Corrective Measures Assessment

Baldwin Fly Ash Pond System
Baldwin Energy Complex
10901 Baldwin Road
Baldwin, Illinois

Dynegy Midwest Generation, LLC

September 5, 2019

OBG
Part of Ramboll

SEPTEMBER 5, 2019 | PROJECT #72856

Corrective Measures Assessment

Baldwin Fly Ash Pond System
Baldwin Energy Complex
10901 Baldwin Road
Baldwin, Illinois

Prepared for:

Dynegy Midwest Generation, LLC

FRANCES ACKERMAN
Senior Managing Engineer

BRIAN G. HENNINGS
Managing Hydrogeologist

ERIC J. TLACHAC, PE
Managing Engineer

NICOLE M. PAGAO, PG
Senior Managing Engineer

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

O'Brien & Gere Engineers, Inc., part of Ramboll (OBG), has prepared this Corrective Measures Assessment (CMA) for the Baldwin Fly Ash Pond System located at the Baldwin Energy Complex (BEC, the Site). This CMA report complies with the requirements of Title 40 of the Code of Federal Regulations (C.F.R.) § 257, Subpart D Standards for the Disposal of Coal Combustion Residuals (CCR) in Landfills and Surface Impoundments (CCR Rule). Under the CCR Rule, owners and operators of existing CCR surface impoundments (SIs) must initiate a CMA, in accordance with 40 C.F.R. § 257.96, when one or more Appendix IV constituents are detected at statistically significant levels (SSLs) above groundwater protection standards (GWPS) in the Uppermost Aquifer, and the owner or operator has not completed an alternate source demonstration demonstrating that a source other than the CCR unit has caused the contamination. This CMA is responsive to the 40 C.F.R. § 257.96 and § 257.97 requirements for assessing potential corrective measures to address the exceedance of the GWPS for lithium in the Uppermost Aquifer.

In March 2016, Dynegy Midwest Generation, LLC (DMG) submitted the Closure and Post-Closure Care Plan for the Baldwin Fly Ash Pond System (Closure Plan[AECOM, 2016]) to the Illinois Environmental Protection Agency (IEPA); the Closure Plan set forth source control measures and sought approval to close the Fly Ash Pond System by leaving CCR in place and constructing a final cover system of earthen material. The final cover system will have lower permeability than the subsoils underlying the CCR, will control the potential for water infiltration into the closed CCR unit, and will allow drainage of water off of, and water out of, the closed CCR unit. The Closure Plan included provisions for performing groundwater monitoring to assess natural attenuation and maintenance of the final cover system as measures to address exceedances of GWPS. The IEPA subsequently approved the Closure Plan in a letter to Dynegy Operating Company dated August 16, 2016 (IEPA, 2016). Construction of the final cover system is currently underway and will be completed by November 2020.

This CMA is the first step in developing a long-term corrective action plan to address lithium SSLs in the Uppermost Aquifer. Source control measures are currently being implemented, including pumping to remove surface water, dewatering the CCR, relocating and/or reshaping the existing CCR to achieve acceptable grades for closure, and constructing an earthen cover system (additional details are discussed in Section 2). The source control measures also address CCR constituents in groundwater in the unlithified deposits above the Uppermost Aquifer. This CMA has been prepared to evaluate applicable remedial measures to address the lithium SSLs in the Uppermost Aquifer. The results of the CMA will be used to guide whether additional site-specific data are necessary to develop a long-term corrective action plan for the Uppermost Aquifer, consistent with 40 C.F.R. § 257.96 and § 257.97 requirements.

1.1 CORRECTIVE MEASURES ASSESSMENT OBJECTIVES AND METHODOLOGY

The objective of this CMA is to begin the process of evaluating appropriate corrective measure(s) to address impacted groundwater in the Uppermost Aquifer potentially associated with the Fly Ash Pond System at the BEC. The CMA evaluates the effectiveness of the corrective measures in meeting the requirements and objectives of the remedy, as described under 40 C.F.R. § 257.96(c), by addressing the following evaluation criteria:

- Performance
- Reliability
- Ease of implementation
- Potential impacts of appropriate potential remedies (safety impacts, cross-media impacts, and control of exposure to any residual contamination)
- Time required to begin and complete the remedy
- Institutional requirements that may substantially affect implementation of the remedy(s) (permitting, environmental or public health requirements)

The CMA provides a systematic, rational method for evaluating potential corrective measures. The assessment process documented herein: a) identifies the site-specific conditions that will influence the effectiveness of the potential corrective measures (Section 2); b) identifies applicable corrective measures (Section 3); c) assesses the corrective measures against the evaluation criteria to select potentially feasible corrective measures (Section 4); and d) summarizes the remedy selection process and future actions (Section 5).

1.2 EVALUATION CRITERIA

The evaluation criteria are defined below to provide a common understanding and consistent application. The evaluation included qualitative and/or semi-quantitative screening of the corrective measures relative to their general performance, reliability and ease of implementation characteristics, and their potential impacts, timeframes and institutional requirements. Evaluations were at a generalized level of detail in order to screen out corrective measures that were not expected to meet 40 C.F.R. § 257.97 design criteria, while retaining corrective measures that would meet the design criteria.

The evaluation does not explicitly address and document compliance with each of the specific elements included in the definitions below. Rather, the evaluation considered the elements qualitatively, applying engineering judgement, to provide a reasoned set of corrective measures that could be used, either individually or in combination, to supplement the source control measures and achieve GWPS in the most effective and protective manner.

1.2.1 Performance

The performance of potentially applicable corrective measures was evaluated for the:

1. Potential to ensure that any environmental releases to groundwater, surface water, soil and air will be at or below relevant regulatory and health-based benchmarks for human and ecological receptors.
2. Degree to which the corrective measure isolates, removes or contains SSLs identified in the Uppermost Aquifer.
3. Ability of the corrective measure to achieve GWPS within the Uppermost Aquifer at the compliance boundaries.

1.2.2 Reliability

The reliability of the corrective measure is a description of its ability to function as designed until the GWPS are achieved in the Uppermost Aquifer at the compliance boundaries. Evaluation of the reliability included considering:

1. Type and degree of long-term management required, including monitoring, operation, and maintenance.
2. Long-term reliability of the engineering and institutional controls associated with the corrective measure.
3. Potential need for replacement of the corrective measure.

1.2.3 Ease of Implementation

The ease or difficulty of implementing a given corrective measure was evaluated by considering:

1. Degree of difficulty associated with constructing the corrective measure.
2. Expected operational reliability of the corrective measure.
3. Need to coordinate with and obtain necessary approvals and permits.
4. Availability of necessary equipment and specialists.
5. Available capacity and location of needed treatment, storage, and disposal services.

1.2.4 Potential Impacts of the Remedy

Potential impacts associated with a given corrective measure included consideration of impacts on the distribution and/or transport of contaminants, safety impacts (the short-term risks that might be posed to the community or the environment during implementation), cross-media impacts (increased traffic, noise, fugitive dust), and control of potential exposure of humans and environmental receptors to remaining wastes.

1.2.5 Time Required to Begin, Implement, and Complete the Remedy

Evaluating the time required to begin the remedy focused on the site-specific conditions that could require additional or extended timeframes to characterize, design, and/or field test a corrective measure to verify the applicability and effectiveness of a corrective measusre. The length of time that would be required to begin and implement the remedy was considered to be the total time to: 1) verify applicability and effectiveness; and 2) to complete construction of the corrective measure.

The time required to complete the remedy considered the total time after the corrective measure was implemented until GWPS would be achieved in the Uppermost Aquifer at the compliance boundaries.

1.2.6 Institutional, Environmental or Public Health Requirements

Institutional, environmental and public health requirements considered state, local, and site-specific permitting or other requirements that could substantially affect construction or implementation of a corrective measure.

2 SITE HISTORY AND CHARACTERIZATION

2.1 SITE DESCRIPTION AND HISTORY

The BEC is owned and operated by DMG, and is located in southwest Illinois in Randolph and St. Clair Counties. The Randolph County portion of the BEC 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 Baldwin Fly Ash Pond System is approximately one-half mile west-northwest of the Village of Baldwin (Figure 1).

The BEC is a coal-fired electrical generating plant that began operation of its first unit in 1970; two additional generating units were put into service in 1973 and 1975. The plant initially burned bituminous coal from Illinois and switched to subbituminous coal in 1999. Total plant generating capacity is approximately 1,892 megawatts.

The BEC property is bordered on the west by the Kaskaskia River; on the east by Baldwin Road, farmland, and strip mining areas; on the southeast by the village of Baldwin; on the south by the Illinois Central Gulf railroad tracks, scattered residences, and State Route 154; and on the north by farmland. The St. Clair/Randolph County Line crosses east-west at approximately the midpoint of the Baldwin Power Plant Cooling Lake. Figure 1 shows the location of the plant; Figure 2 is a site plan showing the location of the Fly Ash Pond System and groundwater monitoring system established in accordance with the requirements of 40 C.F.R. § 257.91.

The Fly Ash Pond System at the BEC is a CCR Multi-Unit consisting of three unlined SIs: the East Fly Ash Pond, Old East Fly Ash Pond, and West Fly Ash Pond, with a combined surface area of approximately 232 acres. The Fly Ash Pond System discharged to the Bottom Ash Pond, which discharged to the Secondary Pond, and in turn to the Tertiary Pond, which ultimately discharges to a tributary of the Kaskaskia River, south of the Cooling Pond intake structure. The elevation of the top of ash is lower than the surrounding berms, which provide full ash containment. The Fly Ash Pond System is estimated to contain about 10,000,000 cubic yards (CY) of CCR.

2.2 GEOLOGY AND HYDROGEOLOGY

Geologic units present at the Fly Ash Pond System include fill, ash generated at BEC, and unlithified glacial deposits overlying Mississippian and Pennsylvanian bedrock. Outside of the fill material, groundwater in the unlithified deposits from the water table to the top of bedrock is monitored per Illinois EPA's request and is referred to as the Upper Groundwater Unit. This unit includes the Cahokia Alluvium, Peoria Loess, Equality Formation, and Vandalia Till Member, as described below. The Bedrock Unit beneath the unlithified deposits constitute the geologic formation nearest the natural ground surface that is an aquifer. Thus, per 40 C.F.R. § 257.53, the Bedrock Unit comprises the Uppermost Aquifer and is monitored in accordance with 40 C.F.R. § 257.90.

The five principal types of unlithified materials (Upper Groundwater Unit) present above the Bedrock Unit (Uppermost Aquifer), in the vicinity of the Fly Ash Pond System, consist of the following, in descending order:

- UNLITHIFIED DEPOSITS (UPPER GROUNDWATER UNIT)
  - Fill, predominantly coal ash - (fly ash, bottom ash, and slag). Fill is within the Fly Ash Pond System, but also includes constructed berms around the ponds and constructed railroad embankment to the south.
  - Cahokia Formation - (alluvial clay, sandy clay, and clayey sand). The Cahokia Formation is the uppermost unlithified unit between the ash ponds and the Kaskaskia River, and along the south side of the western third of the Fly Ash Pond System. The Cahokia, an alluvial deposit of the Kaskaskia River and its tributaries, consists predominantly of clay with some clayey sand and sandy clay intervals.
  - Peoria Loess - (silt and silty clay). The Peoria Loess occurs in topographically higher areas and bedrock upland areas and is typically underlain by the Vandalia Till Member of the Glasford Formation. It was categorized as silt and silty clay and ranges from 2 to 23 ft. in thickness.

   - Equality Formation - (clay and sandy clay with occasional sand seams and lenses). The Equality Formation is present as the lowermost unlithified geologic layer along the southwestern portion of the Fly Ash Pond System, where it lies between the Cahokia and bedrock. It is present as the uppermost unlithified layer at the south-central portion of the Fly Ash Pond System where the Cahokia pinches out. It is also the present as the middle or uppermost unlithified layer in the central portion of the Fly Ash Pond System, where it is either the uppermost unit above the Vandalia Till Member or lies between the Vandalia Till Member and either the Peoria Loess or CCR and fill material. The Equality was deposited in a slackwater lake formed as a result of back flooding of the Kaskaskia River during flooding events of the Mississippi River. The Equality ranged in thickness from 8 to 20 ft.
   - Vandalia Till Member - (clay and sandy clay diamictons with intermittent and discontinuous sand lenses). The Vandalia Till Member of the Glasford Formation is the lowermost and oldest unlithified geologic material in the vicinity of the Fly Ash Pond System. The Vandalia Till is a diamicton and occurs beneath the Equality in the central portion of the Site as the Cahokia pinches out and as the topographic and bedrock uplands are approached. At the higher topographic elevations (*i.e.*, bedrock uplands) to the east and southeast of the ash ponds, the Vandalia Till is the principal unlithified geologic material, but may be mantled in some areas by 4 to 6 ft of the Peoria Loess. The Vandalia Till also exhibits some intermittent and discontinuous sand lenses. The lowermost portion of the Vandalia Till may become shaley within a few feet of the top of bedrock.
- BEDROCK UNIT (UPPERMOST AQUIFER)
   - Bedrock Unit (Uppermost Aquifer). - The Bedrock Unit is the Uppermost Aquifer beneath the Fly Ash Pond System. The Bedrock Unit consists of Pennsylvanian and Mississippian bedrock, mainly limestone and shale. The shallow bedrock transitions from Mississippian-age limestone and shale beneath the western portion of the Site, to Pennsylvanian-age limestone and shale toward the east (Willman, 1967). The change from Mississippian bedrock to Pennsylvanian bedrock occurs beneath the central portion of the ash ponds. The shallow bedrock is composed of interbedded and undifferentiated limestone and shale. Bedrock topography slopes generally to the west and southwest across the Fly Ash Pond System. A bedrock low is present at the southwest corner of the Site and extends northeastward. The topographic relief of the bedrock (change in bedrock elevation beneath the site) is approximately 45 ft.

Field measurements indicated that the horizontal hydraulic conductivity for the Upper Groundwater Unit ranged from 3.5×10^{-7} to 6.8×10^{-4} cm/s, with a geometric mean of 3.2×10^{-5} cm/s. Laboratory testing of vertical hydraulic conductivity measurements from the units that comprise the Upper Groundwater Unit have a geometric mean value of 8.6×10^{-7}. Based on field testing, the geometric mean horizontal hydraulic conductivity for the Uppermost Aquifer (Bedrock Unit) was 5.0×10^{-6} cm/s (NRT, 2014).

Groundwater flow in the unlithified glacial materials, and in the bedrock, is to the west and southwest, and ultimately discharges to the Kaskaskia River or its tributaries, which border the BEC to the west and south. The Kaskaskia River is a regional groundwater discharge sink. The horizontal migration of CCR constituents in groundwater is limited by the low permeability of both the unlithified deposits, and the Uppermost Aquifer.

2.3 GROUNDWATER QUALITY

Detection monitoring in the Uppermost Aquifer, per 40 C.F.R. § 257.90, was initiated in November 2015; statistically significant increases (SSIs) of Appendix III parameters over background concentrations were detected in October 2017. Alternate source evaluations were inconclusive for one or more of the SSIs. Therefore, in accordance with 40 C.F.R. § 257.94(e)(2), an Assessment Monitoring Program was established on April 9, 2018. Assessment Monitoring results identified statistically significant levels (SSLs) of the Appendix IV parameter lithium over the GWPS based on background concentrations of 0.0693 milligrams per Liter (mg/L). SSLs for lithium were identified in downgradient monitoring wells MW-375 and MW-391 (Figure 2). Lithium was observed in these wells at concentrations ranging from 0.032 mg/L to 0.135 mg/L. No other SSLs have been identified for the Fly Ash Pond System. Lithium in the Uppermost Aquifer is limited to the area close to the BEC's south and southwest property boundary.

2.4 SOURCE CONTROL: IEPA-APPROVED CLOSURE IN PLACE (SOIL COVER SYSTEM) AND MNA

Construction of source control measures is underway and includes pumping to remove surface water, dewatering the CCR, relocating and/or reshaping the existing CCR to achieve acceptable grades for closure, constructing an earthen cover system, and monitoring natural attenuation. The earthen cover system complies with applicable design requirements of the CCR Rule, including establishment of a vegetative cover to minimize long-term erosion. The new cover system will significantly minimize water infiltration into the closed CCR unit (the primary source of CCR constituents in groundwater) and improve surface water drainage off the cover system, thus reducing generation of potentially impacted water, and ultimately reducing the extent of lithium impacts in the Uppermost Aquifer.

Natural attenuation processes will constitute a "finishing step" after effective source control. Ongoing groundwater monitoring will document the attenuation and long-term effectiveness of the source control. The IEPA-Approved source control measures include, but are not limited to, the following primary components:

- Pumping to remove surface water.
- Dewatering the CCR to allow cover system construction.
- Relocating and/or reshaping the existing CCR to achieve acceptable grades for closure. Plant-generated CCR may be placed in the Baldwin Fly Ash Pond System as beneficial reuse.
- Constructing an earthen cover system that complies with the CCR Rule, including establishment of a vegetative cover to minimize long-term erosion. The soil cover system consists of a minimum 18-inch infiltration layer of compacted earthen material, with a permeability less than 1×10^{-5} cm/sec, which is less than the permeability of the subsoils present below the CCR to allow water in the pore space of the CCR to drain into the foundation soils and not accumulate in the closed impoundment.
- Constructing a stormwater management system to convey runoff from the final cover system into a system of interior collection channels for routing through two new stormwater detention ponds and ultimately discharging through the existing Secondary Pond and Tertiary Pond prior to discharge through the BEC's existing NPDES permitted Outfall.
- An operational sewage lagoon with a geomembrane liner is located in the northernmost end of the Baldwin Fly Ash Pond System. The sewage lagoon was constructed on top of CCR, in the northeast corner of the Baldwin Fly Ash Pond System; and, will remain open and operational after the closure of the Baldwin Fly Ash Pond System. The area surrounding this sewage lagoon will be closed in place with a final cover system, in compliance with the CCR Rule, and the final cover system will tie into the lagoon perimeter berm.
- Monitoring attenuation processes in groundwater of the Upper Groundwater Unit and the Uppermost Aquifer, to demonstrate that the extent of groundwater impact is decreasing in size and concentration following closure. In accordance with the IEPA-approved Groundwater Monitoring Plan (NRT, 2016), if a statistically significant increasing trend is observed to continue over a period of two or more years, and a subsequent hydrogeologic site investigation demonstrates that such exceedances are due to a release from Ash Pond 2 and corrective actions are necessary and appropriate to mitigate the release, a corrective action plan will be proposed as a modification to the Post-Closure Care Plan.
- Ongoing inspection and maintenance of the cover system and stormwater and property management, per the approved Post-Closure Care Plan.

3 DESCRIPTION OF CORRECTIVE MEASURES

3.1 OBJECTIVES OF THE CORRECTIVE MEASURES

The following performance standards, per 40 C.F.R. § 257.97, must be met by the selected corrective measures:

- Be protective of human health and the environment
- Attain the groundwater protection standards per 40 C.F.R. § 257.95(h)
- Provide source control to reduce or eliminate, to the maximum extent feasible, further releases of Appendix IV constituents
- Remove from the environment as much of the contaminated material as feasible
- Comply with waste management standards, per 40 C.F.R. § 257.98(d)

3.2 POTENTIAL GROUNDWATER CORRECTIVE MEASURES

Site-specific considerations regarding the Fly Ash Pond System provided in Section 2 were used to evaluate potential corrective measures. Each of the corrective measures evaluated may be capable of satisfying the performance standards listed above to varying degrees of effectiveness. The corrective measure review process yields a set of applicable corrective measures that can be used to supplement the source control activities described in Section 2. The corrective measures may be used independently or may be combined into specific remedial alternatives to leverage the advantages of multiple corrective measures to attain GWPS in the Uppermost Aquifer.

The following potential corrective measures are commonly used to mitigate groundwater impacts and were considered as a part of the CMA process:

- Monitored Natural Attenuation (MNA)
- Groundwater Extraction
- Groundwater Cutoff Wall
- Chemical Treatment/Permeable Reactive Barrier

One commonly considered corrective measure, In-situ solidification/stabilization (ISS), was considered but not retained for further analysis. ISS is technically infeasible given the site-specific geologic and hydrogeologic characteristics of the Uppermost (bedrock) Aquifer. ISS is a treatment technology which consists of encapsulating waste within a cured monolith having increased compressive strength and reduced hydraulic conductivity. Hazards can be reduced by both converting waste constituents into a less soluble and mobile forms and isolating waste from groundwater, thus facilitating groundwater remediation and reduction of leaching to groundwater. ISS encapsulates the contaminants through in-place mechanical mixing with dry reagent in an engineered grout mixture. The grout is typically emplaced using augers, backhoes or injection grouting. The Uppermost Aquifer (Bedrock Unit) would not allow mechanical grout mixing using augers, backhoes or injection methods. As such, ISS cannot be effectively implemented in the Uppermost Aquifer.

3.2.1 Monitored Natural Attenuation

Both federal and state regulators have long recognized that MNA can be an acceptable component of a remedial action when it can achieve remedial action objectives in a reasonable timeframe. In 1999, the USEPA published a final policy directive (USEPA, 1999) for use of MNA for groundwater remediation and described the process as follows:

- The reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods. The 'natural attenuation processes' that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in-situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants.

The USEPA has stated that source control (like the IEAP-approved earthen cover system currently being constructed) was the most effective means of ensuring the timely attainment of remediation objectives (USEPA, 1999). Natural attenuation processes may be appropriate as a "finishing step" after effective source control implementation, if there are no risks to receptors and/or the contaminant plume is not expanding. Thus, MNA would be used in conjunction with source control measures currently under construction and described in Section 2.

The 1999 MNA document was focused on organic compounds in groundwater. However, in a 2015 companion document, the USEPA addressed the use of MNA for inorganic compounds in groundwater. The USEPA noted that the use of MNA to address inorganic contaminants: (1) is not intended to constitute a treatment process for inorganic contaminants; (2) when appropriately implemented, can help to restore an aquifer to beneficial uses by immobilizing contaminants onto aquifer solids and providing the primary means for attenuation of contaminants in groundwater; and (3) is not intended to be a "do nothing" response (USEPA, 2015). Rather, documenting the applicability of MNA for groundwater remediation should be thoroughly and adequately supported with site-specific characterization data and analysis in accordance with the USEPA's tiered approach to MNA (USEPA 1999, 2007, and 2015):

1. Demonstrate that the area of groundwater impacts is not expanding.
2. Determine the mechanisms and rates of attenuation.
3. Determine that the capacity of the aquifer is sufficient to attenuate the mass of constituents in groundwater and that the immobilized constituents are stable and will not remobilize.
4. Design a performance monitoring program based on the mechanisms of attenuation and establish contingency remedies (tailored to site-specific conditions) should MNA not perform adequately.

Both physical and chemical attenuation processes can contribute to the reduction in mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. Physical attenuation processes applicable to CCR include dilution, dispersion and flushing. Chemical attenuation processes applicable to CCR include precipitation and coprecipitation (*i.e.*, incorporation into sulfide minerals), sorption (*i.e.*, to iron, manganese, aluminum, or other metal oxides or oxyhydroxides, or to sulfide minerals or organic matter), and ion exchange. Based on MNA case histories evaluated for 24 inorganic constituents, including most Appendix III and Appendix IV constituents, in other industries,

All inorganic compounds are subject to physical attenuation processes. Physical mechanisms may be the primary natural attenuation processes acting upon CCR constituents such as boron, chloride and lithium, that are relatively mobile (poorly chemically attenuated). The performance of MNA as a groundwater corrective measure varies based on site-specific conditions. Additional data collection and analysis may be required to support the USEPA's tiered approach to MNA (USEPA, 2015) and obtain regulatory approval.

3.2.2 Groundwater Extraction

Groundwater extraction is one of the most widely used groundwater corrective measures and has a long history of performance. This corrective measure includes installation of a series of groundwater pumping wells or trenches to control and extract impacted groundwater. Groundwater extraction captures and contains impacted groundwater and can limit plume expansion and/or off-site migration. Construction of a groundwater extraction system typically includes, but is not limited to, the following primary project components:

- Designing and constructing a groundwater extraction system consisting of a series of extraction wells located around the perimeter of site and operating at a rate to allow capture of CCR impacted groundwater within the

Uppermost Aquifer. Trenches would likely not be feasible due to the depth and lithified character of the Uppermost Aquifer.

- Designing a system to manage extracted groundwater, which may include modification to the existing NPDES permit, including treatment prior to discharge, if necessary.
- Ongoing inspection and maintenance of the groundwater extraction system.

Remediation of inorganics by groundwater extraction can be effective, but systems do not always perform as expected. A combination of factors, including geologic heterogeneities, difficulty in flushing low permeability zones, and sorbed contaminants (desorption rate limited cleanup process) can inhibit effective remediation. Groundwater extraction systems require ongoing operation and maintenance to ensure optimal performance and the extracted groundwater must be managed, either by ex-situ treatment or disposal.

3.2.3 Groundwater Cutoff Wall

Since the late 1970s and early 1980s, vertical cutoff walls have been used to control and/or isolate impacted groundwater. Low permeability cutoff walls can be used to prevent horizontal off-site migration of potentially impacted groundwater. Cutoff walls act as barriers to transport of impacted groundwater and can isolate soils that have been impacted by CCR to prevent contact with unimpacted groundwater. Cutoff walls are often used in conjunction with an interior pumping system to establish a reverse gradient within the cutoff wall. The reverse gradient maintains an inward flow through the wall, keeping it from acting as a groundwater dam and controlling potential end-around or breakout flow of contaminated groundwater.

A commonly used cutoff wall construction technology is the slurry trench method, which consists of excavating a trench and backfilling it with a soil-bentonite mixture, often created with the soils excavated from the trench. The trench is temporarily supported with bentonite slurry that is pumped into the trench as it is excavated (D'Appolonia & Ryan, 1979). Excavation for cutoff walls is conducted with conventional hydraulic excavators, hydraulic excavators equipped with specialized booms to extend their reach (*i.e.*, long-stick excavators), or chisels and clamshells, depending upon the depth of the trench and the material to be excavated. In order for a cutoff wall to be technically feasible, there must be a low-permeability lower confining layer into which the barrier can be keyed, and it must be at a technically feasible depth.

Cutoff walls could be used in combination with groundwater extraction or as part of a permeable reactive barrier system (as the "funnel" in a funnel and gate system; Section 3.2.4). The strength of the bedrock and the required cutoff wall design depth are not known; verifying whether a cutoff wall could be constructed in the bedrock Uppermost Aquifer would be necessary.

3.2.4 Chemical Treatment/Permeable Reactive Barrier

Chemical treatment via a Permeable Reactive Barrier (PRB) is defined as an emplacement of reactive materials in the subsurface designed to intercept a contaminant plume, provide a flow path through the reactive media, and transform or otherwise render the contaminant(s) into environmentally acceptable forms to attain remediation concentration goals downgradient of the barrier (Powell and Powell, 1998; Powell et al., 1998; cited by EPRI, 2006).

As groundwater passes through the PRB under natural gradients, dissolved constituents in the groundwater react with the media and are transformed or immobilized. A variety of media have been used or proposed for use in PRBs. Zero-valent iron has been shown to effectively immobilize some CCR constituents, including arsenic, chromium, selenium, sulfate and molybdenum. It has not been proven effective for boron, antimony, or lithium (EPRI, 2006).

System configurations include continuous PRBs, in which the reactive media extends across the entire path of the contaminant plume; and funnel-and-gate systems, where barrier walls are installed to control and direct groundwater flow through a permeable gate containing the reactive media. Continuous PRBs intersect the entire contaminant plume and do not materially impact the groundwater flow system. Design may or may not include keying the PRB into a low-permeability unit at depth. Funnel and gate systems utilize a system of barriers to groundwater flow (funnels) to direct the contaminant plume through the reactive gate. The barriers, typically some form of cutoff wall, are keyed into a low-permeability unit at depth to prevent short circuiting of the plume. Funnel and gate design must consider the residence time to allow chemical reactions to occur. Directing the contaminant plume through the reactive gate can significantly increase the flow velocity, thus reducing residence time.

The Uppermost Aquifer is a Bedrock Unit consisting mainly of limestone and shale overlain by tens of feet of unlithified, fine-grained soil deposits. Constructing an effective PRB system, including emplacement of reactive media, within the bedrock of the Uppermost Aquifer would be difficult, and may not be possible. In addition, the CCR constituent detected in the Uppermost Aquifer, lithium, has not been proven to be amenable to transformation or immobilization using reactive media. Therefore, PRB was not retained as a viable corrective measure to address SSLs of lithium in the Uppermost Aquifer.

4 EVALUATION OF POTENTIAL CORRECTIVE MEASURES

4.1 EVALUATION CRITERIA

The corrective measures described in the previous section were evaluated relative to the criteria presented in Section 1.2 and reiterated below:

- Performance
- Reliability
- Ease of implementation
- Potential impacts of appropriate potential remedies (safety impacts, cross-media impacts, and control of exposure to any residual contamination)
- Time required to begin and complete the remedy
- Institutional requirements that may substantially affect implementation of the remedy(s) (permitting, environmental or public health requirements)

These factors are presented in Table 1 with the retained corrective measures to allow a qualitative evaluation of the ability of each corrective measure to address SSLs for lithium in the Uppermost Aquifer. The goal is to understand which corrective measures could be used, either independently or in combination, to protect human health and the environment by attaining GWPS, as discussed in the following report sections.

4.2 POTENTIAL GROUNDWATER CORRECTIVE MEASURE EVALUATION

Based on the corrective measure review presented in the previous section, the following corrective measures are potentially viable to address SSLs for lithium in the Uppermost Aquifer:

- MNA
- Groundwater Extraction
- Groundwater Cutoff Wall

These corrective measures are discussed below relative to their ability to effectively address the SSLs for lithium in the Uppermost Aquifer. Additional site-specific data collection and analyses will be required to verify the feasibility of selected corrective measures and to design the corrective measure(s), consistent with 40 C.F.R. § 257.97 requirements.

4.2.1 Monitored Natural Attenuation

MNA is a widely accepted corrective measure for groundwater remediation and is routinely approved by the IEPA paired with source control. The performance of MNA as a groundwater corrective measure can vary based on site-specific conditions and would require additional data collection to support the design and regulatory approval consistent with the USEPA's tiered approach to MNA (USEPA 1999, 2007, and 2015). Source control corrective measures (Section 2) will reduce the mass loading to the Uppermost Aquifer to the extent that MNA, as a finishing step, could attain GWPS.

MNA is a relatively reliable groundwater corrective measure because operation and maintenance requirements are limited. However, the reliability can also vary based on site-specific hydrogeologic and geochemical conditions. Additional groundwater sample collection and analyses would be required to characterize potential attenuation mechanisms as discussed above. Following characterization and approval, implementation of MNA may consist of installing additional monitoring wells. Construction could be completed within 1 year. Time of construction could be reduced if existing groundwater monitoring well systems could be utilized for MNA. Time of implementation is approximately 2 to 3 years, including characterization, design, permitting and construction.

No potential safety impacts or exposure to human health or environmental receptors are expected to result from implementing MNA. Timeframes to achieve GWPS are dependent on site-specific conditions, which require detailed technical analysis. MNA requires approval by the IEPA to be implemented.

4.2.2 Groundwater Extraction

Groundwater extraction is a widely accepted groundwater corrective measure with a long track record of performance and reliability. It is routinely approved by the IEPA. The performance of a groundwater extraction system is dependent on site-specific hydrogeologic conditions and would require additional data collection and possibly groundwater fate and transport modeling to support the design and regulatory approval. The low-permeability bedrock and heterogeneous lithology of the Uppermost Aquifer could present difficulties for designing an effective system. The Uppermost Aquifer bedrock has a mean horizontal hydraulic conductivity of $5.0x10^{-6}$ cm/s. For a corrective measure using groundwater containment to effectively control off-site flow or to remove potentially contaminated groundwater, horizontal and vertical capture zone(s) must be created using pumping wells. However, the low permeability Uppermost Aquifer would restrict the ability to pump at rates high enough to establish the required capture zone(s) or require a high density of wells. Cutoff walls (Section 4.2.3) could also be used in conjunction with a pumping system to control groundwater movement. Source control measures (Section 2) will reduce the mass loading to the Uppermost Aquifer, thus reducing the total contaminant mass that would need to be flushed to attain GWPS.

Implementation of a groundwater extraction system presents design challenges due to the low permeability and heterogeneous lithology of the Uppermost Aquifer. Details of the bedrock bedding planes, fracture distribution and density, as well as the contaminant distribution within the fracture system, would be needed to effectively design the extraction system. Extracted groundwater would need to be managed, which may include modification to the existing NPDES permit and treatment prior to discharge, if necessary.

There could be some impacts associated with constructing and operating a groundwater extraction system, including some limited exposure to extracted groundwater. Additional data collection and analyses would be required to design an extraction system. Construction could be completed within 1 year. Time of implementation is approximately 3 to 4 years, including characterization, design, permitting and construction. Timeframes to achieve GWPS are dependent on site-specific conditions, which require detailed technical analysis. Groundwater extraction requires approval by the IEPA to be implemented.

4.2.3 Groundwater Cutoff Wall

Groundwater cutoff walls are a widely accepted corrective measures used to control and/or isolate impacted groundwater and are routinely approved by the IEPA. Cutoff walls have a long history of reliable performance as hydraulic barriers provided they are properly designed and constructed. Construction of a cutoff wall extending into the Uppermost Aquifer would be difficult, if it is technical feasible, because the aquifer is in bedrock. Cutoff walls are generally constructed in unconsolidated soil deposits and keyed into low permeability materials such as bedrock. Additional site investigation would be required to verify the feasibility of a cutoff wall in the bedrock Uppermost Aquifer.

Cutoff walls are designed to act as hydraulic barriers, as a result, cutoff walls inherently alter the existing groundwater flow system. Changes to the existing groundwater flow system may need to be controlled to maximize the effectiveness of the remedy, for example, groundwater extraction may be required to control build-up of hydraulic head upgradient and around the cutoff walls. The effectiveness of a cutoff wall as a hydraulic barrier also relies on the contrast between the hydraulic conductivity of the aquifer and the cutoff wall. The most effective barriers have hydraulic conductivity values that are several orders of magnitude lower than the aquifer that it is in contact with. A cutoff wall designed with hydraulic conductivity of 1x10-7 cm/sec would be less than two orders of magnitude lower than the aquifer with a mean conductivity of 5x10-6 cm/sec.

Additional data collection and analyses would be required to design a cutoff wall. Construction could be completed within 2 to 3 years. Time of implementation is approximately 5 to 8 years, including characterization, design, permitting and construction. To attain GWPS, cutoff walls require a separate groundwater corrective measures to operate in concert with the hydraulic barriers. Cutoff walls are commonly coupled with MNA and/or groundwater extraction as groundwater corrective measures. The time to attain GWPS is dependent on the selected groundwater corrective measure or measures that are coupled with the cutoff walls. Cutoff walls required approval by the IEPA to be implemented.

5 REMEDY SELECTION PROCESS

5.1 RETAINED CORRECTIVE MEASURES

This CMA was prepared to address the requirements of 40 C.F.R. § 257.96. The following potentially viable corrective measures were identified based upon site-specific conditions:

- MNA
- Groundwater Extraction
- Groundwater Cutoff Wall

Per 40 C.F.R. § 257.97, a remedy must be selected to address the SSLs in the Uppermost Aquifer, based on the results of the CMA. The remedy should be selected as soon as possible and must meet the following standards:

- Be protective of human health and the environment
- Attain the groundwater protection standard as specified pursuant to § 257.95(h)
- Control the source(s) of releases so as to reduce or eliminate, to the maximum extent feasible, further releases of constituents in appendix IV to this part into the environment
- Remove from the environment as much of the contaminated material that was released from the CCR unit as is feasible, taking into account factors such as avoiding inappropriate disturbance of sensitive ecosystems
- Comply with standards for management of wastes as specified in § 257.98(d)

Source control measures currently under construction will significantly minimize water infiltration into the closed CCR unit and allow surface water to drain off the cover system, thus reducing the generation of potentially impacted water and reducing the extent of groundwater impacts by natural attenuation, both in the unlithified deposits above bedrock and in the bedrock Uppermost Aquifer.

The Post-Closure Care Plan includes on-going groundwater monitoring to demonstrate that the extent of groundwater impact is decreasing in size and concentration in the Uppermost Aquifer following closure. In accordance with the IEPA-approved Groundwater Monitoring Plan (NRT, 2016), if a statistically significant increasing trend is observed to continue over a period of two or more years, and a subsequent hydrogeologic site investigation demonstrates that such exceedances are due to a release from Ash Pond 2, and corrective actions are necessary and appropriate to mitigate the release, a corrective action plan will be proposed as a modification to the Post-Closure Care Plan. The corrective action plan may incorporate one or more of the corrective measures identified in this CMA to address impacts from CCR constituents in the Uppermost Aquifer.

5.2 FUTURE ACTIONS

Source control by IEPA-Approved closure in place is underway and will be completed by November 2020. MNA will be implemented as part of the approved Closure Plan, including monitoring of the Uppermost Aquifer. Semiannual reports per § 257.97 will be prepared to describe the progress in selecting and designing the remedy that addresses SSLs for lithium in the Uppermost Aquifer. A final report describing the selected remedy and how it meets the standards listed above will also be prepared, per § 257.97.

6 REFERENCES

AECOM, 2016. Closure and Post-Closure Care Plan for the Baldwin Fly Ash Pond System at Dynegy Midwest Generation, LLC Baldwin Energy Complex, Baldwin, Illinois, March, 2016.

D'Appolonia, D.J., and Ryan, C.R., 1979, Soil-Bentonite Slurry Trench Cut-Off Walls, Geotechnical Exhibition and Technical Conference, Chicago, Illinois.

Electric Power Research Institute (EPRI), 2006. Groundwater Remediation of Inorganic Constituents at Coal Combustion Product Management Sites, Overview of Technologies, Focusing on Permeable Reactive Barriers. Electric Power Research Institute, Palo Alto, California. Final Report 1012584, October 2006.

Illinois Environmental Protection Agency, 2016. "Dynegy Midwest Generation, Inc. – Baldwin Energy Complex: Baldwin Fly Ash Pond System Closure – NPDES Permit No. IL000043", letter from William Buscher (IEPA) to Rick Diericx (Dynegy Operating Company) dated August 16, 2016.

Natural Resource Technology, Inc. 2014. Groundwater Quality Assessment and Phase II Hydrogeologic Investigation, Baldwin Ash Pond System, Baldwin, Illinois. Prepared for Dynegy Midwest Generation, LLC by Natural Resource Technology, Inc. June 11, 2014.

Natural Resource Technology, Inc. 2016. Supplemental Hydrogeologic Site Characterization and Groundwater Monitoring Plan, Baldwin Fly Ash Pond System, Baldwin, Illinois. Prepared for Dynegy Midwest Generation, LLC by Natural Resource Technology, Inc. March 31, 2016.

USEPA (United States Environmental Protection Agency), 1999. Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. Directive No. 9200.U-17P. Washington, D.C.: EPA, Office of Solid Waste and Emergency Response.

USEPA (United States Environmental Protection Agency), 2007. Monitored Natural Attenuation of Inorganic Contaminants in Ground Water, Volume 1 – Technical Basis for Assessment. EPA/600/R-07/139. National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio. October 2007.

USEPA (United States Environmental Protection Agency), 2015. Use of Monitored Natural Attenuation for Inorganic Contaminants in Groundwater at Superfund Sites. Directive No. 9283.1-36. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. August 2015.

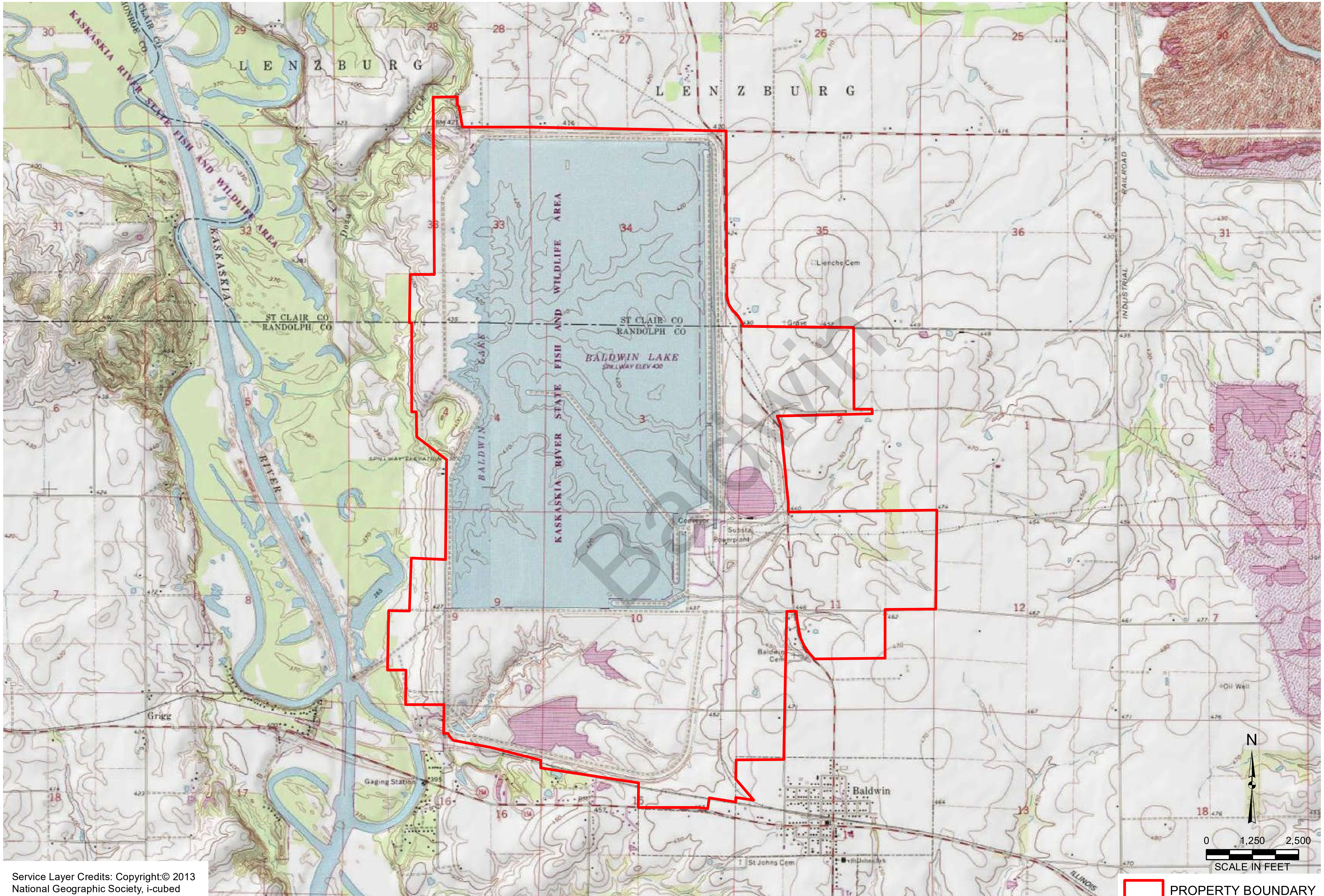
Tables

Table 1. Corrective Measures Assessment Matrix
Corrective Measures Assessment
Baldwin Fly Ash Pond System
September 5, 2019

Evaluation Factors	Performance	Reliability	Ease of Implementation	Potential Impacts of Remedy (safety impacts, cross-media impacts, control of exposure to any residual contamination)	Time Required to Begin and Implement Remedy[1]	Time to Attain Groundwater Protection Standards	Institutional Requirements (state/local permit requirements, environmental/public health requirements that affect implementation of remedy)
MNA	Widely accepted, routinely approved; variable performance based on site-specific conditions.	Reliable, but dependent on site-specific conditions.	Easy.	None identified.	2 to 3 years.	Dependent on site-specific conditions.	Requires regulatory approval processes.
Groundwater Extraction	Widely accepted, routinely approved; variable performance based on site-specific conditions. May be limited by low permeability bedrock Uppermost Aquifer.	Reliable if properly designed, constructed, and maintained.	Design challenges due to hydraulic conditions of bedrock aquifer and plume configuration. Extracted groundwater would require management.	Alters groundwater flow system. Potential for some limited exposure to extracted groundwater.	3 to 4 years	Dependent on site-specific conditions.	Extracted groundwater will require management and approval from IEPA.
Groundwater Cutoff Wall	Widely accepted, routinely approved, good performance if properly designed and constructed. May not be feasible for the Uppermost Aquifer.	Reliable if properly designed and constructed (if feasible).	Widely used, established technology. May not be feasible in bedrock Uppermost Aquifer.	Alters groundwater flow system.	5 to 8 years	Needs to be combined with other corrective measures. Time required to attain GWPS dependent on corrective measures.	Requires regulatory approval processes.

Notes: [1] Time required to begin and implement remedy includes design, permitting and construction.

Figures



DRAWN BY/DATE: SDS 7/23/19
REVIEWED BY/DATE: F_A 7/23/19
APPROVED BY/DATE: BGH 7/23/19

SITE LOCATION MAP

CORRECTIVE MEASURES ASSESSMENT
BALDWIN FLY ASH POND SYSTEM
BALDWIN ENERGY COMPLEX
BALDWIN, ILLINOIS

PROJECT NO: 72855

FIGURE NO: 1

OBG
Part of Ramboll

DRAWN BY/DATE:
SDS 7/23/19
REVIEWED BY/DATE:
F_A 7/23/19
APPROVED BY/DATE:
BGH 7/23/19

BALDWIN FLY ASH POND SYSTEM WITH CCR GROUNDWATER MONITORING WELL LOCATIONS

CORRECTIVE MEASURES ASSESSMENT
BALDWIN FLY ASH POND SYSTEM
BALDWIN ENERGY COMPLEX
BALDWIN, ILLINOIS

PROJECT NO: 72855

FIGURE NO: 2

OBG Part of Ramboll

Y:\Mapping\Projects\22\2285_Baldwin\MXD\2019_CMA\Figure 2_GWS_WellLoc_Baldwin_OE.mxd Author: STOLZSD; Date/Time: 7/24/2019, 3:22:10 PM

OBG
Part of Ramboll