



Assessment of Corrective Measures Boiler Slag Pond Michigan City Generating Station

Michigan City, Indiana

Prepared for:

Northern Indiana Public Service Company, LLC

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Wood Project Number: 7382193341

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8 January 2020

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Subject: Assessment of Corrective Measures Report
Boiler Slag Pond, Michigan City Generating Station, Michigan City, IN
Wood Project No. 7382193341

Dear Mr. Kutch:

Wood Environment & Infrastructure Solutions, Inc. (Wood) is pleased to provide to NiSource this Assessment of Corrective Measures Report prepared for the Boiler Slag Pond at the Michigan City Generating Station.

If you have any questions, please do not hesitate to contact either of the undersigned.

Sincerely,

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Attachments



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LIST OF ACRONYMS AND ABBREVIATIONS

AAO	amended agreed order
ACM	assessment of corrective measures
BSP	Boiler Slag Pond
CAOs	corrective action objectives
CCR	coal combustion residuals
COC	constituent of concern
CSM	conceptual site model
FGD	flue gas desulphurization
ft amsl	feet above mean sea level
gpm	gallons per minute
gpd/ft	gallons per day per foot
gpd/mi ²	gallons per day per square mile
GRA	General Response Actions
GWPS	Groundwater Protection Standard
IDEM	Indiana Department of Environmental Protection
MCGS	Michigan City Generating Station
ug/L	microgram per liter
MNA	monitored natural attenuation
NPDES	National Pollutant Discharge Elimination System
NIPSCO, LLC	Northern Indiana Public Service Company, LLC
POTW	publicly-owned treatment works
PPE	personal protective equipment
PRB	permeable reactive barrier
RCRA	Resource Conservation and Recovery Act
redox	oxidation/reduction potential
SSL	statistically significant level
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
ZVI	zero-valent iron

1.0 INTRODUCTION

The Michigan City Generating Station (MCGS, or Station) is a coal-fired power plant located on the southern shore of Lake Michigan in Michigan City, Indiana. The MCGS is located on an approximately 123-acre site about one-mile northwest of Michigan City, at 101 Wabash Street (**Figure 1**). It is owned by Northern Indiana Public Service Company, LLC (NIPSCO, LLC). The coal combustion residuals (CCR) generated by the coal-fired units have been historically placed in five on-site surface impoundments with a combined surface area of approximately 11.4 acres located southwest of the generating station (**Figure 2**). The five MCGS surface impoundments that historically managed CCR are regulated under different federal and state programs. Two of the surface impoundments are subject to the federal CCR Rule published in 40 CFR §257 and the Indiana state CCR program promulgated in 329 IAC 10. The remaining three surface impoundments were removed from service prior to the effective date of the federal CCR Rule and closure of these three units is regulated by an Amended Agreed Order (AAO) between NIPSCO, LLC and the Indiana Department of Environmental Protection (IDEM) dated September 22, 2015 to be closed under 329 IAC 10.

Of the two surface impoundments regulated under the CCR Rule, the Boiler Slag Pond (BSP) was an active pond at the effective date of the regulation and is subject to the original compliance schedule; the Primary Settling Pond 2 was inactive at the effective date of the regulation and is subject to an extended compliance schedule approximately 18 months behind the original CCR Rule timeframe. A summary of the surface impoundments and governing regulatory programs is presented below on **Table 1**.

Table 1: MCGS Surface Impoundments by Regulatory Program
 Assessment of Corrective Measures, Michigan City Generating Station

Subject to CCR Rule		Subject to IDEM/NIPSCO, LLC Amended Agreed Order Under RCRA 22 September 2015
Original Schedule for Active Ponds 15 October 2015 Rule	Extended Schedule for Inactive Ponds 5 August 2016 Direct Final Rule	
Boiler Slag Pond	Primary Settling Pond No. 2	Primary Settling Pond No. 1
		Secondary Settling Pond No. 1
		Secondary Settling Pond No. 2



1.1 DOCUMENT PURPOSE

On June 12, 2019, NIPSCO, LLC reported that arsenic had been detected at a statistically significant level (SSL) above its Groundwater Protection Standard (GWPS) of 14 micrograms per liter (ug/L) based on the background concentration developed for the BSP. The assessment of corrective measures (ACM) documented in this report has been prepared in accordance with §257.96 to evaluate remedial alternatives for the BSP “to prevent further releases, to remediate any releases and to restore the affected area to original conditions” (§257.96[a]). Closure by removal will “prevent further release” and is an important component of the corrective measure at the BSP as detailed in the closure application for surface impoundments at the MCGS, which was filed with IDEM on December 20, 2018. This ACM addresses the groundwater component of the BSP remedy.

1.2 DATA SOURCES REVIEWED

The following data sources were reviewed to develop an understanding of conditions at the Station, which are summarized in the bullets below. In addition, Wood has relied on published technical reports and regulatory guidance that are cited as appropriate in **Section 6**.

- 2017 Annual Groundwater Monitoring and Corrective Action Report – Boiler Slag Pond, Golder, Inc., dated 31 January 2018
- Assessment Monitoring Notification for the Boiler Slag Pond, prepared by NIPSCO, LLC, dated 13 August 2018.
- Surface Impoundment Closures (CCR Final Rule and RCRA Regulated) Closure Application, Michigan City Generating Station, Michigan City, Indiana, prepared by Wood Environment & Infrastructure Solutions, Inc., dated 20 December 2018.
- 2018 Annual Groundwater Monitoring and Corrective Action Report – Boiler Slag Pond, Golder, Inc., dated 31 January 2019
- CCR Conceptual Closure Plan, Version #2, Boiler Slag Pond, Haley & Aldrich, Inc., dated 7 February 2019
- Notification of Statically Significant Levels above Groundwater Protection Standards, prepared by NIPSCO, LLC, dated 12 June 2019

2.0 SITE BACKGROUND

The MCGS is a 469-megawatt, coal-fired, steam turbine electric generating station located on the southern shore of Lake Michigan in Michigan City, LaPorte County, Indiana. The MCGS is located on an approximately 123-acre site about one-mile northwest of Michigan City, at 101 Wabash Street and Latitude 41° 43' 15" N, Longitude 86° 54' 30" W. The facility is bounded on the north by Lake Michigan; Trail Creek on the east; Chicago Southshore South Bend railroad to the south; and Indiana Dunes National Lake Shore on the west (**Figure 1**).

2.1 SITE DESCRIPTION AND HISTORY

NIPSCO, LLC purchased the property in 1925 and started construction in 1929. Until NIPSCO, LLC purchased the property, it was utilized by the railroads as a dock for unloading cargo from ships (IDEM, 2012). The MCGS began electricity generation in February 1931 using several different power generating units that were built and decommissioned between 1931 and 2012 (Units 1, 2, and 3). Currently, Unit 12 is the only unit in operation and is planned for continued operation (Golder, 2018). Unit 12 is a coal-fired boiler/steam turbine that has been active since 1974 and was upgraded in 2016 to include a dry flue gas desulphurization (FGD) "scrubber" technology to reduce emissions. The FGD by-product that is generated is transported offsite for reuse or disposal. Most of the remaining MCGS site surface area, specifically the Power Generation Area and the CCR Management Area (**Figure 2**), is paved with asphalt or covered by inert materials that include gravel and steel slag.

2.2 CCR REGULATORY STATUS

Groundwater corrective action under the federal CCR Rule is triggered through a two-phase program of groundwater monitoring: detection and assessment. The BSP is currently in the Assessment Monitoring phase of the program (40 CFR §257.95). A statistical evaluation of groundwater monitoring data has been conducted, and the unit is required to enter Groundwater Corrective Action (§257.96 through §257.98) based on exceedances of the GWPS for arsenic.

As indicated in Section 1.2, a closure application dated December 20, 2018 (Wood, 2018) was submitted to IDEM for all five CCR impoundments, including the BSP. A Supplemental Addendum dated February 28, 2019 (Wood 2019) was subsequently submitted to IDEM specific to the post-closure monitoring well network for all five units. The proposed network is comprised of 16 existing wells, which includes the six BSP CCR monitoring wells discussed herein, and 12 new wells. During development of the post-closure application and in discussions with IDEM a two-year,

post-closure monitoring period was proposed to evaluate the effectiveness of source removal and attenuation before implementing a groundwater corrective action. During this two-year monitoring period additional data will also be collected to further evaluate groundwater corrective action alternatives, if needed.

2.3 DESCRIPTION OF THE BOILER SLAG POND

Sargent & Lundy Engineers designed the MCGS surface impoundments in the early 1970s. Construction of the surface impoundments was completed in 1973 to manage CCR material generated from the coal-fired Unit 12 boiler, which was placed in service in 1974. The BSP was constructed by grading a flat area with side slopes 2.5(H):1(V) and is currently situated beneath the 345 kV and 138 kV transmission lines, which are supported by steel towers with foundations constructed around this surface impoundment.

Boiler slag is formed in wet-bottom furnaces, where the non-combustible minerals melt into a liquid which is quenched in the ash hopper furnace. The BSP is not considered a significant source of arsenic to groundwater. As described by EPRI (2009), boiler slag is comprised of large particles that fall to the bottom of the boiler and are composed primarily of amorphous or glassy aluminosilicate materials derived from the melted mineral phases. The availability of a constituent for leaching often depends on whether the element resides on the surface of the ash particle, in the outer glass hull, or within the interior glass matrix. Because boiler slag particulates are relatively large glassy materials the potential to leach inorganics is low.

Boiler slag from the Unit 12 boiler was mixed with recirculated water from the Final Pond and sluiced through the Pipe Trench to the BSP. The boiler slag settled in the pond and the clarified water flowed into the Final Pond where it is recycled back into the cooling water system. Excess water is occasionally discharged to Lake Michigan from the Final Pond through a permitted National Pollutant Discharge Elimination System (NPDES) outfall. Boiler slag that settled into the BSP was periodically dredged and dewatered, then either sold for beneficial use or disposed of in the permitted CCR landfill at the NIPSCO, LLC R.M. Schahfer Generating Station in Wheatfield, IN.

2.4 CONCEPTUAL SITE MODEL

In order to support the assessment of corrective measures, a Conceptual Site Model (CSM) has been developed for the BSP. The following sections provide information on the hydrogeologic setting at the MCGS, including climate, physiography and drainage, geology, hydraulic properties of the principal groundwater flow zone, and surface water. The CSM then identifies the specific

Constituent of Concern (COC) in the environment and describes how it migrates in the subsurface along potential transport pathways.

2.4.1 Climate and Water Budget

The temperatures in the northern area of Laporte County are moderated by Lake Michigan creating a warmer winter and cooler summer compared to central Indiana. National Oceanic and Atmospheric Administration's National Weather Service 2000 to 2018 average temperatures reported at Laporte, IN ranging from a monthly mean average low of 24.7 degrees Fahrenheit in January to a monthly mean average high of 73.1 degrees Fahrenheit in July (<http://w2.weather.gov/climate/>). The normal annual average amount of precipitation from 2000 to 2018 was 43.03 inches recorded at Laporte, IN (<http://w2.weather.gov/climate/>).

2.4.2 Regional and Local Geologic Setting

Most of Laporte County lies within the glaciated plateau region. The Pennsylvanian bedrock system in this area consists of recurring beds of undifferentiated limestone, shale, sandstone, coal, and clays. The Pennsylvanian system is underlain by Mississippian system sandstones and shales. Bedrock is not exposed in LaPorte County, but is instead overlain by unconsolidated deposits of sand, gravel, silt, and clay. At the MCGS, bedrock is separated from the upper water-bearing sand units by a thick sequence dominated by clay, with interbedded silts and sands. This unit is identified as the "Lower Clay" in **Figures 3 and 4**, which depict glacial deposits and fill near the BSP based on logs from soil borings and monitoring wells.

During the Pleistocene Epoch, the entire county was subject to multiple glacial advances and retreats. Till and meltwater deposits of sand and gravel were deposited over bedrock as glaciers advanced and retreated across the landscape; however, sediment deposited from the most recent glacial advance, the Wisconsinan glaciation, are the only remnant left from these glacial periods. As the Wisconsinan glacier retreated from Indiana, the ancestral Lake Michigan began to form as a proglacial lake. The water was held back by a complex of end moraines to the south (referred to as the Valparaiso Moraine) and the retreating glacier to the north. Subsequent rising and lowering of the lake elevation (due to another glacier advance and retreat, isostatic rebound, and climate changes) resulted in depositional sequences of sand, gravel, silt, and clay. The total thickness of unconsolidated sediment within the vicinity of the MCGS facility ranges between 50 and 250 feet.

2.4.3 Groundwater Flow System Characteristics

2.4.3.1 Regional Aquifers

Unconsolidated deposits are the principal source of groundwater supply in LaPorte County (IDNR, 1994). Five unconsolidated aquifers have been mapped across the County: 1) Calumet Aquifer system; 2) Lacustrine Plain Aquifer system; 3) Valparaiso Moraine Aquifer system; 4) Valparaiso Outwash Apron Aquifer system; and 5) Kankakee Aquifer system (IDNR, 2010). The Calumet Aquifer System and Lacustrine Plain Aquifer System are present in the northwest corner of LaPorte County and in the Lake Michigan Region.

The Lacustrine Plain Aquifer system is a series of confined aquifers consisting of fine to medium grained glaciolacustrine sand capped by lacustrine silt and clay or till. Static water level depths in the Lacustrine Plain Aquifer system are variable and some flowing artesian wells exist in LaPorte County. The average thickness is approximately 24 feet (IDNR, 2010); however, thicknesses as much as 90 feet have been observed in local bedrock valleys. Transmissivity values reported for the Lacustrine Plain Aquifer system range between 10,000 and 50,000 gallons per day per foot (gpd/ft). Reported well yields are up to 500 gallons per minute (gpm) (IDNR, 1994). Typical well yields range between 5 and 50 gpm for domestic wells and between 80 and 500 gpm for higher capacity wells (IDNR, 1994). Long-term sustainability varies and depends on thickness and lateral continuity of the aquifer. Due to the low permeability clay and till capping the Lacustrine Plain Aquifer, it is most likely not hydraulically connected to the Calumet Aquifer system.

The Calumet Aquifer system is present beneath the MCGS facility and is comprised of fine to medium grained glaciolacustrine or coastal sands interbedded with lacustrine silt and clay. Static water levels vary according to surface elevation. The Calumet Aquifer system is unconfined to semi-confined. Saturated thickness ranges between 5 and 40 feet but is commonly between 20 and 30 feet (IDNR, 2010). Transmissivity values reported by Rosenshein and Hunn (1968) for the Calumet Aquifer are up to 50,000 gpd/ft and hydraulic conductivity ranges between 150 to 1,000 gallons per day per square foot. Transmissivity values reported by the IDNR (1994) range between 10,000 and 25,000 gpd/ft; however, where fine-grained sand is predominant (in the northwest corner of LaPorte County), estimated transmissivity values are typically less than 10,000 gpd/ft. The Calumet Aquifer is not well developed and there are no significant groundwater withdrawals from this aquifer (IDNR, 2010). The reported well yields are up to 150 gpm (IDNR, 1994); however, typical reported well yields are between 5 and 20 gpm for domestic wells and between 30 and 150 gpm for higher capacity wells.

2.4.3.2 Groundwater Recharge

Infiltration from precipitation is relatively high for the Calumet Aquifer system due to the sandy soils located within the Calumet Lacustrine Plain. As discussed previously, average annual precipitation recorded between 2000 and 2018 at LaPorte, IN is 43.03 inches. Only a percentage of precipitation reaches the water table due to surface run-off and evapotranspiration. The potential for surface run-off is greatest during intense storms and in urban areas where the ground surface is paved. Annual evapotranspiration estimated for northwest LaPorte County is approximately 25 to 26 inches during an average year (IDNR, 1994; Jones, 1966; and Newman, 1981). In the summer, evapotranspiration typically exceeds annual precipitation. This deficit causes groundwater levels to decline during the warmer months. During the cooler months, precipitation exceeds evapotranspiration which in turn allows more precipitation to reach the water table. The IDNR (1994) reported an annual groundwater recharge rate of 500,000 gallons per day per square mile (gpd/mi²) (10.5 inches per year) for the Calumet Aquifer System. Rosenshein and Hunn (1968) provided a slightly higher recharge rate of 600,000 gpd/mi² (12.6 inches per year). Recharge is much lower in areas where urbanization and industrialization have occurred.

2.4.3.3 Groundwater Flow

Groundwater flow in the unconsolidated sediments is primarily within the sand units and flows regionally to the north and northwest, toward Lake Michigan (Scott, 2012). Groundwater level data within approximately a 1.5-mile radius of the site was obtained from Indiana Department of Natural Resources (IDNR) water well record database and was interpolated in combination with site-specific well data to develop a sub-regional potentiometric surface for comparison to the regional potentiometric surface from Scott (2012). The regional and sub-regional potentiometric contours are shown together on **Figure 5**. Both sets of contours generally indicate a similar flow of groundwater from the south toward the north and northwest. The sub-regional contouring also indicates groundwater flow in the unconsolidated aquifer is flowing towards Trail Creek. There is also a steeper gradient just south of the MCGS site for the sub-regional interpolation and differences are likely related to the scale of the interpolation and datasets used. A more refined water-table contour map focussing on the MCGS site is presented on **Figure 6**.

2.4.4 Surface Water

Natural drainage ways in the Lake Michigan Region of LaPorte County drain towards Lake Michigan. Trail Creek drains directly into Lake Michigan and is a commercial harbor where it

adjoins the northeast border of the MCGS facility. The Trail Creek watershed drains approximately 93.2 square miles in the Lake Michigan Region. The average estimated run-off directly into Lake Michigan (which includes surface run-off and groundwater discharge to streams) for the watershed is 18.87 inches (IDNR, 1994). The run-off estimate was determined using stream flow records with at least 20 years of recorded data. Annual run-off estimated for Trail Creek at Michigan City is 20.35 inches (IDNR, 1994). Seventy-six percent of the total run-off is baseflow (IDNR, 1994).

A United States Geological Survey (USGS) gauging station (USGS 04095380 at Michigan City Harbor) is located approximately one-half mile upstream of the confluence between Trail Creek and Lake Michigan. The average monthly discharge measured over a 12-year period (from October 1994 to October 2016) ranges between 88 and 134 cubic feet per second. Discharge is typically lowest in September and peaks during the month of March (USGS, 2018). Daily gage height measured from October 2007 through March 2018 shows, on average, the highest stage elevation occurs in July and the lowest stage elevation occurs in January. Stage elevation during this period ranges between 575.6 feet above mean sea level (ft amsl) as recorded on November 11, 2008, and 581.7 ft amsl as recorded on July 13, 2017.

Lake Michigan surface water levels are monitored at the National Water Level Observation Network Calumet Harbor station (Station 9087044). Trail Creek water elevations at USGS gaging station 04095380 track with changes in Lake Michigan surface water elevations with a difference of approximately 0.5 foot. The average Lake Michigan and Trail Creek surface water levels between mid-June and mid-August 2018 were 580.9 and 581.3 ft amsl, respectively. Lake Michigan and Trail Creek are inferred as discharge points for shallow unconsolidated groundwater when comparing the surface water levels to the groundwater elevation contours (**Figure 6**).

2.4.5 Arsenic in Groundwater

Groundwater at the MCGS has been monitored since 2014 as part of the ongoing RCRA Corrective Action Program, and voluntarily before 2014. Two existing monitoring wells were identified as being appropriately located and constructed to serve as CCR Rule-compliant monitoring wells for the BSP, including GMMW-2 (installed during voluntary site assessment activities) and GAMW-05 (installed during the RCRA Corrective Action program). To complete the monitoring system, four additional wells were installed in June 2016. **Figure 7** shows the CCR compliance wells for the BSP, including three background wells (GAMW-05, GAMW-12 and GAMW-18) and three downgradient wells (GAMW-10, GAMW-11 and, GMMW-2). NIPSCO, LLC obtained certification

from a qualified professional engineer stating that the groundwater monitoring system was designed and constructed to meet the requirements of 40 CFR §257.91.

During the latter half of 2016 and throughout 2017 background groundwater samples were collected at the BSP and the first Detection Monitoring was performed pursuant to requirements of 40 CFR §257.94 (Golder, 2018). The second Detection Monitoring event was conducted in April 2018 and the first Assessment Monitoring event was conducted in October 2018 (Golder, 2019). The only SSL for the BSP is arsenic. The background concentration (and GWPS) for the BSP was established as 14 ug/L. The range of detected arsenic concentrations at the three downgradient wells at the BSP for the period 2016 to 2018 are as follows:

- GAMW-10 - 12 to 23 ug/L
- GAMW-11 - 2.1J (estimated) to 16 ug/L
- GMMW-02 - 11 to 40 ug/L

Arsenic is not a conservative constituent, meaning the mass of arsenic dissolved in groundwater can change significantly as the result of geochemical interactions. According to the USGS and others (Smith 1999, Hinkle and Polette 1999), arsenic mobility in groundwater is largely controlled by one of two geochemical interactions: (1) adsorption and desorption reactions and (2) precipitation and dissolution reactions. The mass of arsenic migrating in groundwater from CCR sites is primarily influenced by changes in pH or by reduction/oxidation (redox) reactions. Arsenic can be present within groundwater under different redox states (e.g. As(III) versus As(V)) that effect its sorption characteristics (Smith 1999, Hinkle and Polette 1999). Arsenic speciation testing on groundwater samples collected from select wells at the MCGS in support of an ongoing treatability study has shown that some of the highest concentrations detected in groundwater to date are associated with the presence of arsenite (As(V)), which is more soluble than arsenate (As(III)). Additionally, arsenic sorption is affected by solution chemistry (i.e. pH) and aquifer mineralogy (Smith 1999, Hinkle and Polette 1999).

Under the site-specific conditions at Michigan City, circumneutral pH and relatively oxic, arsenic is expected to be retained on aquifer solids and relatively immobile. Sequential extraction results from the 2018 investigation (Appendix B; Golder 2018) also support attenuation of arsenic on aquifer sediments and indicate a potential for additional arsenic attenuation in some areas, with limited additional attenuation capacity in other areas. The indication is that arsenic concentrations have the potential to decrease along a flow path where there is greater remaining attenuation capacity, and where the attenuation capacity is limited, arsenic will instead continue to migrate with decreasing concentrations attributed to dispersion and dilution. The low levels of arsenic

detected in groundwater downgradient of the BSP are expected to fall below the GWPS before reaching Lake Michigan or Trail Creek.

Current redox conditions in groundwater may also change post-closure that favor attenuation of arsenic on aquifer solids, which may not be immediately evident. Groundwater geochemistry will be evaluated during a 2-year, post-closure period to assess changes over time that may favor arsenic removal from the dissolved phase.

3.0 IDENTIFICATION AND DEVELOPMENT OF CORRECTIVE MEASURE ALTERNATIVES

This section describes the initial screening of applicable remedial technologies and process options to address groundwater impacts for the BSP. The size and nature of the site may require corrective action to address more units than the BSP alone, but appropriate CCR Rule requirements are addressed for the BSP in this document.

3.1 ESTABLISHMENT OF CORRECTIVE ACTION OBJECTIVES (CAOS)

The objective of corrective action under the CCR Rule is to “attain the groundwater protection standard as specified pursuant to §257.95(h)” and “to remediate any releases and to restore affected area to original conditions” (40 CFR §257.96(a)). Evaluation criteria specified in §257.96(c) include:

- 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 remedy; 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 remedy(s).

The cleanup criteria used for corrective action is the site-specific GWPS, calculated for each Appendix IV COC. Only arsenic exceeded its site-specific GWPS of 14 ug/L.

3.2 SCREENING AND EVALUATION OF REMEDIAL TECHNOLOGIES

General Response Actions (GRAs) are categories of remedial actions that can reduce the concentrations of arsenic in groundwater. Remedial alternatives are combinations of specific process options within each of the GRAs that are selected for detailed evaluation (as described in **Section 4**, below). In a traditional CERCLA Feasibility Study, the “No Action” alternative is a GRA that is required to be analyzed as a baseline for comparison to other alternatives. However, in this ACM, the “No Action” alternative has been eliminated from consideration since it is not permitted under the federal CCR Rule once corrective action has been triggered by statistical

analysis of groundwater monitoring results. Monitored Natural Attenuation (MNA) is a GRA that is allowed under the current CCR Rule. Note that MNA is different than groundwater monitoring only in that it is necessary to demonstrate irreversible sorption of arsenic to aquifer solids to justify MNA as a remedy. Studies in support of an MNA demonstration will be conducted during the 2-year, post-closure groundwater monitoring period.

As a primary corrective measure, source control will be conducted for the BSP. Surface impoundment contents (CCR) will be excavated and removed during the closure process. A two-foot soil cover having a permeability of 1×10^{-5} centimeters per second, or less will then be placed over the excavated area. In addition to source control, hydraulic containment of groundwater can be achieved by construction of a barrier wall, extraction with treatment for discharge or re-injection, or a combination of barriers and pumping. Although these technologies are routinely employed to remediate groundwater, they are not necessarily well-suited for all sites.

Certain traditional remediation technologies are not well suited for arsenic because of its physical and chemical characteristics. For example, many organic COCs can be degraded over time into harmless by-products through biological or chemical processes. Some organics can be volatilized and removed from the groundwater by transferring them into the air phase (air sparging), and or by heating the aquifer matrix to more aggressively volatilize the compounds (steam stripping or electrical resistance heating). These types of technologies were not evaluated, because arsenic is a naturally-occurring metalloid, which is a type of chemical element that has properties in between, or that are a mixture of, those of metals and nonmetals. Arsenic cannot be degraded into harmless by-products like many organic compounds. Arsenic at the BSP is in a relatively soluble form and generally less volatile than water, which prohibits phase transfer.

Arsenic can be made immobile through stabilization within the aquifer matrix, either through adsorption or conversion into less soluble forms. Alternately, extraction of impacted groundwater can be used to accelerate the migration and removal of arsenic from the aquifer system since pore volumes are replaced by upgradient groundwater and infiltrating rainwater. However, this ability to accelerate remediation via groundwater extraction is limited by adsorption of arsenic to the aquifer soils and the slow processes of desorption and diffusion from that matrix. The treatment technologies presented in the following section have been selected on the basis of feasibility and demonstrated success at similar sites.

The technology types and process options presented in **Table 2** were screened for applicability at the BSP and either retained or not retained for further evaluation regarding effectiveness, and

implementability. As an outcome of this screening process, the process options that were retained for development of alternatives (as described in the next section) are identified in **Table 2**.

3.3 DEVELOPMENT OF CORRECTIVE MEASURES ALTERNATIVES

Corrective action measures assessed for the BSP at the MCGS have been developed based on site-specific conditions at the station, in conjunction with remedial actions that are technically implementable and effective for arsenic. Corrective Measure Alternatives were developed that combine the effects of source control on groundwater quality (CCR removal), followed by other combinations of technologies retained for additional evaluation. **Section 4** contains a detailed evaluation of each alternative, compared to CAOs specified in §257.96(a).

4.0 DETAILED EVALUATION OF CORRECTIVE MEASURE ALTERNATIVES

This section presents descriptions of the rationale, conceptual design, and performance monitoring of the retained remedial alternatives for the treatment of arsenic in groundwater at the BSP. As indicated in earlier sections, removal of CCR from within the unit will provide a source control corrective measure for the BSP and will be the initial component of any of the remedial alternatives described below. The following five remedial alternatives have been retained for evaluation:

- Alternative No. 1: Monitored Natural Attenuation.
- Alternative No. 2: Groundwater Extraction and Discharge of Treated Groundwater to Surface Water.
- Alternative No. 3: Groundwater Extraction and Discharge of Treated Groundwater to a Publicly Owned Treatment Works.
- Alternative No. 4: Groundwater Extraction and Discharge of Treated Groundwater to the Subsurface.
- Alternative No. 5: Permeable Reactive Barrier (PRB).

Each alternative is evaluated against the following criteria included in 40 CFR §257.96:

1. **Effectiveness and Implementability:** 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.
2. **Timeframe:** The time required to begin and complete the groundwater corrective action, where completion is defined by §257.98(c).
3. **Institutional Requirements:** The institutional requirements, such as state or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy(s).

4.1 ALTERNATIVE NO 1: MONITORED NATURAL ATTENUATION

4.1.1 Description

In contrast to more active remedial alternatives, MNA relies on demonstrated natural processes ongoing in the subsurface to achieve site-specific CAOs by irreversibly removing dissolved-phase

inorganics from groundwater. Natural attenuation includes physical, chemical and biological processes in the groundwater flow system that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants. Attenuation processes are controlled by many complex variables, including the amount of iron or organic carbon present in the groundwater flow system matrix, redox conditions, and overall groundwater geochemistry. For inorganics, the United State Environmental Protection Agency (USEPA, 2007) states that "...risk reduction in ground water is realized through the sorption of the inorganic contaminant onto aquifer solids in combination with the long-term stability of the immobilized contaminant to resist remobilization due to changes in ground-water chemistry."

Arsenic can be very amenable to the geochemical "sequestering" mechanisms in aquifer systems under favorable conditions. The amount of arsenic detected at the BSP is limited to a finite source and based on sequential extraction data loading away from the BSP is still possible and may provide additional attenuation capacity. While redox conditions may change post-closure that could promote desorption, post-closure conditions are potentially likely to increase the redox potential of the system by allowing more oxygen from fresh recharge in areas that were previously inundated by stagnant impoundment water therefore increasing the attenuation capacity for arsenic. As described in **Section 2.4.5**, sequential extraction testing on the aquifer solids from native sands below fill at the MCGS indicate that arsenic has the potential to migrate away from high concentration source areas but still have the potential to attenuate away from source areas where redox and aquifer conditions may become more favorable.

Closure under this option is accompanied by a groundwater monitoring program to track the progress of MNA and demonstrate progress toward achieving the GWPS. The BSP monitoring wells would be sampled semi-annually for appropriate CCR Appendix III and IV constituents, total organic carbon, sulfate, alkalinity, and field parameters including pH and redox potential. Analytical results would be evaluated to assess overall reduction in groundwater concentrations of arsenic. Additionally, the collection of soil samples can be used in conjunction with site groundwater to assess mass transfer and attenuation of inorganics including arsenic. Studies including sequential extractions, batch extractions, and columns can all be used to assess MNA.

4.1.2 Effectiveness and Implementability

Arsenic concentrations in groundwater are frequently less than 20 ug/L in the three monitoring wells located downgradient of the BSP, and sometimes fall below the GWPS of 14 ug/L. Source removal will reduce future contributions of arsenic to the subsurface.

Implementation of MNA is relatively easy, which does not alter naturally-occurring geochemical conditions at the site and would not limit options for more active remediation if required in the future. All services need to implement the remedy (well installation, environmental sampling activities, laboratory analysis, and environmental reporting) are readily available.

4.1.3 Timeframe

Initial testing indicates that sorption of arsenic may be limited to certain areas within the aquifer downgradient of the BSP and that desorption of arsenic (i.e. reversible sorption) may occur in other areas unless there is a change in redox conditions that favor additional irreversible sorption of arsenic. However, because arsenic concentrations are relatively low downgradient of the BSP, the desorption and transport of arsenic away from the BSP may result in acceptable improvement in groundwater quality in a reasonable timeframe.

As part of the closure process, NIPSCO, LLC proposes a 2-year period of groundwater monitoring after source removal before implementing corrective action for groundwater. This will allow time to evaluate the benefit of the source control measure and to demonstrate MNA. The supplemental addendum to the closure plan included additional wells downgradient of the BSP to monitor improvement in groundwater quality (Wood, 2019). Soil and groundwater data collected during the 2-year monitoring period will be used to determine if MNA is a viable technology and to develop a groundwater flow and transport model to assess the time needed to achieve compliance with the arsenic GWPS at the BSP waste boundary. If studies support MNA, then monitoring will be conducted and compared with the model-predicted concentration trends to assess MNA effectiveness. If field results indicate that MNA will not achieve the GWPS within a reasonable timeframe another groundwater corrective measure would be implemented if that alternate remedy were deemed to significantly accelerate remediation compared to MNA.

4.1.4 Institutional Requirements

A restrictive environmental covenant will be required to limit the use of groundwater at the MCGS. The only additional institutional requirement would be IDEM concurrence. No other permits or agency coordination are required.

4.2 ALTERNATIVE NO. 2: GROUNDWATER EXTRACTION AND DISCHARGE OF TREATED GROUNDWATER TO SURFACE WATER

4.2.1 Description

Extraction wells placed at or near the downgradient waste boundary of the BSP can be used as a hydraulic barrier to minimize migration of the arsenic plume away from the unit. The extraction-well system would be designed to recover the amount of groundwater that flows through the saturated thickness above the underlying clay unit (approximately 10-15 feet). As indicated in **Figures 3 and 4**, the limited saturated thickness near the BSP may require several well points to achieve the desired capture. Trenches may be more effective than wells if the saturated thickness of the aquifer does not allow the drawdown necessary to affect the same capture efficiency as a trench, especially one that penetrates the entire thickness of the plume down to clay. For the purposes of this ACM, it is assumed that pumping wells can be properly positioned to achieve the desired capture zone. This option assumes that extracted groundwater is collected and treated at the surface, prior to discharge under a NPDES permit to Lake Michigan.

Once the groundwater is extracted, several treatment technologies can be used to physically or chemically remove arsenic from the groundwater prior to discharge. One of the most commonly used treatment technologies is chemical precipitation, which allows the soluble metal ions to be converted into insoluble precipitates using coagulants such as iron salts and polymers. Clarification removes the insoluble precipitates and other suspended solids, and filtration polishes the effluent prior to discharge. Other technologies include filtration through granular ferric media, reverse osmosis and ion exchange. Since arsenic is a chemical element, it cannot be destroyed by treatment. Treatment only transfers arsenic from one medium (groundwater) into another (sludge or concentrated brine). These media must be shipped offsite for appropriate disposal.

4.2.2 Effectiveness and Implementability

This alternative effectively decreases the total mass of arsenic in the subsurface because the material is removed through groundwater extraction. Treatment will effectively reduce arsenic concentrations to acceptable levels prior to discharge and will isolate and concentrate the mass of extracted arsenic for offsite disposal. Groundwater extraction rates can be also be modified and extraction-well locations can be added as necessary to improve capture efficiency. Ex-situ treatment allows for different technologies to be added as needed to address the different groundwater constituents identified near the BSP, as pumping may induce the capture of inorganics from portions of the aquifer affected by other CCR units located near the BSP.

It is important to note that other inorganics that do not exceed the GWPS established for the BSP will nonetheless be present with arsenic in the extracted groundwater and that all inorganics must be treated to meet existing surface water criteria. A treatment technology that is very effective for arsenic removal from the extracted groundwater may not be effective for other inorganics (e.g., selenium). In those cases, additional treatment technologies would have to be employed with potential technology limitations for achieving some criteria for surface water discharge. It may also be difficult to secure a separate NPDES permit for long-term discharge of treated groundwater to Lake Michigan from a pump and treat system that may be required to operate beyond the expected closure of the MCGS in 2028.

The characteristics of the groundwater flow system make it relatively easy to extract groundwater, but modeling will be required to site and size the extraction wells needed for an efficient pumping network. Treatment plant operators will be exposed to untreated groundwater and will need to handle treatment chemicals as part of the process. These risks can be mitigated by proper engineering controls and personal protective equipment (PPE).

4.2.3 Timeframe

The design, construction and start-up of a groundwater extraction system and treatment plant will likely take at least 18 months following closure of the BSP. Permitting requirements described in **Section 4.2.4** will be a primary driver in the time to initiate treatment. Pumping removes arsenic from the groundwater system, instead of relying on natural processes to remove arsenic from the aqueous phase via irreversible sorption onto aquifer solids. Extraction generally decreases the time to achieve compliance with the GWPS when compared to MNA; however, the decrease associated with pumping may not be significant if the groundwater extraction rate is designed to capture the volume of groundwater flow under natural (i.e., pre-pumping) gradients that would exist for MNA. Modeling will be necessary to predict the total time needed to achieve the GWPS at the waste boundary under pumping conditions to compare with the MNA alternative.

4.2.4 Institutional Requirements

A restrictive environmental covenant will be required to limit the use of groundwater at the MCGS. While no water withdrawal permits are required in Indiana, the station must register with IDEM as a Significant Water Withdrawal Facility if the total flow rate for the extraction system exceeds 100,000 gallons per day. A NPDES discharge permit is required for direct discharge into Lake Michigan. By regulation, IDEM is allotted 270 days to review a new major individual NPDES permit application plus a public notice period for a minimum of 30 days; additional time can also be

required for addressing agency comments and information requests. While IDEM has primacy to issue these permits, the USEPA has the right to comment on all draft major discharger permits. In addition, IDEM requires the identification and notification of Potentially Affected Parties at the time the permit application is submitted. An IDEM-issued Wastewater Facility Construction permit is also required prior to construction of the treatment facility.

4.3 ALTERNATIVE NO. 3: GROUNDWATER EXTRACTION AND DISCHARGE OF TREATED GROUNDWATER TO A PUBLICALLY-OWNED TREATMENT WORKS

4.3.1 Description

This alternative is identical to Alternative No. 2 except that extracted groundwater is treated and discharged to a publicly-owned treatment works (POTW). While anticipated treatment technologies would be identical to those considered in Alternative No. 2, it is possible that discharge limits to the POTW would be higher and less aggressive treatment may be required. Based on current conditions, it is anticipated that treated groundwater would be discharged to the Michigan City Sanitary District wastewater treatment plant located on Trail Creek, about 1.8 miles upstream of the confluence with Lake Michigan.

4.3.2 Effectiveness and Implementability

All aspects of effectiveness and implementability described in **Section 4.2.2** for the extraction and treatment of groundwater are applicable for this alternative. However, additional challenges may be presented by construction of an adequately-sized discharge pipe from the extraction system to the nearest entrance to the Michigan City Sanitary District sewer system. Moreover, the existing sewer may need to be upgraded to convey the additional volume of treated water from the extraction wells if not already sized for additional flows. The ability of the POTW to accept the additional volume of treated groundwater would have to be confirmed.

4.3.3 Timeframe

The design, construction and startup of a groundwater extraction system and treatment plant will likely take at least 18 months following closure of the BSP. Less permitting time may mean the alternative could be implemented faster than those requiring direct discharge through an NPDES permit. The time to achieve compliance with the GWPS would be the same as Alternative No. 2 because the groundwater extraction and treatment system would be the same.

4.3.4 Institutional Requirements

A restrictive environmental covenant will be required to limit the use of groundwater at the MCGS. While no water withdrawal permits are required in Indiana, the station must register with IDEM as a Significant Water Withdrawal Facility if the total flow rate for the extraction system exceeds 100,000 gallons per day. An IDEM-issued Wastewater Facility Construction permit is also required prior to construction of the treatment facility and a pre-treatment permit must be obtained from the Michigan City Sanitary District prior to beginning discharge. No IDEM permits are required for discharge or construction under this alternative.

4.4 ALTERNATIVE NO. 4: GROUNDWATER EXTRACTION AND DISCHARGE OF TREATED GROUNDWATER TO THE SUBSURFACE

4.4.1 Description

This alternative is identical to Alternative No. 2 except that extracted groundwater is treated and discharged to the subsurface using a recharge trench. While anticipated treatment technologies would be identical to those considered in Alternative No. 2, it is possible that discharge limits to subsurface would be higher and less aggressive treatment may be required than might be required for discharge to Lake Michigan. This alternative would be considered in the event that permitting surface water discharge is not allowed and the POTW infrastructure or treatment capacity cannot accept the additional volume of treated groundwater.

4.4.2 Effectiveness and Implementability

All aspects of effectiveness and implementability described in **Section 4.2.2** for the extraction and treatment of groundwater are applicable for this alternative. However, additional challenges may be presented by construction of an adequately-sized and positioned recharge gallery and the potential for fouling of the gallery with inorganic precipitates, typically iron. If the recharge gallery is properly installed and maintained, this alternative would be more effective than Alternatives No. 2 and 3 in that treated groundwater introduced to the subsurface would enhance flushing of arsenic from the aquifer.

4.4.3 Timeframe

The design, construction and startup of a groundwater extraction system and treatment plant will likely take at least 18 months following closure of the BSP. The time to achieve compliance with

the GWPS would be accelerated compared to Alternatives No. 2 and 3 as a result of enhanced flushing due to the introduction of treated groundwater to the subsurface. Modeling would be required to quantify this difference in the time to achieve the GWPS.

4.4.4 Institutional Requirements

A restrictive environmental covenant will be required to limit the use of groundwater at the MCGS. While no water withdrawal permits are required in Indiana, the station must register with IDEM as a Significant Water Withdrawal Facility if the total flow rate for the extraction system exceeds 100,000 gallons per day. An IDEM-issued Wastewater Facility Construction permit is also required prior to construction of the treatment facility. Groundwater recharge activities are regulated under EPA Region 5's Underground Injection Control (UIC) program. Recharge of treated groundwater into the upper aquifer would constitute a Class V underground injection well that will require submission of inventory information to the EPA prior to implementation, and possibly permitting. Typically, Class V wells used for groundwater cleanup are authorized by rule (i.e., no permit required), if the project is being done under a State or Federal program.

4.5 ALTERNATIVE NO. 5: PERMEABLE REACTIVE BARRIER (PRB)

4.5.1 Description

In-situ treatment methods for arsenic operate on the same principals that occur in natural attenuation: dissolved arsenic is chemically sequestered onto a treatment medium as a relatively insoluble solid. In-situ treatment removes the arsenic from solution more permanently than the existing aquifer solids because a significant amount of reactive medium is added to the subsurface and allowed to contact the arsenic-impacted groundwater. A permeable reactive barrier, or PRB, is a passive technology that places treatment medium in a concentrated and permeable "wall," constructed in a trench across the flowpath of the groundwater plume. As the impacted groundwater flows through the barrier wall, treatment medium in the wall remove the arsenic from groundwater. The wall is designed to have relatively minimal impact on the natural groundwater flow conditions at a site.

While effective treatment media do not exist for all Appendix IV constituents, PRBs have been implemented successfully for arsenic removal using a variety of medium including zero-valent iron (ZVI). Arsenic removal by ZVI occurs using the same processes observed in MNA (adsorption and co-precipitation with iron corrosion products) but at a much faster rate due to the

concentration of excess iron in the PRB. Other proprietary media have been developed using additional additives to accelerate or enhance the removal process.

4.5.2 Effectiveness and Implementability

PRB technology for arsenic removal has been demonstrated at the field test and full-scale implementation (USEPA, 2008, Bain et.al., 2006, ITRC, 2011). The technology is relatively passive and has been proven to be effective in removing and bonding arsenic. It can be challenging to install, since the barrier wall must be constructed in a way that groundwater will flow through it and not around it. Therefore, the design usually requires the wall to be keyed into a relatively impermeable layer below the plume, such as bedrock or clay. Subsurface investigations have identified a suitably thick layer of clay under near the BSP, about 30 feet below the surface, which provides an excellent material for anchoring the barrier wall.

Wall thickness is another important design consideration as it controls the amount of time where the arsenic is in contact with the medium, as well as the overall mass of the treatment medium. Effective implementation is limited by the presence of other inorganic constituents in the groundwater that can form mineral precipitates on the surface of the reactive medium. This process reduces the potential treatment sites and can clog the PRB (ITRC, 2011). The reactive medium in the barrier wall can also become exhausted over time and may require replacement before the cleanup standards are achieved upgradient of the PRB.

A funnel-and-gate system is a special type of PRB that uses impermeable barrier walls (the funnel) to encompass and direct the plume to a relatively narrow and permeable treatment zone (the gate), where media have been placed to remove arsenic from the groundwater. Funnel construction often employs sheet pile. The funnel and gate design can increase residence time in the reactive medium and reduce the total amount of reactive medium required compared to a trench-style PRB design. A funnel-and-gate system can be a very effective enhancement in some settings, especially where existing sheet pile may be incorporated into the design; however, the overhead transmission lines that run above the BSP may preclude construction of sheet-pile barrier walls, and the additional effort to create a funnel-and-gate system is not warranted for the size and concentration of the arsenic plume arising from the BSP.

4.5.3 Timeframe

The time required to achieve the GWPS downgradient of the PRB is relative short, since new water flowing out of the PRB will contain very little (if any) arsenic. Upgradient of the PRB the time to

achieve compliance with the GWPS is expected to take slightly longer than a pump & treat alternative because the PRB does not accelerate the rate of groundwater flow. Modeling will be necessary to predict the total time needed to achieve the GWPS at the BSP waste boundary, depending on the location and design of the PRB.

4.5.4 Institutional Requirements

A restrictive environmental covenant will be required to limit the use of groundwater on the site. Beyond approval by the agency, there are no additional institutional requirements for installing a PRB. Exposure to the impacted groundwater is limited to construction and can be addressed with proper PPE. Otherwise, treatment occurs passively below ground surface.

5.0 SUMMARY AND CONCLUSION

It is anticipated that the BSP closure will be completed in 2021. The BSP is not considered a significant source of arsenic to groundwater because boiler slag particulates are relatively large glassy materials with a low potential to leach inorganics. Moreover, the concentrations of arsenic are frequently less than 20 ug/L in the three monitoring wells located downgradient of the BSP, and sometimes fall below the GWPS of 14 ug/L. Source removal will reduce future contributions of arsenic to the subsurface.

Twelve new monitoring wells will be installed and developed within 90 days of NIPSCO, LLC's placing a notification of completion of closure of the CCR surface impoundments in the operating record per 40 CFR §257.100(c)(3) followed by a two-year monitoring period to evaluate the effectiveness of the impoundment closures on groundwater quality improvements. During this time, NIPSCO, LLC will continue to evaluate the alternatives described in Section 4, collecting field data as necessary to support the most promising corrective measure alternatives, and the eventual selected remedy.

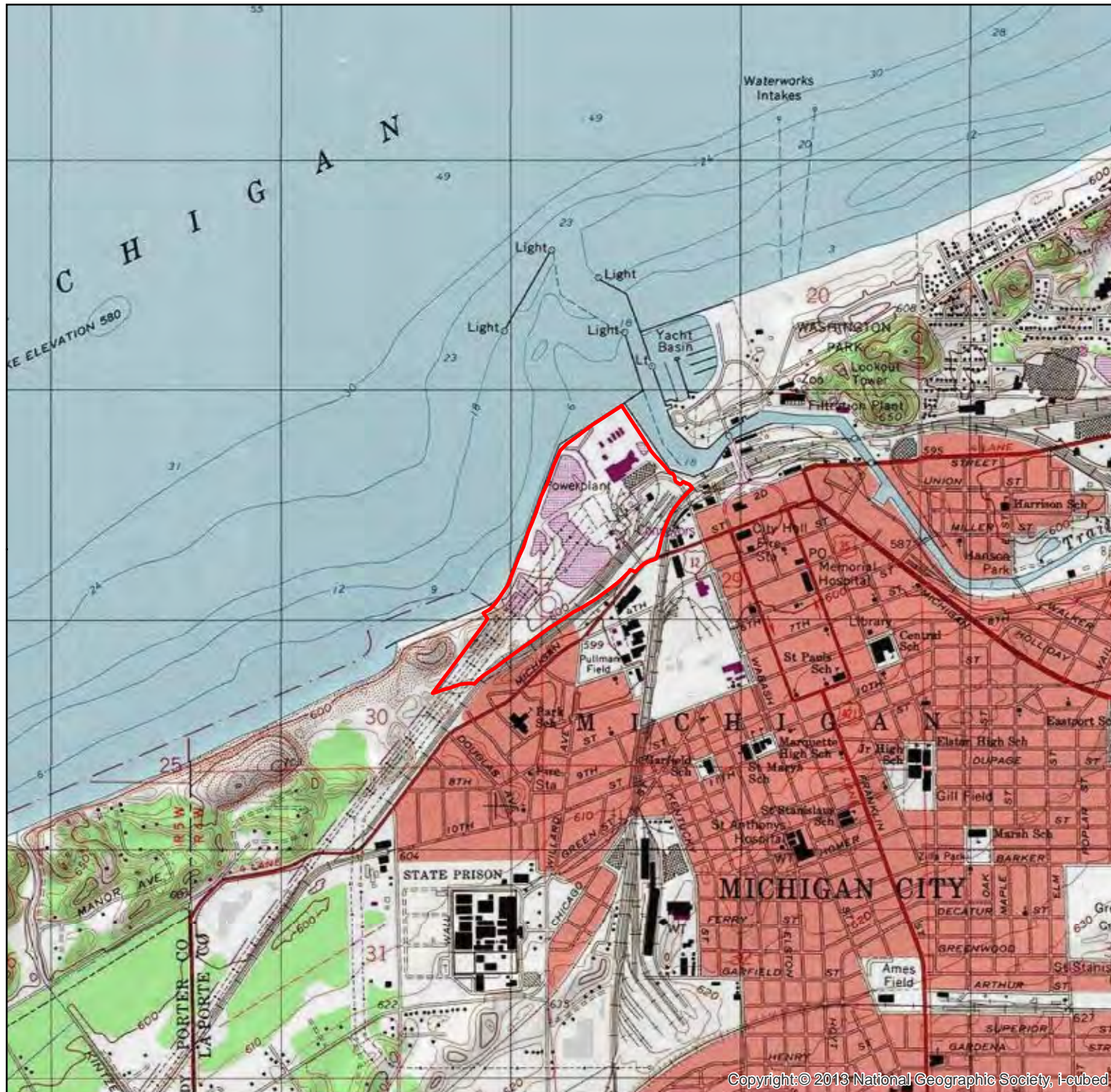
Due to the relatively low concentrations of arsenic in groundwater at the BSP and the proposed removal of CCR as the initial step in the corrective action measure, MNA is a viable technology if irreversible sorption can be demonstrated. If active remediation is required, arsenic can be readily treated in-situ (e.g., using a PRB) or ex-situ following groundwater recovery. In situ treatment would target arsenic and is anticipated to be very successful. Groundwater recovery would be a secondary option because the extracted water would have to be treated for disposal. Multiple inorganics in the extracted groundwater would have to be treated to achieve standards for discharge to Lake Michigan, the POTW, or the subsurface. Some inorganics are difficult to treat with low discharge standards, making groundwater extraction, treatment and disposal potentially difficult, and not warranted for the low concentrations measured at the BSP.

As soon as feasible, NIPSCO LLC will select a remedy that meets the requirements of §257.97(b), and as required by §257.96(e) NIPSCO LLC, will discuss the results of the corrective measures assessment in a public meeting 30 days prior to selecting the final remedy.

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SITE LOCATION MAP

Michigan City Generating Station

Northern Indiana
Public Service Company
Michigan City, Indiana

Legend

Site Boundary



Notes & Sources

0 2,000 Feet

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Chelmsford, MA 01824
(978) 692-9090

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FIGURE

1

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LOCATION OF CCR UNITS AND PONDS

Michigan City Generating Station

Northern Indiana
Public Service Company
Michigan City, Indiana

Legend

- Existing Sheet Piles
- CCR Rule Impoundment
- RCRA Amended Agreed Order Impoundment
- Power Generation Area
- CCR Management Area

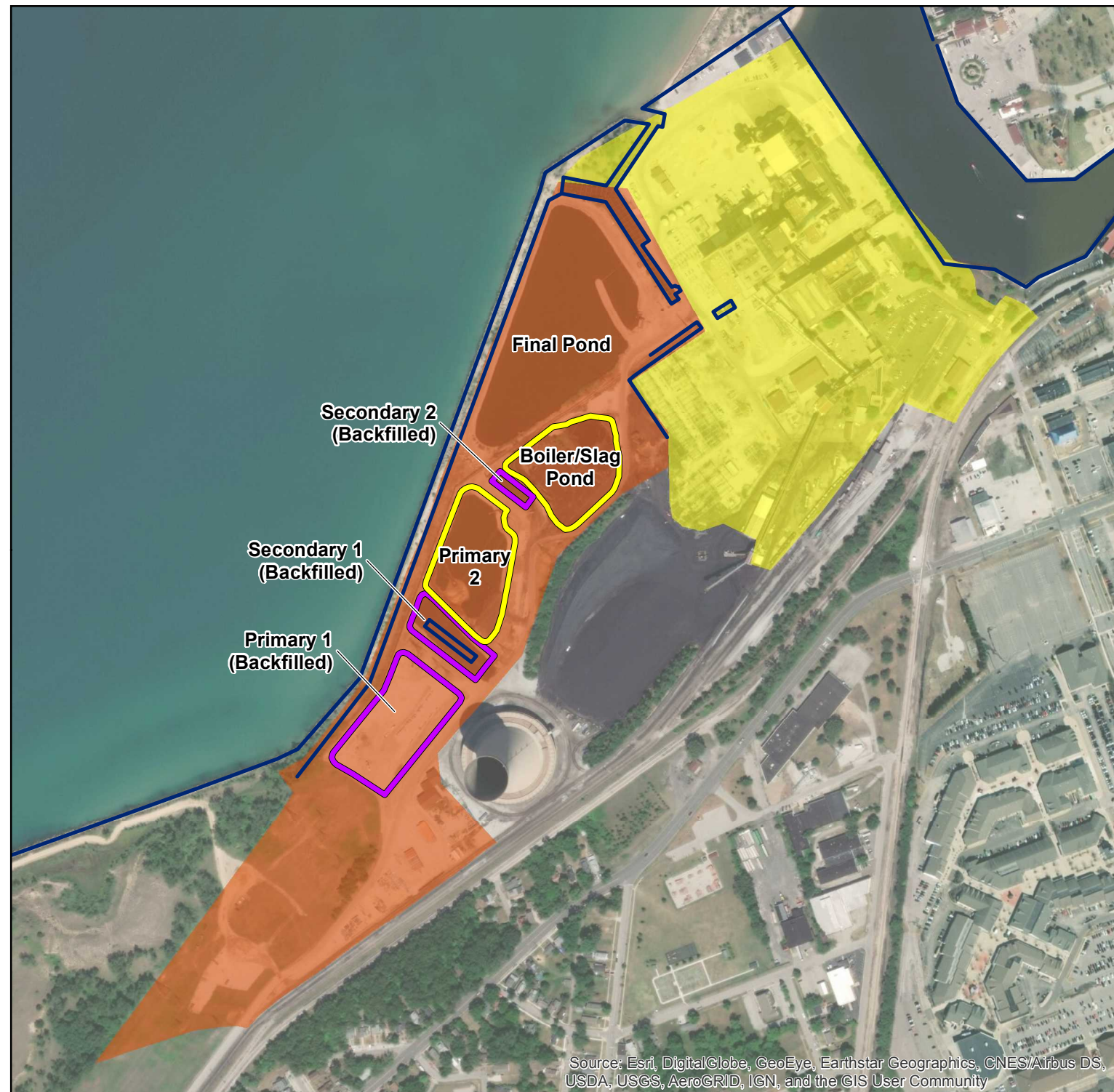
Location of Site



Notes & Sources

0 550 Feet

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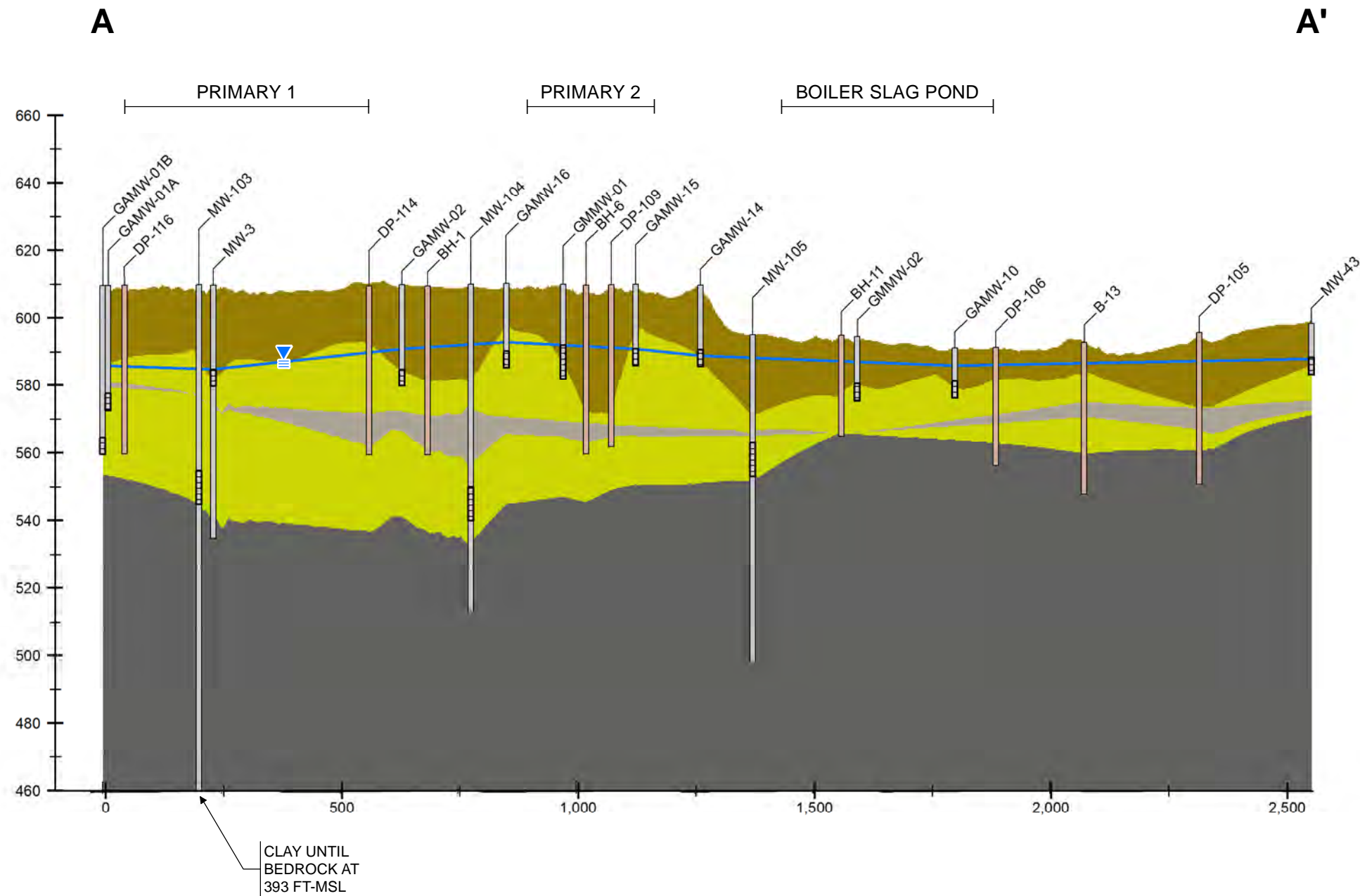
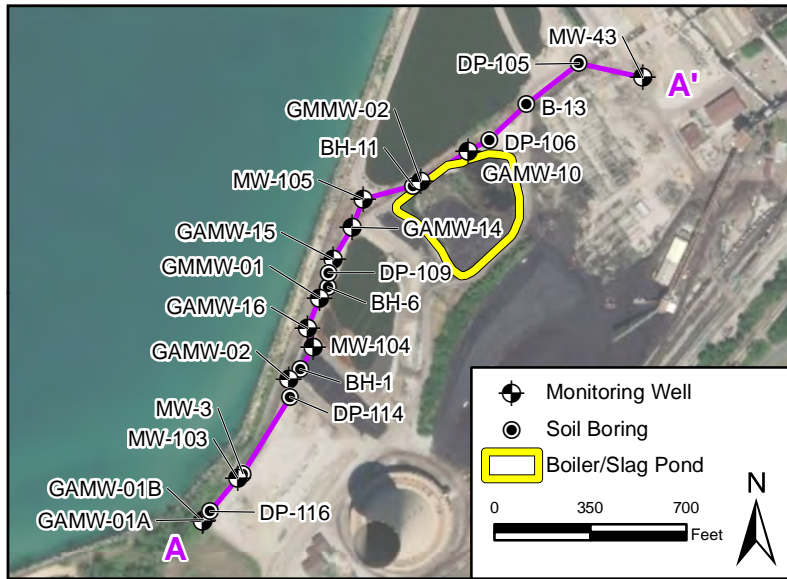


Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

CONCEPTUAL CROSS SECTION A - A'

Michigan City Generating Station

Northern Indiana
Public Service Company
Michigan City, Indiana



Legend

- Soil Boring
- Existing Monitoring Well
- Screened Interval of Monitoring Well
- Water Table
- Soil Type**
- Fill
- Sand
- Upper Clay
- Lower Clay

Notes & Sources

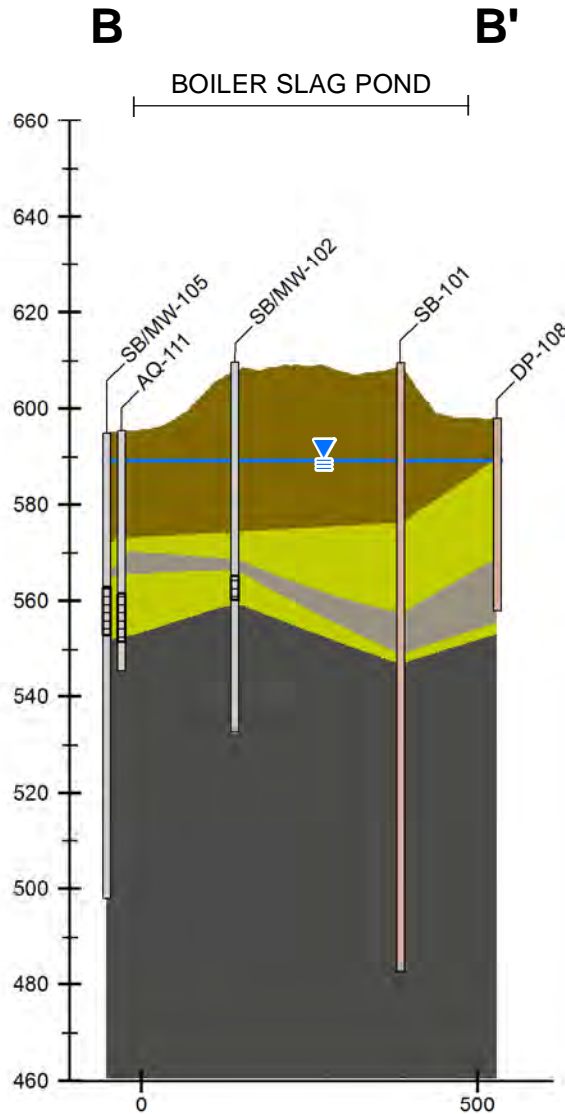
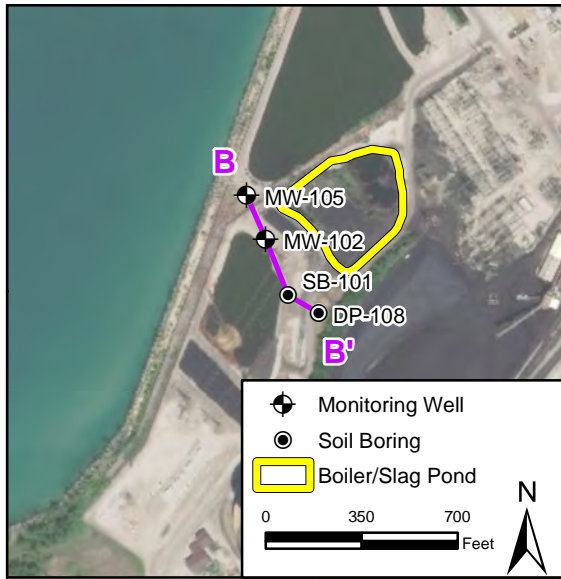
Vertical Scale: 1 inch = 40 feet

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Louisville, Kentucky 40299

FIGURE

3



CONCEPTUAL CROSS SECTION B - B'

Michigan City Generating Station

Northern Indiana
Public Service Company
Michigan City, Indiana

Legend

- Soil Boring
- Existing Monitoring Well
- Screened Interval of Monitoring Well
- Water Table
- Soil Type**
- Fill
- Sand
- Upper Clay
- Lower Clay

Notes & Sources

Vertical Scale: 1 inch = 40 feet

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FIGURE

4



REGIONAL POTENTIOMETRIC CONTOURS

Michigan City Generating Station

Northern Indiana
Public Service Company
Michigan City, Indiana

Legend

- MCGS Monitoring Well
- State Well
- Existing Sheet Piles
- Sub-Regional Groundwater Contour (Feet) (Interpolated)
- Regional Groundwater Contour (Feet) (Scott 2012)
- Site Boundary

Location of Site

Notes & Sources

0 2,000
Feet

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FIGURE
5





Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FACILITY WATER TABLE CONTOUR PLAN August 6, 2018

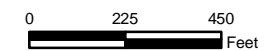
Michigan City Generating Station

Northern Indiana
Public Service Company
Michigan City, Indiana

Legend

-  Monitoring Well with Water Table Elevation (Feet)
-  Staff Gauge with Surface Water Elevation (Feet)
-  Groundwater Contour
-  Boiler/Slag Pond

Notes & Sources



FIGURE

6

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BOILER SLAG POND GROUNDWATER MONITORING NETWORK

Michigan City Generating Station

Northern Indiana
Public Service Company
Michigan City, Indiana

Legend

-  Background Groundwater Monitoring Well
-  Downgradient Groundwater Monitoring Well
-  Existing Sheet Piles
-  Boiler/Slag Pond

Location of Site



Notes & Sources



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FIGURE
7

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Table 2
Screening and Evaluation of Remedial Technologies for Groundwater Corrective Measures
Based on Closure by Removal at the Boiler Slag Pond
Michigan City Generating Station, Michigan City, IN

General Response Action	Remedial Action Technology Type	Process Option and Description	Relative Performance/ Reliability/ Ease of Implementation (Low-Medium-High)	Relative Time Required to Begin and Complete Remedy (Short-Medium-Long)	Institutional Requirements that May Affect Implementation (Few-Some-Many)	Result of Screening
LIMITED ACTION Physical or administrative restrictions designed to prevent access to groundwater.	Institutional Controls	Legal and administrative restrictions designed to reduce or eliminate access to groundwater.	High/High/High Availability of public water supply limits impact of groundwater restrictions.	Short/Short Lowest time requirements, as remedy is effective as soon as restrictions are implemented.	Few Requires restrictive environmental covenant to limit access to groundwater.	Not Retained: Easily implemented but not consistent with requirements of federal Coal Combustion Residual (CCR) Rule. Unlikely to receive regulatory approval.
	Monitored Natural Attenuation (MNA)	Allowing ongoing, naturally-occurring processes to remove dissolved arsenic from groundwater through irreversible sorption to aquifer solids. Includes long-term monitoring to document decline in constituent concentrations.	Low-Med/Medium/High Both effectiveness and reliability (permanence) dependent upon site-specific geochemical interactions between arsenic and aquifer solids.	Short/Long Easy to implement. Time to complete depends upon rate of groundwater flow and available recharge to replace impacted groundwater. Sorption/desorption dynamics could extend timeframe to reach Groundwater Protection Standard (GWPS).	Few Ongoing monitoring and reporting would be required.	Retained: Easily implemented, additional studies of groundwater geochemistry, aquifer solid characteristics and post-closure oxidation/reduction conditions would be required to understand attenuation mechanisms. Serves as baseline for other remedial actions.
IN-SITU CONTAINMENT Restricts movement of arsenic and creates a barrier to prevent access to groundwater. <u>Compliments cap included as part of closure by removal.</u>	Vertical Barrier	Sheet-pile wall or slurry wall to fully encircle affected groundwater and keyed into native clay below the Boiler Slag Pond (BSP).	High/High/Low Sheet-pile wall or slurry wall requires exacting construction to assure complete encapsulation. Placement must consider above- and below-ground structures. Sheet-pile installation may be prevented by overhead transmission lines. Most effective in combination with capping and impermeable base.	Medium/Long Up to a year may be required for construction. Will require long-term monitoring to assure continued integrity.	Few Ongoing monitoring and reporting would be required.	Not Retained. In-situ containment methods must be managed in perpetuity to ensure arsenic does not migrate and may require hydraulic control within the containment area (i.e., groundwater extraction and treatment). Not appropriate for the low concentrations of arsenic observed at the BSP. Unlikely to receive regulatory approval.
	Impermeable Base	In-situ stabilization (ISS) beneath contaminated groundwater to prevent vertical migration if native clay not continuous below the BSP.	High/High/Low ISS barrier is difficult to construct, but effective once in place in combination with capping and vertical barrier.	Medium/Long Up to a year may be required for construction. Will require long-term monitoring to assure continued integrity.		

**Table 2
Screening and Evaluation of Remedial Technologies for Groundwater Corrective Measures
Based on Closure by Removal at the Boiler Slag Pond
Michigan City Generating Station, Michigan City, IN**

General Response Action	Remedial Action Technology Type	Process Option and Description	Relative Performance/ Reliability/ Ease of Implementation (Low-Medium-High)	Relative Time Required to Begin and Complete Remedy (Short-Medium-Long)	Institutional Requirements that May Affect Implementation (Few-Some-Many)	Result of Screening
REMOVAL AND CONTAINMENT Physical removal of groundwater from the aquifer through various approaches. Hydraulic containment may be possible depending upon approach.	Extraction Wells	Removes contaminated groundwater and provides hydraulic containment to limit plume migration.	<u>Med-High/Med-High/High</u> Mechanical system needs basic operation, maintenance and monitoring (OM&M). Addition of new wells or revision of extraction well field commonly required where duration is extended.	<u>Short/Long</u> Capture is effective soon after system is installed and started up. Corrective Action Objectives (CAOs) are met once arsenic concentrations upgradient of wells are below GWPS. Modeling would be needed to evaluate effectiveness of design.	<u>Few</u> Ongoing monitoring and reporting would be required.	Retained. Must be implemented in conjunction with ex-situ treatment. Can meet CAOs eventually but may require many years. Easily expandable to address other potential groundwater treatment areas. Will require OM&M for duration.
	Extraction Trench	Intercepts contaminated groundwater. Effectiveness of containment depends on design of extraction trench and groundwater extraction rate.	<u>High/Med-High/Medium</u> Placement must consider above- and below-ground structures. Extraction system will require OM&M for many years.	<u>Short/Long</u> Capture is effective soon after system is installed and started up. CAOs are met once arsenic concentrations upgradient of the trench are below GWPS. Modeling would be needed to evaluate effectiveness of design.	<u>Few</u> Ongoing monitoring and reporting would be required.	Retained. Must be implemented in conjunction with ex-situ treatment. Can meet CAOs eventually but may require many years. Will require OM&M for duration.
EX-SITU TREATMENT Treatment to reduce concentrations of inorganics in extracted groundwater.	Groundwater Treatment Technologies	Multiple Process Options Multiple process options are available for treatment of extracted groundwater, including settling, pH adjustment, flocculants, clarification, carbon adsorption, oxidation, adsorption, and filtration.	<u>Variable/Variable/Med-Low</u> Once extracted, must meet discharge standards for multiple inorganics, not just arsenic. Some inorganics easy to remove (e.g., arsenic), whereas others are more resistant to treatment (e.g., selenium).	<u>Medium/Long</u> Treatment is required for as long as extraction is required. OM&M required for duration of operation.	<u>Few</u> Ongoing monitoring and reporting would be required.	Retained. A treatability study has been initiated to evaluate effective technologies for treating arsenic and other inorganic constituents. Routine discharge monitoring required. All treatment options generate waste requiring offsite disposal.
IN-SITU TREATMENT Treatment to reduce concentrations of arsenic in groundwater without extraction.	Chemical Addition/ Treatment	Inject chemicals or additives into the aquifer to treat arsenic in groundwater.	<u>Unknown/Unknown/Low</u> A treatability study would be required to determine the appropriate treatment reagents and to ensure permanence. Reagent introduction is feasible but spacing to ensure proper distribution can be difficult.	<u>Medium/Med-Long</u> Injections can take months to complete. Treatment can be completed soon after final injection, or multiple injections may be required.	<u>Few</u> Underground Injection Control (UIC) permit required.	Not Retained: Even if appropriate treatment reagents are identified, requires effective distribution of reagents across a large area around and within the BSP footprint (i.e., through the two-foot soil cap).
	Permeable Reactive Barrier (PRB)	Install PRB along downgradient boundary of the BSP.	<u>High/High/Medium</u> Very effective at removing arsenic. Trench placement would have to consider below-ground structures.	<u>Medium/Med-Long</u> Groundwater downgradient of the PRB would be improved relatively quickly. Time for groundwater improvement upgradient of the barrier would be similar to MNA.	<u>Few</u> Ongoing monitoring and reporting would be required.	Retained: Careful construction techniques and testing required to ensure uniform distribution of barrier. Reagent in the PRB may become spent after years of operation. Monitoring required to determine if additional reagent is required.

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IN-SITU TREATMENT Treatment to reduce concentrations of arsenic in groundwater without extraction (continued).	Funnel and Gate System	Use sheet pile to direct groundwater to treatment zone.	High/High/Low Very effective at removing arsenic. Sheet pile installation would have to consider below-ground structures and may be hindered or prevented by overhead transmission lines.	Medium/Med-Long Groundwater downgradient of the treatment zone would be improved relatively quickly. Time for groundwater improvement upgradient of the treatment zone would be similar to MNA.	Few Ongoing monitoring and reporting would be required.	Retained: Technology reduces size of reactive zone for treatment. Reagent in the treatment zone may become spent after years of operation. Monitoring required to determine if additional reagent is required. Careful construction techniques and testing required to ensure effective flow management.
	Stabilization/ Solidification	A solidifying agent is mixed into the subsurface to fix arsenic onto aquifer solids and significantly reduce leaching of arsenic into groundwater.	High/High/Very Low Extremely effective with the right solidification agent. Large area would require solidification. Process disruptive to above- and below-ground structures and may be hindered or prevented by overhead transmission lines.	Med-Long/Med-Long ISS can take months to complete. Treatment can be completed soon after solidification/ stabilization.	Few UIC permit required.	Not Retained: Solidifying a large area can significantly alter groundwater flow patterns. Modeling required to assess unintended consequences.
	Biological Treatment	Microbial Induced Calcite Precipitation: a biological process for catalyzing native soil bacteria such that it cements together particles, increases compressibility and shear strength, and reduces pore space, thereby reducing the soil's solubility and mobility (leach capacity).	Medium/High/Very Low Effective when bacteria and substrate can contact the impacted groundwater. Maintaining biological activity can be challenging if preferential flow paths develop as calcite precipitates. Multiple injections may be required to achieve treatment across impacted zones.	Unknown/Unknown Injections can take months to complete. Treatment can be completed soon after final injection, or multiple injections may be required.	Few UIC permit required.	Not Retained: Extensive geochemical testing and pilot scale tests would be required. Unknown if conditions are favorable.
DISPOSAL On-site (treated) or offsite (untreated) disposal of extracted groundwater.	On-Site Discharge	Discharge to Lake Michigan	High/High/Low-Med Effective, but requires National Pollutant Discharge Elimination System (NPDES) permit for long-term discharge.	Short-Med/Long Time to begin discharge will be governed by time required to obtain NPDES permit. Discharge will be required throughout life of remedy.	Some NPDES permit required; direct discharge permits to Lake Michigan take a significant time to obtain due to review process. Permit may not be issued for long-term discharge (i.e., 30 years).	Retained: Even though permitting may be a lengthy process, direct discharge is a reliable and an easy-to-maintain disposal option and may be worth additional studies and agency interaction.
		Discharge to local Publicly-Owned Treatment Works (POTW)	High/High/Med Effective and reliable, may present difficulty to construct discharge pipeline to appropriate point in sewer system due to underground utilities and limitations to conveyance system leading to the POTW.	Medium/Long Up to a year may be required for construction. Discharge to POTW will be required throughout life of remedy.	Some POTW industrial pretreatment permit will be required. Usually easier to obtain than a direct-discharge (NPDES) permit.	Retained: Discharge to POTW usually has less stringent limitations than direct discharge to Lake Michigan since additional treatment occurs at POTW.

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DISPOSAL On-site (treated) or offsite (untreated) disposal of extracted groundwater (continued).	On-Site Discharge (continued)	Reinjection of treated groundwater to the subsurface within the MCGS property boundaries.	High/High/Low-Med Effective throughout life of the remedy and will accelerate arsenic removal through enhanced flushing; placement must consider above- and below-ground structures.	Medium/Long Up to a year may be required for construction. Reinjection will be required throughout life of remedy.	Few UIC permit required.	Retained: Modeling required to determine impacts to groundwater flow/quality. Will require routine OM&M to prevent fouling. Long-term reduction in aquifer permeability possible. Retained because discharge of treated water to Lake Michigan or POTW may not be allowed.
	Off-Site Disposal	Transport contaminated groundwater to an off-site permitted treatment and disposal facility.	High/High/Low Effective, but requires continuous traffic at the site to transport extracted groundwater throughout life of the remedy.	Short/Long Relatively easy to construct holding tank and schedule disposal. Required throughout the life of the remedy.	Some Identification of disposal facility is required.	Not Retained: Volume of water needed for extraction likely to make offsite disposal infeasible. Truck traffic creates air pollution and inconvenience to community.