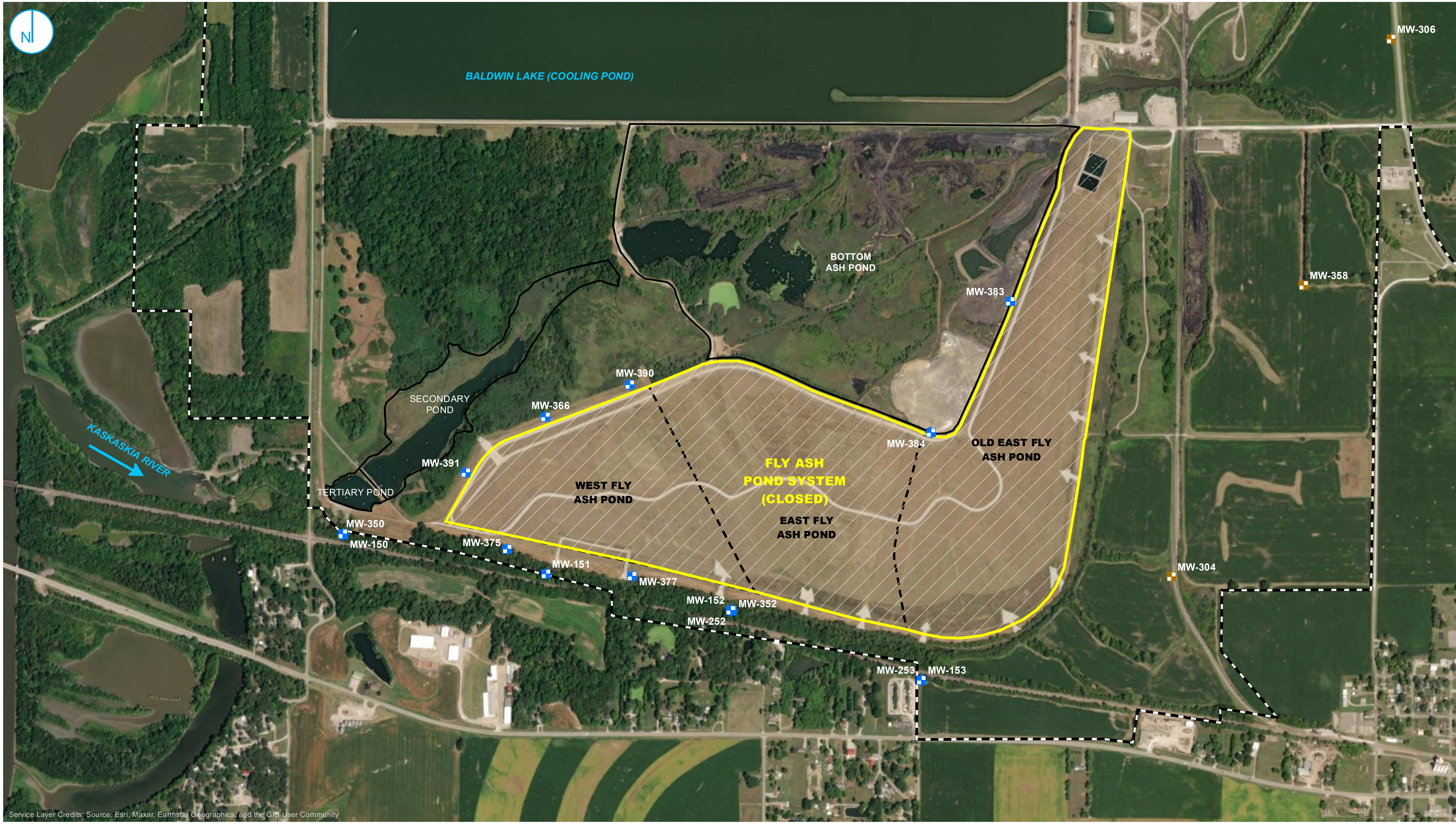

Y:\Mapping\Projects\22\2285\MXD\845_Operating_Permit\Baldwin\FAPS\GMP\Figure 2-2_BAL FAPS Expanded Monitoring Well Network.mxd

PROJECT: 169000XXXX | DATED: 7/31/2023 | DESIGNER: GALARNMC

BACKGROUND MONITORING WELL
COMPLIANCE MONITORING WELL
REGULATED UNIT (SUBJECT UNIT) SITE
FEATURE
CAPPED AREA
PROPERTY BOUNDARY

0 400 800 Feet

PROPOSED 35 I.A.C. § 845 GROUNDWATER MONITORING NETWORK

FIGURE 2-2

35 I.A.C. § 845 GROUNDWATER MONITORING PLAN REVISION 1
FLY ASH POND SYSTEM
BALDWIN POWER PLANT
BALDWIN, ILLINOIS

RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.

APPENDIX A
STATISTICAL ANALYSIS PLAN REVISION 1

Date
August 25, 2023

Project No.
1940103649-002

STATISTICAL ANALYSIS PLAN REVISION 1

FLY ASH POND SYSTEM
BALDWIN POWER PLANT
BALDWIN, ILLINOIS

Bright ideas. Sustainable change.

STATISTICAL ANALYSIS PLAN REVISION 1
BALDWIN POWER PLANT FLY ASH POND SYSTEM

Project name	**Baldwin Power Plant Fly Ash Pond System**
Project no.	**1940103649-002**
Recipient	**Vistra Corp**
Document type	**Statistical Analysis Plan**
Revision	**FINAL**
Revision No.	**1**
Date	**August 25, 2023**
Prepared by	**Rachel Banoff and Alison O'Connor**
Checked by	**Eric J. Tlachac, PE**
Approved by	**Brian G. Hennings, PG**

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Senior Managing Hydrogeologist

LICENSED PROFESSIONAL CERTIFICATIONS

This certification is based on the description of the statistical methods selected to evaluate groundwater as presented in the following Statistical Analysis Plan Revision 1; Baldwin Power Plant Fly Ash Pond System. The procedures described in the plan will be used to establish background conditions and implement compliance and corrective action monitoring as necessary and required by 35 I.A.C. §§ 845.640, 845.650, and 845.680. The Statistical Analysis Plan Revision 1 was prepared in accordance with the requirements of 35 I.A.C. § 845.640(f), with reference to the acceptable statistical procedures provided in the United States Environmental Protection Agency (USEPA)'s *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (*Unified Guidance,* March 2009), and is intended to provide a logical process and framework for conducting the statistical analysis of the data obtained during groundwater monitoring. In accordance with 35 I.A.C. § 845.640(f)(1), the statistical method chosen for analysis of background groundwater quality is the tolerance interval procedure for each constituent listed in 35 I.A.C. § 845.600(a)(1) at this CCR unit per 35 I.A.C. § 845.640(f)(1)(C). Groundwater Protection Standards (GWPS) will be established in accordance with 35 I.A.C. § 845.600(a) (greater of the background concentration or numerical limit specified in 35 I.A.C. § 845.600(a)(1)). The GWPS will be compared to the lower confidence limit for the observed concentrations for each constituent in each compliance well. Consistent with the *Unified Guidance*, the same general statistical method of confidence interval testing against a fixed GWPS is recommended in compliance and corrective action programs. Confidence intervals provide a flexible and statistically accurate method to test how a parameter estimated from a single sample compares to a fixed numerical limit. Confidence intervals explicitly account for variation and uncertainty in the sample data used to construct them.

Description of the statistical methods chosen for analysis of groundwater monitoring data and application of these methods for determining exceedances of the GWPS identified in 35 I.A.C. § 845.600(a) is provided in this Statistical Analysis Plan Revision 1.

35 I.A.C. § 845.640 Statistical Analysis (PE)

I, Eric J. Tlachac, a qualified professional engineer in good standing in the State of Illinois, certify that the statistical methods summarized above and described in this document (Statistical Analysis Plan Revision 1; Baldwin Power Plant Fly Ash Pond System) are appropriate for evaluating the groundwater monitoring data collected as described in the attached document and are in substantial compliance with 35 I.A.C. § 845.640.

Eric J. Tlachac
Qualified Professional Engineer
062-063091
Illinois
Date: August 25, 2023

35 I.A.C. § 845.640 Statistical Analysis (PG)

I, Brian G. Hennings, a qualified professional geologist in good standing in the State of Illinois, certify that the statistical methods described in this document (Statistical Analysis Plan Revision 1; Baldwin Power Plant Fly Ash Pond System) are appropriate for evaluating the groundwater monitoring data collected as described in the attached document and are in substantial compliance with 35 I.A.C. § *845.640.*

Brian G. Hennings
Professional Geologist
196.001482
Illinois
Date: August 25, 2023

LICENSED PROFESSIONAL GEOLOGIST
BRIAN G. HENNINGS
196.001482
ILLINOIS

35 I.A.C. § 845.640 Statistical Analysis

I, Rachel A. Banoff, a qualified professional, certify that the statistical methods described in this document (Statistical Analysis Plan Revision 1; Baldwin Power Plant Fly Ash Pond System), are appropriate for evaluating the groundwater monitoring data collected as described in the attached document and are in substantial compliance with 35 I.A.C. § *845.640.*

Rachel A. Banoff, EIT
Project Statistician
Date: August 25, 2023

CONTENTS

FIGURES

ACRONYMS AND ABBREVIATIONS

%	percent
§	Section
35 I.A.C.	Title 35 of the Illinois Administrative Code
40 C.F.R.	Title 40 of the Code of Federal Regulations
ANOVA	analysis of variance
ASD	alternate source demonstration
BPP	Baldwin Power Plant
CCR	coal combustion residuals
CCR Rule	Subtitle D of RCRA (40 C.F.R. § 257 Subpart D) published in Volume 80 of the F.R. 21302-21501, April 17, 2015, and amended as published in 83 F.R. 36435-36456, July 30, 2018
CMA	Corrective Measures Assessment
DQR	Double Quantification Rule
FAPS	Fly Ash Pond System
F.R.	Federal Register
GMP	Groundwater Monitoring Plan
GWPS	groundwater protection standard
HBL	health-based level
IEPA	Illinois Environmental Protection Agency
LCL	lower confidence limit
LPL	lower prediction limit
MCL	maximum contaminant level
MDL	Method Detection Limit
MSE	mean squared error
PQL	Practical Quantitation Limit
RCRA	Resource Conservation and Recovery Act
RL	reporting limit
ROS	regression on order statistics
SI	surface impoundment
SSL	statistically significant level
SWFPR	site-wide false positive rate
UCL	upper confidence limit
Unified Guidance	Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance (USEPA, 2009)
USEPA	United States Environmental Protection Agency
UTL	upper tolerance limit

REVISION SUMMARY

Revision Date	Description of Changes (Section title or number – description)
10/25/2021	•Original Document
8/25/2023	•Updated statistical methodology for determining background concentrations •Updated statistical methodology for determining compliance with groundwater protection standards and background concentrations •Added statistical methodology for corrective action monitoring

1. INTRODUCTION

In April 2021, the Illinois Environmental Protection Agency (IEPA) issued a final rule for the regulation and management of Coal Combustion Residuals (CCR) in surface impoundments (SIs) under the Standards for the Disposal of CCR in Surface Impoundments: Title 35 of the Illinois Administrative Code (35 I.A.C.) § 845. Facilities regulated under 35 I.A.C. § 845 are required to develop and sample a groundwater monitoring well network to evaluate whether impounded CCR materials are impacting compliance groundwater quality. The groundwater quality evaluation must include selection and certification by a qualified professional engineer of the statistical procedures to be used. The procedures described in the evaluation will be used to establish background conditions and implement compliance and corrective action monitoring as necessary and required by 35 I.A.C. §§ 845.640, 845.650, and 856.680. This Statistical Analysis Plan was prepared for the Fly Ash Pond System (FAPS) at the Baldwin Power Plant (BPP) in accordance with the requirements of 35 I.A.C. § 845.640(f), with reference to the acceptable statistical procedures provided in United States Environmental Protection Agency's (USEPA's) Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance (Unified Guidance) (March 2009).

This Statistical Analysis Plan does not include procedures for groundwater sample collection and analysis, as these activities are conducted in accordance with the Groundwater Monitoring Plan (GMP) Revision 1 prepared for the FAPS in accordance with 35 I.A.C. § 845.640. This Statistical Analysis Plan will be used as the primary reference for evaluating groundwater quality during operation, post-closure care, and corrective action, if necessary.

1.1 Statistical Analysis Objectives

This Statistical Analysis Plan Revision 1 is intended to provide a framework for conducting the statistical analyses of data obtained during groundwater monitoring conducted in accordance with the GMP Revision 1. It will enable a qualified professional engineer to certify that the selected statistical methods are appropriate for evaluating the groundwater monitoring data for FAPS.

1.2 Statistical Analysis Plan Approach

The main sections of this Statistical Analysis Plan Revision 1 should be viewed as a "generic" outline of statistical methods for each CCR unit and required constituent. The statistical analysis of the groundwater monitoring data, however, will be conducted on an individual constituent basis, and may involve the use of appropriate statistical procedures depending on multiple factors such as detection frequency and normality.

35 I.A.C. § 845 outlines three phases of groundwater monitoring:

- Baseline monitoring in accordance with 35 I.A.C. § 845.650(b)(1)
- Compliance monitoring in accordance with 35 I.A.C. § 845.650
- Corrective action monitoring in accordance with 35 I.A.C. § 845.780(c)

Each phase of the groundwater monitoring program requires specific statistical procedures to accomplish the intended purpose. During the first phase, background groundwater quality is established utilizing background wells. Compliance monitoring then evaluates whether exceedances occur for 20 required constituents relative to the groundwater protection standard

(GWPS) established in accordance with 35 I.A.C. § 845.600(a) (concentration specified in 35 I.A.C. § 845.600(a)(1) or an IEPA-approved background concentration). If an exceedance is confirmed and not demonstrated to be caused by a source other than the CCR unit being monitored, corrective measures will be evaluated for implementation to respond to and control a release. Corrective action monitoring is initiated upon implementation of the selected corrective measures.

2. BASELINE MONITORING AND DATA PREPARATION

The background and compliance monitoring wells were sampled and analyzed for constituents, as listed in 35 I.A.C. §§ 845.600(a)(1) and 845.650(a) (antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chloride, chromium, cobalt, fluoride, lead, lithium, mercury, molybdenum, pH, radium 226 and 228 combined, selenium, sulfate, thallium, total dissolved solids, and turbidity), during the baseline phase of the groundwater monitoring program.

The background monitoring well(s) were placed upgradient of the CCR unit, or at an alternative background location, where they are not influenced by the CCR unit. Compliance monitoring wells were placed at the waste boundary of the CCR unit, along the same groundwater flow path. As 35 I.A.C. § 845.630(a) specifies, the location of these wells ensures that background accurately represents the quality of unaffected groundwater, while compliance wells accurately represent groundwater quality at the waste boundary and monitor all potential contaminant pathways.

The following subsections outline the statistical tests and procedures (methods) utilized to evaluate data collected for each constituent in both background and compliance wells for baseline, compliance, and corrective action monitoring. When necessary and contingent upon equivalent statistical power, an alternative test not included in this Statistical Analysis Plan may be chosen due to site-specific data requirements.

2.1 Sample Independence

Independence of sample results is a major assumption for most statistical analyses. To ensure physical independence of groundwater sampling results, the minimum time between sampling events must be longer than the time required for groundwater to move through the monitoring well. Therefore, the minimum time interval between sampling events is a function of the groundwater velocity and well bore volume (diameter of the well and surrounding filter pack). The sampling schedules for both the baseline and compliance monitoring periods are specified in 35 I.A.C. § 845.650(b) and may conflict with the statistical assumption of independence of sample results.

2.2 Non-Detect Data Processing

Groundwater sample analysis results below the reporting limit (RL), also referred to as the Practical Quantitation Limit (PQL), will not be used in statistical calculations due to the inherent uncertainty in results that are estimated between the Method Detection Limit (MDL) and RL/PQL, and error assumptions inherent to the statistical calculations. Results below the RL/PQL will be considered non-detect data. For all statistical test procedures:

- If the frequency of non-detect data are less than or equal to 15 percent (%), half of the RL will be substituted for these data.
- If the non-detect frequency is between 15% and 50% non-detect, and the data is normally distributed, the Kaplan-Meier method will be used to estimate the mean and standard deviation adjusted for the presence of left-censored values.
- If the non-detect frequency is greater than 50%, a non-parametric test or calculation will be used.

- If only one background result is detected, that value will be used as the non-parametric upper tolerance limit (UTL).

2.3 Testing for Normality

Parametric statistical analyses assume that sample data are normally distributed. However, environmental data are frequently non-normally distributed, and therefore require non-parametric analyses. 35 I.A.C. § 845.640(g) requires the knowledge of the distribution, or normality, of the constituent data for selection of the appropriate statistical methods. The Unified Guidance document recommends the Shapiro-Wilk normality test for sample sizes of 50 or less, and the Shapiro-Francia normality test for sample sizes greater than 50. When possible, transformation of datasets to achieve normal distributions is preferred.

2.4 Testing for Outliers

Groundwater analytical data will be screened for the existence of outliers using methods described by the Unified Guidance. Outliers are extreme data points that may represent an anomaly or erroneous data point. To test for outliers, one or more of the following outlier tests will be utilized:

- Dixon's test, for well-constituent pairs with less than 25 samples, assumes normally distributed data.
- Rosner's test, for well-constituent pairs with more than 20 samples, assumes normally distributed data.
- Grubb's test for well-constituent pairs with seven or more samples, assumes normally distributed data.
- Time series, box-whisker plots, and probability plots provide visual tools to identify potential outliers, and evaluation of seasonal, spatial, or temporal variability for both normally and non-normally distributed data.

When necessary, a confirmatory sample will be collected to allow the facility to distinguish between an outlier and a true release from the facility. If re-sampling is necessary, this sample will be collected within 90 days following outlier identification. If the confirmatory sample indicates the original result as an outlier, it will be reported as such, and not as a release from the CCR unit. Data quality control, groundwater geochemistry, and sampling procedures will be evaluated as potential sources of error leading to an outlier result. Professional judgement will be used to exclude extreme outliers from further statistical analyses. Outliers will be retained in the database.

2.5 Trend Analysis

Statistical analyses confirming the lack of trend are a fundamental step to confirm the assumption that groundwater quality values (*i.e.,* constituent means) are stationary or constant over time at a CCR unit. These analyses allow for evaluation of variation in the background and compliance data for each constituent over time. A statistically significant increasing trend in the background data could indicate an existing release from the CCR unit or alternate source requiring further investigation. In addition, statistically significant trending background data can result in increased standard deviation and, therefore, greater prediction or tolerance limits. Consequently, the increased prediction or tolerance limit will have less statistical power or ability to identify a release from a CCR unit.

A linear regression, coupled with a t-test for slope significance, may be used on datasets for each constituent with few non-detects and a normally distributed variance of the mean to evaluate time trends. The Theil-Sen trend line, coupled with the Mann-Kendall test for slope significance, will be used for datasets with frequent non-detects or non-normal variance. Similarly, trend analyses could also be used on compliance data to evaluate a possible release from the CCR unit.

2.6 Spatial Variation

Spatial trends and/or variation between background wells could indicate an existing release from a CCR unit. If the spatial variability is not due to an existing release, intrawell comparisons in compliance wells may be used to account for spatial variability and monitor for a future release. However, the FAPS was placed into service prior to the start of groundwater monitoring, and it is unknown whether a previous release has occurred. Accordingly, intrawell comparisons in compliance wells cannot be used to determine the occurrence of a future release. Interwell comparisons between compliance wells and background wells will be used in these cases.

2.7 Temporal Variation

Time series plots can be used to identify temporal dependence. Potentially significant temporal components of variability can be identified by graphing single constituent data from multiple wells together on a time series plot. With temporal dependence, the time series plot has a pattern of parallel traces, in which the individual wells will tend to rise and fall together across the sequence of sampling dates. Time series plots can be helpful by plotting multiple constituents over time for the same well, or averaging values for each constituent across wells on each sampling event and then plotting the averages over time. In either case, the plots can signify whether the general concentration pattern over time is simultaneously observed for different constituents. If so, it may indicate that a group of constituents is highly correlated in groundwater or that the same artifacts of sampling and/or lab analysis impacted the results of several monitoring parameters.

Hydrologic factors such as drought, recharge patterns or regular (*e.g.,* seasonal) water table fluctuations may be responsible for the temporal variation. In these cases, it may be useful to test for the presence of a significant temporal effect by first constructing a parallel time series plot and then running a formal one-way analysis of variance (ANOVA) ($\alpha = 0.05$) for temporal effects. A one-way ANOVA for temporal effects considers multiple well data sets for individual sampling events or seasons as the relevant statistical factor. If event-specific analytical differences or seasonality appear to be an important temporal factor, the one-way ANOVA for temporal effects can be used to formally identify seasonality, parallel trends, or changes in lab performance that affect other temporal effects. The one-way ANOVA for temporal effects assumes that the data groups are normally distributed with constant variance. It is also assumed that for each of a series of background wells, measurements are collected at each well on sampling events or dates common to all the wells. Results of the ANOVA can also be used to create temporally stationary residuals, where the temporal effect has been 'subtracted from' the original measurements. These stationary residuals may be used to replace the original data in subsequent statistical testing.

If the data cannot be normalized, a similar test for a temporal or seasonal effect can be performed using the Kruskal-Wallis test ($\alpha = 0.05$). Each sampling event should be treated as a separate 'well,' while each well is treated as a separate 'sampling event.' In this case, no residuals can be computed since the Kruskal-Wallis test employs ranks of the data rather than the measurements themselves.

Where both spatial and temporal variation occur, two-way ANOVA can be considered where both well location and sampling event/season are treated as statistical factors. This procedure is described in Davis (1994).

2.8 Updating Background

Updating the background dataset periodically by adding recent results to an existing background dataset can improve the statistical power and accuracy of the statistical analysis, especially for non-parametric prediction intervals. The Unified Guidance recommends updating statistical limits (background) when at least four to eight new measurements (every 2 to 4 years under a semiannual monitoring program or 1 to 2 years under a quarterly monitoring program) are available for comparison to historical data. Professional judgement will be used to evaluate whether any background data appear to be affected by a release and need to be excluded from a background update. A t-test for equal means (if normal data distribution) or a Mann-Whitney or Wilcoxon test for equal medians (if non-normal data distribution) will be conducted to verify that the two groups of background sample populations are statistically different prior to updating any background datasets. A 0.05 significance level will be utilized when evaluating the two populations, with the null hypothesis that the two populations have equal means or medians. In addition, time series graphs or other trend evaluation statistics (such as a Mann-Kendall test) will be conducted on the new background dataset to verify the absence of a release or changing groundwater quality. If the tests indicate that there are no statistical differences between the two background populations, the new data will be combined with the existing dataset. If the two populations are found to be different, the data will be reviewed to evaluate the cause of the difference. If the differences appear to be caused by a release (*i.e.,* if the new data are significantly higher, or lower for pH), then the previous background dataset may continue to be used. Furthermore, verified outliers will not be added to an existing background dataset. Spatial variability among background wells will also be assessed when background datasets are updated to determine whether pooling data and interwell comparisons are appropriate.

For intrawell evaluations, once an exceedance has been identified for a constituent at a particular well, no additional updates of the background datasets for any parameter will be allowed, unless the exceedance is determined to be caused by something other than a release from the CCR unit. The background dataset can only be updated with new data if the exceedance is proven to be attributed to an alternate source.

3. COMPLIANCE MONITORING PROGRAM

Compliance monitoring is designed to evaluate whether concentrations of constituents listed in 35 I.A.C. § 845.600(a)(1) in compliance wells exceed GWPS or background in a statistically significant manner.

3.1 GWPS Establishment and Exceedance Determination

The GWPS will be the concentration specified in 35 I.A.C. § 845.600(a)(1), unless the background concentration is greater. For this exception, background concentrations will be used to define the GWPS. Background concentrations will be calculated using a parametric or non-parametric upper tolerance limit (UTL), depending on the data distribution.

GWPS exceedances will be determined by comparing the lower confidence limit (LCL) of the compliance well concentrations to the GWPS, except for pH where the LCL will be compared to the upper end of the GWPS range, and the upper confidence limit (UCL) compared to the low end of the GWPS range. A GWPS exceedance is determined if the LCL is greater than the GWPS, and, for pH, either the LCL is greater than the upper end of the GWPS range or the UCL is less than the low end of the GWPS range. The method of calculating the LCL will be determined by sample size, trends in the data, and data normality. The significance level (alpha) for this calculation will be fixed at 0.01 (99% confidence) due to the complexity of evaluating a site-wide false positive rate (SWFPR), as recommended by Unified Guidance. If there are too few data points to calculate an LCL (a minimum of four data points is required), the most recent data point will be compared to the GWPS.

Background exceedances will be determined by comparing the LCL of the compliance well concentrations to the background UTL, with the exception of pH where the UCL of the compliance well concentrations will also be compared to the background lower tolerance limit (LTL). A background exceedance is determined if the LCL is greater than the background UTL, or, for pH, either the LCL is greater than the UTL or the UCL is less than the LTL. If there are too few data points to calculate an LCL (a minimum of four data points is required), the most recent data point will be compared to the background UTL (and LTL for pH).

Additionally, an exceedance of either background or GWPS will be identified if the constituent monitored was not detected in all previous samples at a compliance well and the two most recent samples have both detections and exceed the GPWS (or are less than the low end the GWPS range for pH) or background UTL (or are less than the LTL for pH).

Details regarding the calculation of the UTL and the LCL are described in detail below and outlined in Figures 1 and 2, respectively. Exceedance determination will be completed within 60 days of sampling and analysis.

3.1.1 Upper Tolerance Limit

A parametric UTL will be used to calculate the GWPS when the background data are normally distributed and have a non-detect frequency of 50% or less. The Unified Guidance recommends 95% confidence level and 95% coverage (95/95 tolerance interval). When the non-detect frequency is 15% or less, half the RL will be substituted for non-detects (simple substitution), and the normal mean and standard deviation will be calculated. The Kaplan-Meier method will be used when the detection frequency is between 15% and 50%. The Kaplan-Meier method assesses the linearity of a censored probability plot to determine whether the background sample can be approximately normalized. If so, then the Kaplan-Meier method will be used to compute estimates of the mean and standard deviation adjusted for the presence of left-censored values. The Kaplan-Meier estimate of the mean and standard deviation will be substituted for the sample mean and standard deviation.

The parametric UTL on a future mean will be calculated from the background dataset as follows:

$$UTL = \overline{x} + \kappa\,(n, \gamma, \alpha - 1) \cdot s$$

$\overline{x}$ = background sample mean

s = background sample standard deviation

$\kappa\,(n, \gamma, \alpha - 1)$ = one-sided normal tolerance factor based on the chosen coverage (γ) and confidence level (α -1) and the size of the background dataset (n). Values may be calculated per Millard (2013) or looked up in Table 17-3 in Appendix D of the Unified Guidance.

If the UTL is constructed on the logarithms of original observations to achieve normality, where $\overline{y}$ and s_y are the log-mean and log-standard deviation, the limit will be exponentiated for back-transformation to the concentration scale as follows:

$$TL = \exp\left[\overline{y} + \kappa\,(n, \gamma, \alpha - 1) \cdot s_y\right]$$

$\overline{y}$ = background sample log-mean

s_y = background sample log-standard deviation

If the background data set is non-parametric or has a non-detect frequency greater than 50%, a non-parametric UTL is used. The maximum concentration is used as the non-parametric UTL due to the advantages described in the Unified Guidance. These advantages include the resulting UTL reflecting actual concentration magnitudes, and the UTL more likely representing a detected concentration (unless all the data were non-detect).

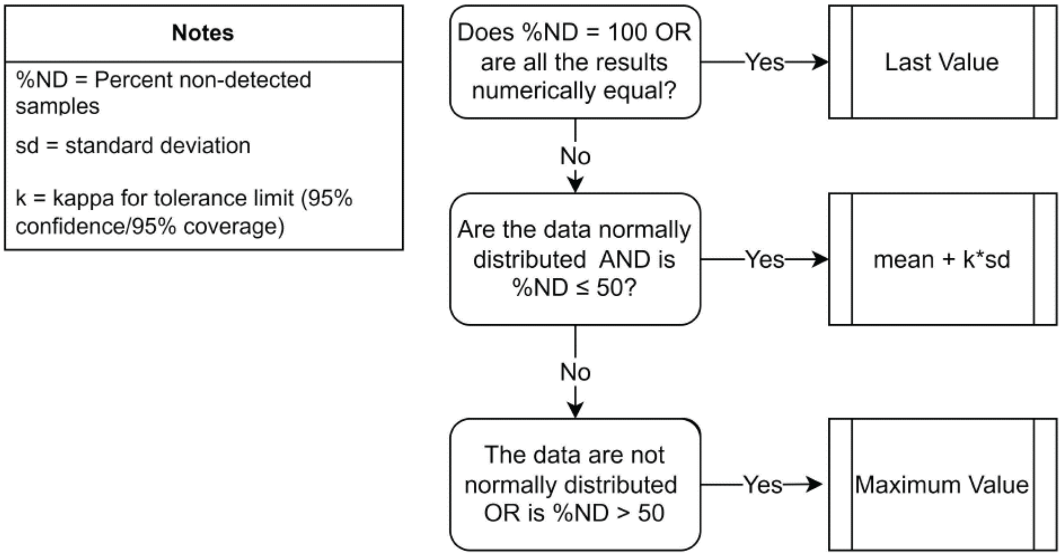

Figure 1. Flow chart illustrating the statistical methods used for calculating background under compliance monitoring.

3.1.2 Confidence Intervals Around Trending Data

If compliance data exhibit a statistically significant trend based on results from a Mann-Kendall trend test, confidence bands accounting for trends will be constructed to account for the trend-induced variation. If this is not accounted for, a wider confidence interval will inevitably be calculated for a given confidence level and sample size (*n*). A wider confidence interval will result in less statistical power, or ability to demonstrate an exceedance or return to compliance. When a linear trend line has been estimated, a series of confidence intervals is estimated at each point along the trend. This creates a simultaneous confidence band that follows the trend line. As the underlying population mean increases or decreases, the confidence band does also to reflect this change at that point in time.

Linear regression will be used when compliance data are approximately normally distributed, with a constant sample variance around the mean, and the frequency of non-detects is below 50%. The linear regression of concentration against sampling date (time) will be computed as follows:

$$\hat{b} = \sum_{i=1}^{n}(t_i - \bar{t}) \cdot x_i/(n-1) \cdot s_t^2$$

x_i = i^{th} concentration value and

t_i = i^{th} sampling date

$\bar{t}$ = sampling mean date

s_t^2 = variance of the sampling dates

This estimate leads to the following regression equation:

$$\hat{x} = \overline{x} + \hat{b} \cdot (\mathrm{t} - \overline{t})$$

$\overline{x}$ = mean concentration level

$\hat{x}$ = estimated mean concentration at time t

The regression residuals will also be computed at each sampling event to ensure uniformity and lack of significant skewness. Regression residuals will be computed at each sampling event as follows:

$$r_i = x_i - \hat{x}_i$$

The estimated variance around the regression line, or mean squared error (MSE) will be computed as follows:

$$s_e^2 = \frac{1}{n-2}\sum_{i=1}^{n} r_i^2$$

The confidence intervals around a linear regression trend line given confidence level (1-α) and a point in time (t_0), will be computed as follows:

$$LCL_{1-\alpha} = \hat{x}_0 - \sqrt{2s_e^2 \cdot F_{1-2\alpha,2,\mathrm{n}-1} \cdot \left[\frac{1}{n} + \frac{\left(t_0 - \overline{t}\right)^2}{(n-1) \cdot s_t^2}\right]}$$

$$UCL_{1-\alpha} = \hat{x}_0 - \sqrt{2s_e^2 \cdot F_{1-2\alpha,2,\mathrm{n}-2} \cdot \left[\frac{1}{n} + \frac{\left(t_0 - \overline{t}\right)^2}{(n-1) \cdot s_t^2}\right]}$$

$\hat{x}_0$ = estimated mean concentration from the regression equation at time t_0

$F_{1-2\alpha,2,\mathrm{n}-2}$ = upper (1-2α)th percentage point from an *F*-distribution with 2 and (*n*-2) degrees of freedom

If the compliance data is not normally distributed or has a non-detect frequency greater than 50%, the Thiel-Sen trend line will be used as a non-parametric alternative to linear regression for calculation of the LCL. The Thiel-Sen trend line estimates the median concentration over time by combining the median pairwise slope with the median concentration value and the median sample date. To compute the Thiel-Sen line, the data will first be ordered by sampling event x_1, x_2, x_n. All possible distinct pairs of measurements (x_i, x_j) for $j > i$ will be considered and the simple pairwise slope estimate will be computed for each pair as follows:

$$m_{ij} = (x_j - x_i)/(j - i)$$

With a sample size of *n*, there will be a total of *N* = *n*(*n*-1)/2 pairwise estimates m_{ij}. If a given observation is a non-detect, half the RL will be substituted. The *N* pairwise slope estimates (m_{ij}) will be ordered from least to greatest (renamed $m_{(1)}$, $m_{(2)}$,..$m_{(N)}$). The Thiel-Sen estimate of slope (*Q*) will be calculated as the median value of the list depending on whether *N* is even or odd as follows:

$$Q = \begin{cases} m_{([N+1]/2)} \; if\ N\ is\ odd \\ (m_{(N/2)} + m_{([N+2]/2)})/2 \; if\ N\ is\ even \end{cases}$$

The sample concentration magnitude will be ordered from least to greatest, $x_{(1)}$, $x_{(2)}$, to $x_{(n)}$ and the median concentration will be calculated as follows:

$$\tilde{x} = \begin{cases} x_{([n+1]/2)} \; if \; n \; is \; odd \\ (x_{(n/2)} + x_{([n+2]/2)})/2 \; if \; n \; is \; even \end{cases}$$

The median sampling date ($\tilde{t}$) with ordered times ($t_{(1)}$, $t_{(2)}$, to $t_{(n)}$) will also be determined in this way. The Thiel-Sen trend line will then be computed for an estimate at any time (t) of the expected median concentration (x) as follows:

$$x = \tilde{x} + Q \cdot (\mathrm{t} - \tilde{t}) = (\tilde{x} - Q \cdot \tilde{t}) + Q \cdot \mathrm{t}$$

In accordance with the Unified Guidance, a confidence band around the Theil-Sen line will only be calculated if at least seven data points are available. To construct a confidence band around the Thiel-Sen line, sample pairs (t_i, x_i) will be formed with a sample date (t_i) and the concentration measurement from that date (x_i). Bootstrap samples (B) will be formed by repeatedly sampling n pairs at random with replacement from the original sample pairs. This will be repeated 500 times. For each bootstrap sample, a Thiel-Sen trend line will be constructed using the equation above. A series of equally spaced time points (t_j) will be identified along the range of sampling dates represented in the original sample, j =1 to m. The Thiel-Sen trend line associated with each bootstrap replicate will be used to compute an estimated concentration ($\hat{x}_j^B$). An LCL will be constructed for the lower αth percentile $\hat{x}_j^{[\alpha]}$from the distribution of estimated concentrations at each time point (t_j). For an upper confidence limit (UCL), compute the upper (1-α)th percentile, $\hat{x}_j^{[1-\alpha]}$ at each time point (t_j).

3.1.3 Parametric Confidence Intervals around a Mean

If compliance data do not show a trend and are normal or log-normal, one-sided parametric confidence intervals around a sample mean will be constructed for each constituent and well pair. The LCL will be calculated as:

$$LCL_{1-\alpha} = \overline{x} - t_{1-\alpha,n-1} \cdot \frac{s}{\sqrt{n}}$$

The UCL will be calculated as:

$$UCL_{1-\alpha} = \overline{x} + t_{1-\alpha,n-1} \cdot \frac{s}{\sqrt{n}}$$

$\overline{x}$ = compliance sample mean

s = compliance sample standard deviation

n = compliance sample size

$t_{1-\alpha,n-1}$ = obtained from a Student's t-table with (n–1) degrees of freedom (Table 16-1 in Appendix D of the Unified Guidance)

The t value will be calculated using the chosen alpha level (0.01) and the degrees of freedom in the comparison (n-1) using the Student's t distribution.

If compliance data are distributed lognormally, the LCL will be computed around the lognormal geometric mean as:

$$LCL_{1-\alpha} = \exp\left(\overline{y} - t_{1-\alpha,n-1} \cdot \frac{s_y}{\sqrt{n}}\right)$$

The UCL will be computed around the lognormal geometric mean as:

$$UCL_{1-\alpha} = \exp\left(\overline{y} + t_{1-\alpha,n-1} \cdot \frac{s_y}{\sqrt{n}}\right)$$

$\overline{y}$ = compliance sample log-mean

s_y = compliance sample log-standard deviation

3.1.4 Non-Parametric Confidence Intervals around a Median

Non-parametric confidence intervals around the median will be computed if the compliance data do not show a trend and contain greater than 50% non-detects or are non-normally distributed. The mathematical algorithm used to construct non-parametric confidence intervals is based on the probability *p* that any randomly-selected measurement in a sample of *n* concentration measurements will be less than an unknown *p* x 100th percentile of interest (where *P* is between 0 and 1). Then the probability that the measurement will exceed the *p* x 100th percentile is (1–*p*). The number of sample values falling below the *p* x 100th percentile out of a set of *n* should follow a binomial distribution with parameters *n* and success probability *p*, where 'success' is defined as the event that a sample measurement is below the *p* x 100th percentile. The probability that the interval formed by a given pair of order statistics will contain the percentile of interest will then be determined by a cumulative binomial distribution *Bin(x;n,p)*, representing the probability of *x* or fewer successes occurring in *n* trials with success probability *p*. *P* will be set to 0.50 for an interval around the median.

The sample size *n* will be ordered from least to greatest. Given *p* = 0.50, candidate interval endpoints will be chosen by ordered data values with ranks rounded upward to the next higher integers. The ranks of the endpoint will be denoted *L** and U* and are calculated using the following equations (Conover, 1999, p. 144).

$$L^* = np - Z_{1-\alpha}\sqrt{np(1-p)}$$

$$U^* = np + Z_{1-\alpha}\sqrt{np(1-p)}$$

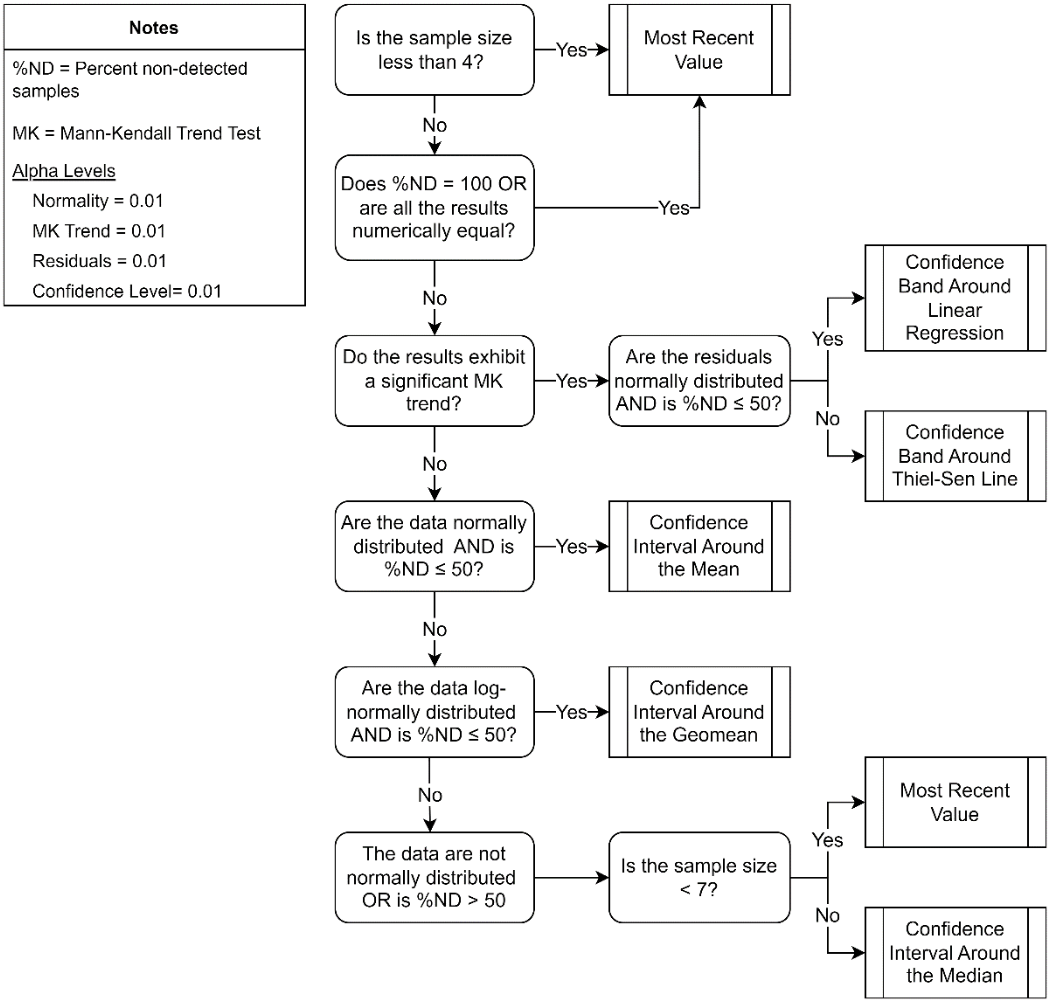

Figure 2. Flow chart illustrating the statistical methods used for calculating confidence intervals in compliance monitoring.

3.2 Resampling

In the event that statistical analyses identify an exceedance relative to the GWPS for one or more parameters, the exceedance parameters and wells of concern may be re-sampled within 90 days. Compliance monitoring statistics will be updated using the compliance verification resample results. If the compliance monitoring statistics using the compliance verification resample results result in an exceedance of the GWPS, the exceedance is confirmed.

4. CORRECTIVE ACTION MONITORING PROGRAM

Corrective action monitoring is performed after a corrective action remedy has been selected and implemented. 35 I.A.C. § 845.680(a)(1) specifies that the corrective action monitoring program must meet all the requirements of a compliance monitoring program required under 35 I.A.C. § 845.650, address any interim measures that might be needed to reduce the contaminants leaching from the CCR unit, and document the effectiveness of the selected remedy. To meet these requirements, the compliance monitoring program described in Section 3 will continue during corrective action monitoring and will be augmented by the procedures described herein and in the corrective action plan required by 35 I.A.C. § 856.670.

4.1 GWPS Establishment and Exceedance Determination

Corrective action monitoring statistical evaluation cannot begin until there are three to eight samples collected for detected 35 I.A.C. § 845.600(a)(1) constituents from corrective action monitoring wells. Verification resamples will not typically be collected in corrective action monitoring unless there are suspected or known errors in field sampling or analysis. Statistical methods used for corrective action monitoring data will be similar to those used for compliance monitoring (Figure 3). One major exception is these analyses will use the UCL to evaluate whether a well is in compliance, rather than the LCL as used in compliance monitoring. This is because, under corrective action monitoring, a release is assumed to have occurred at a facility. Therefore, the null hypothesis is reversed and a facility is assumed to be out of compliance until proven otherwise. A facility is considered to be in compliance when the UCL is lower than the GWPS for all detected 35 I.A.C. § 845.600(a)(1) constituents at all corrective action monitoring wells for 3 consecutive years. Corrective action monitoring will continue if the UCL for any 35 I.A.C. § 845(a)(1) constituent at any corrective action monitoring well is equal to or higher than the GWPS.

5. REFERENCES

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