955952

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
REGION 5

Statement of Basis

For

AREA C

Northern Indiana Public Service Company (NIPSCO)
Bailly Generating Station

Chesterton, Indiana

EPA ID NO. 000 718 114

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FIGURES

TABLES

ATTACHMENTS

ACRONYMS

AOC	Area of Concern
BERA	Baseline Ecological Risk Assessment
BGS	Below Ground Surface
CAO	Corrective Action Objective
CCR	Coal Combustion Residuals aka Coal Ash
CMS	Corrective Measures Study
ESL	Ecological Screening Level
EPA	U.S. Environmental Protection Agency
GLI	Great Lakes Initiative
HHRA	Human Health Risk Assessment
HI	Hazard Index
IC	Institutional Control
ICIAP	Institutional Control Implementation and Assurance Plan
IDEM	Indiana Department of Environmental Management
IDNL	Indiana Dunes National Lakeshore
IDNP	Indiana Dunes National Park formerly known as IDNL
ISS	In-Situ Solidification/Stabilization
MCL	Maximum Contaminant Level (Drinking Water)
MCS	Media Contaminant Standard
MNA	Monitored Natural Attenuation
LTS Plan	Long-Term Stewardship (LTS) Plan
RCRA	Resource Conservation and Recovery Act
RISC	Risk Integrated System of Closure (IDEM)
RSL	Regional Screening Level
RFI	RCRA Facility Investigation
SB	Statement of Basis
SWMU	Solid Waste Management Unit
U.S.C.	United States Code
WQS	Water Quality Standards

SECTION I: INTRODUCTION AND PURPOSE OF THE STATEMENT OF BASIS

The primary purpose of this Statement of Basis ("SB") document is to invite written comments from the public on the approach proposed by the U.S. Environmental Protection Agency (EPA) to remediate and manage contaminated soil and groundwater at Area C of the NIPSCO Bailly Generating Station *(246 Bailly Station Road, Chesterton, Indiana 46304)* ("Facility") (see Figure 1). The Facility burned coal to generate electricity. The byproduct of burned coal, coal ash, was historically disposed of on-site where it contaminated soil and groundwater. This proposed remedy is designed to protect people currently using the Facility, future industrial or commercial workers, and off-site receptors. Off-site receptors include recreational users of the adjacent Indiana Dunes National Park ("IDNP" or "National Park") property. The proposed cleanup involves excavation and off-site disposal of contaminated soils at the source area. In addition, contaminated soil present beneath the water table will be solidified to prevent remaining contaminants from migrating to the groundwater or surface water. This document summarizes the proposed remedy for Area C of the Facility. Additional technical details can be found in the Corrective Measures Proposal (Final Area C Corrective Measures Study, NIPSCO July 9, 2019) and other documents contained in the Administrative Record for this Facility (see Attachment A).

EPA invites written comments from the public on the proposed remedy. Additionally, EPA will host a public meeting to answer questions and receive additional comments. Public comments will be used to inform EPA's final decision regarding the remedy selection. EPA will publish a Final Decision and Response to Comments document conveying EPA's decision about how the Facility will be remediated, after the close of the comment period. See page 24 for instructions explaining how to provide comments to EPA on the SB.

Corrective Action Order on Consent – 3008(h)

In 2005, EPA and the Northern Indiana Public Service Company ("NIPSCO") entered into an Administrative Order on Consent ("Order") requiring that NIPSCO investigate and clean up contamination released at its property and establishing EPA oversight of the remedial process. The Order was issued under the authority of Section 3008(h) of the Solid Waste Disposal Act (commonly referred to as the Resource Conservation and Recovery Act of 1976, "RCRA"), as amended by the Hazardous and Solid Waste Amendments of 1984, 42 U.S.C. § 6928(h).

The work ordered by EPA is designed and implemented to protect human health and the environment. EPA's RCRA Corrective Action program oversees the cleanup of the Facility. The Corrective Action program is responsible for ensuring that facilities investigate and clean up releases of hazardous waste and hazardous constituents at their properties and any releases that have spread beyond the property boundaries, which may pose a risk to human health or the environment. To accommodate the investigation, the Facility was divided into three Areas, A, B and C. Area A and Area B were the subject of an EPA 2012 Final Decision for the NIPSCO Facility. Area C needed additional investigatory work, however, to enable EPA to determine the appropriate cleanup remedy for the remaining portion of the Facility and the adjacent off-site areas. See Figure 3. Area C is the subject of this document. The proposed remedies, or clean-up actions, for the Facility were chosen based upon the current and future anticipated use of the property.

Area C Remedy Summary

After reviewing the results of samples and studies, past environmental practices, historical investigations and remedial activities, a suite of cleanup options were evaluated for each contaminated area that posed a risk to human health or the environment. EPA refers to an area where waste was stored or disposed or routinely released as a Solid Waste Management Unit ("SWMU"or "SWMUs"). Each cleanup option was evaluated for its ability to protect human health and the environment at these contaminated areas or SWMUs. After comparing options and weighing each against EPA standards, EPA is proposing the cleanup actions presented below. Each of the options summarized below are described in more detail in Section VI (see Figure 2 which shows the SWMUs and areas of contamination).

Proposed Remedies

SWMU 15: Partial Excavation and Off-Site Disposal of Coal Combustion Residuals ("CCR") with In-Situ Solidification ("ISS") of CCR Below the Water Table

SWMU 15 is an area where NIPSCO historically disposed of coal combustion residuals on its property. CCR contaminants commonly include metals such as the aluminum, arsenic, boron, molybedenum and selenium that were found in SWMU 15. Under this proposed remedy, NIPSCO will excavate the CCR[1] located above the water table (approximately 100,000 cubic yards) and dispose of it off-site. The remaining CCR located below the water table (approximately 85,000 cubic yards) will be stabilized and contained through the process of solidification (called "in-situ solidification/stabilization" or "ISS"). ISS is a common[2] method of containment involving the mixture of additives with waste to physically and chemically reduce the mobility and toxicity of contaminants. ISS encapsulates the waste and forms a solid material while chemical reactions between the additives and waste further bind the contamination up into the solid mass. ISS is being proposed for the deeper, saturated CCR due to worker safety and logistical reasons, discussed later.

Greenbelt and Eastern Wetland: Excavation and Off-Site Disposal

A small area of CCR was discovered in the off-site Greenbelt[3] area and adjacent IDNP property. The presence of CCR within IDNP is unacceptable and, therefore, excavation and off-site disposal is the only proposed option (referred to as a "presumptive remedy"). NIPSCO will excavate the CCR and intermingled soil for off-site disposal with a target volume of 705 cubic yards, based on the

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[1] Coal combustion residual ("CCR"), commonly known as coal ash, is created when coal is burned by power plants to produce electricity. It consists of the material (ash) that is left after the coal is burned. See page 12, table listing Potential Constituents of Concern Table associated with CCR.

[2] Solidification/stabilization is within the top five most frequently selected in-situ methods for source remediation according to the 2017 Superfund Remedy Report, 15th Edition. As summarized on *clu-in.org,* EPA's 2010 Superfund Remedy Report indicates that 56 Superfund National Priorities List sites used ISS to treat sources between 1982-2008.

[3] In 1996, NIPSCO and the National Park Service ("NPS") entered into a memorandum of agreement related to the Greenbelt property, which exists as a buffer between the developed portions of the Facility and Indiana Dunes National Park. The goal of the agreement was to ensure that the Greenbelt property was managed in a manner consistent with the adjacent IDNP. Through the agreement, a portion of the Greenbelt was conveyed to NPS by donation, a portion of the property was the subject of a perpetual conservation easement granted to NPS, and a portion of the property was made the subject of a revocable license granted to NPS. NIPSCO also entered the Greenbelt property into the Indiana DNR Classified Wetlands Program in 2010. In 2018, as part of a land exchange between NIPSCO and NPS, a 5.6-acre parcel of the Greenbelt located directly east of the operational area of Bailly Generating Station was transferred from NIPSCO to NPS. In 2019, NIPSCO, in coordination with IDNP, commenced ecological restoration efforts within the Greenbelt property and adjoining Park wetlands.

investigation. The excavated material will be replaced with clean dune sand from an approved source and NIPSCO will collaborate with IDNP to restore the area with plantings that are native to the National Park.

IDNP Groundwater: Source Control and Monitored Natural Attenuation ("MNA")

Groundwater contaminated by the CCR in SWMU 15 has migrated to the off-site IDNP property. The primary risk driver to IDNP is boron. This proposed remedy will require regular monitoring of the groundwater with an expectation that remedial objectives will be met within a reasonable timeframe (within 15 years). This approach is predicated on eliminating the leaching CCR in SWMU 15 that is the source of contamination. MNA is being proposed, in consultation with IDNP, as the least disruptive option to the National Park. A contingency plan will be evaluated in the event source control and natural attenuation do not achieve remedial endpoints. A contingency plan could include additional or different monitoring to verify conditions or an alternative cleanup action. Any contingency plan evaluated will be done in consultation with IDNP.

Previously Barren IDNP Soil Area: Monitored Natural Attenuation

This area will continue to be monitored to ensure the historic contamination from the settling ponds is resolved. As a remedial option, MNA requires source control. The source of the altered soil pH in this area was the previously unlined wastewater and coal ash settling ponds. These ponds were lined in 1980. Observed trends in the area indicate conditions are returning to normal and desirable, native plant communities are becoming established. This remedial option requires on-going monitoring with a contingency plan and is proposed, in consultation with IDNP, as the least disruptive option to the National Park.

Facility-Wide: Land Use Institutional Control

To limit exposure to remaining contaminants, EPA will require NIPSCO to establish and record an environmental restrictive covenant, approved by IDEM and EPA, to restrict the land use of the NIPSCO property to industrial or commercial use now and in the future. A restrictive covenant will also prohibit the use of groundwater as a drinking water source. This component of the proposed remedy will only apply to the NIPSCO property and is consistent with NIPSCO's anticipated future land use.

Facility-Wide: Financial Assurance

NIPSCO must demonstrate a financial ability to complete the proposed remedy and long-term monitoring by securing an appropriate financial instrument.

Facility-Wide: Long Term Stewardship/Five Year Remedy Review

EPA will require NIPSCO to establish a long-term stewardship plan, including monitoring and reporting, for the duration of time contamination remains above unrestricted use levels. The frequency of data collection and reporting will be defined within the long-term stewardship plan. Institutional and engineered controls will be certified on a regular schedule in accordance with an Institutional Control Implementation and Assurance Plan (ICIAP). Five-year remedy reviews, a component of long-term stewardship, will be the appropriate means to update the conceptual site model (CSM), as needed.

SECTION II: FACILITY BACKGROUND

Location and Setting

The Facility is in Porter County in northwest Indiana and occupies 350 acres on the eastern edge of an industrial area along the shoreline of Lake Michigan. The Indiana Dunes National Park (formerly Indiana Dunes National Lakeshore[4]) borders the northern and eastern portions of the Facility. The Cowles Bog Wetland Complex, a globally significant and ecologically sensitive feature, is northeast of the SWMU 15 area. The Facility is bordered on the west and south by the ArcelorMittal Steel Burns Harbor Plant. For the purpose of the Corrective Action program, the Facility was divided into three areas, Areas A, B, and C (see Figure 3). EPA's July 9, 2012 Final Decision selected the final remedy for Area A and Area B. This SB proposes a final remedy for Area C.

As the final Area of the NIPSCO Facility to be addressed, Area C has multiple components and is irregularly shaped. Area C consists of the eastern portion of the Facility as shown in Figure 3. Specifically, Area C is comprised of:

1) Areas previously used as CCR disposal areas, including SWMUs 14 and 15. See Figure 2 and Figure 10.

2) A Greenbelt buffer that separates the Facility from the adjacent IDNP. The Greenbelt buffer follows the length of the northern and eastern boundary of the Facility and the IDNP. Generally, the Greenbelt is approximately 300 to 400 feet wide as it follows Facility's property boundary from north to south. However, as the Greenbelt extends south, it becomes irregularly shaped as it encounters SWMU 14 and SWMU 15 and the Eastern Wetlands. Within the Greenbelt are the Southeast Pond, the Previously Barren Soil Area, and portions of the Eastern Wetland and the Northwest and Central Blag Sloughs. See Figure 6.

3) The adjacent IDNP entails approximately 600 acres although CCR has affected groundwater in only a few areas of the IDNP depicted in Figure 10. The IDNP includes parts of the Eastern Wetland and the Northwest and Central Blag Sloughs, Little Lake, the Great Marsh, Cowles Bog Wetland Complex, and the Southeast Pond. See Figure 3 and Figure 6.

This proposed remedy addresses areas of concern ("AOC" or "AOCs") that pose an unacceptable risk to people or ecological receptors. The largest on-site AOC that poses an unacceptable risk is SWMU 15 where CCR was disposed of and came into contact with groundwater. As discussed in more detail in Section IV, SWMU 15 poses an unacceptable risk solely to ecological receptors.

CCR also was disposed of in SWMU 14, but, unlike SWMU 15, the CCR was not placed below the water table. Because the CCR in SWMU 14 does not contact the groundwater, it does not substantially impact

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[4] On February 15, 2019 the Indiana Dunes National Lakeshore (IDNL) was signed into law as the Indiana Dunes National Park (IDNP). The Administrative Record will reflect the prior designation, IDNL; however, this Statement of Basis and all documents hereafter will use the current national park designation, IDNP.

the groundwater. EPA evaluated the potential risk to both human health and ecological receptors associated with SWMU 14 and determined SWMU 14 did not pose an unacceptable risk to any receptor. Consequently, this proposed remedy does not include SWMU 14. The entire Facility, including SWMU 14 of Area C, will be managed with institutional controls to control use of the land and groundwater. The Facility will also require long-term stewardship.

The Facility is located on the southern tip of Lake Michigan. Lake Michigan is hydraulically connected to Area C and the IDNP. Consequently, Lake Michigan water levels influence the groundwater, wetlands, and surface waters throughout Area C and the IDNP.

Recently designated a national park, IDNP is a globally rare landscape with sand dunes and swales (wetlands). It provides habitat to approximately 30 percent of Indiana's rare and endangered species including 60 rare plant and animal species[5]. The Cowles Bog Wetland Complex is a particularly sensitive feature of the National Park located adjacent to the Facility. The 205-acre bog complex is a Congressionally designated National Natural Landmark due to its unique biodiversity[6]. This interdunal wetland complex is supported by emerging groundwater beneath a floating mat of peat moss and unique vegetation.

The cleanup approach being proposed in this document is intended to balance the need to eliminate contamination to IDNP while preserving its fragile ecosystems. Invasive or potentially destructive cleanup methods have not been proposed for IDNP. This approach has been developed in consultation with IDNP.

Ownership History

NIPSCO purchased the 350 acres of undeveloped land at this site in 1932. Though development did not take place until decades later, the land was acquired at a time when the steel industry was expanding in northwest Indiana and NIPSCO anticipated future energy needs[7]. Construction of the coal-fired power plant began in 1959 and it became operational in 1962. In 2017, NIPSCO announced it would be closing the Facility and it ceased operation in 2018.

Manufacturing, Release, and Regulatory History

The Facility included about 300,000 square feet of buildings and production areas within the Area A portion. It generated electricity for distribution to industrial, commercial, and residential customers from two coal-fired, high-pressure steam boilers, each connected to a steam turbine generator. The Facility ceased operation of the coal fired boilers on May 31, 2018. Area C consists of the former wastewater treatment plant and the eastern landfill areas (SWMUs 14 and 15), as well as a portion of the IDNP.

Illinois Basin coal, 4,500 tons of which was burned daily in the two boilers, was delivered to the plant in railroad cars and unloaded into large receiving hoppers located beneath railroad tracks in the rotary dumper building. The coal pile was in the center of Area A. The coal was conveyed by belt from the coal pile to the crusher house, where it was crushed into pieces to meet optimal firing specifications. The crushed coal was conveyed inside the building and placed in two 2,900-ton storage bunkers until

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[5] Shirley Heinze Land Trust, www.heinzetrust.org

[6] The National Park Service, www.nps.gov

[7] Schoon, Kenneth J., *Shifting Sands*, 2016

needed. This coal pile was about 400 by 800 feet in area and could store enough coal for approximately 45 days of power generation.

The Facility obtained makeup and cooling water for plant operations from Lake Michigan. At peak demand, the Facility used up to 300,000 gallons of lake water per minute. Most of this water was used to cool and condense steam. The resulting non-contact cooling water and boiler blowdown were discharged to Lake Michigan in accordance with NIPSCO's National Pollutant Discharge Elimination System (NPDES) permit IN 0000132. The permit was modified in 2019 to reflect changes in operation and is set to expire July 31, 2022.

Several waste streams were generated by the power generation and the Facility's maintenance processes, including bottom and fly ash (CCR), non-contact cooling water, industrial wastewater, cleaning wastes and rinsates, used oil, asbestos insulation, scrap, and limited amounts of spent chemicals. By volume, most of the generated solid waste consisted of CCR. As a result of past activities, EPA identified the Facility as being subject to certain provisions of RCRA (in particular, RCRA Corrective Action). The cleanup activities proposed in this document are required to fulfill that RCRA Corrective Action obligation.

CCR was disposed of on-site between 1962 and approximately 1979 at SWMUs 14 and 15. By approximately 1979, neither SWMU was being used for CCR disposal. Dewatered bottom ash was sent off-site for beneficial recycling as shot blast media. Fly ash was sent off-site for disposal in a regulated landfill.

Physical Setting and Site Characteristics

The Facility has an "L"-shaped footprint and has been divided into Areas A, B, and C as previously described and depicted in Figure 3. Area A includes the western portion of the Facility where the power generation buildings, associated infrastructure and coal storage are located. NIPSCO retired the two coal-fired units on May 31, 2018. The Facility will continue to house equipment to ensure transmission of continuous voltage and a gas-fired "peaking unit" used during high-demand periods.

Area B includes settling ponds associated with the Facility's former wastewater management system, which are in the central portion of the property. As part of the coal-fired unit decommissioning these impoundments are no longer receiving CCR and are in the process of being closed, with State oversight, consistent with the CCR Final Rule (40 CFR Parts 257 and 261).

Area C, the subject of this SB, is comprised of locations where CCR was disposed of including SWMU 15 and SWMU 14. It also includes the Greenbelt, the Southeast Pond and the Eastern Wetlands. Area C also includes portions of the IDNP including a Previously Barren Soil Area and a downgradient portion of the IDNP where the CCR contaminants have been detected in the groundwater and surface water. The IDNP portion of Area C is over 600 acres; however, CCR-related contamination also has been identified in a small downgradient area, shown on Figure 10.

The largest of the CCR disposal areas, SWMU 15, is the source of off-site contaminated groundwater that poses a risk to ecological receptors. The groundwater migrates from upgradient, encounters the underground CCR which contaminates the groundwater and, then, the contaminated water continues to migrate downgradient into the IDNP. The northern portion of SWMU 15 is a mostly vegetated, vacant field and the southern portion of SWMU 15 is also vacant land but covered in gravel and slag. The slag was historically placed as fill and will be removed and disposed of off-site during the proposed remedy.

Soil

Soils located at and near the Facility are composed primarily of five types: Oakville fine sand, Houghton muck, Adrian muck, Maumee loamy fine sand, and Dune sand. The soils are mainly dune deposits that contain sand and some fine gravel. In addition to the dune deposits, the IDNP interdunal wetlands contain paludal deposits (peat, muck, some marl, and mixtures of peat and sand).

Geology

The geology along the southern shore of Lake Michigan represents a complex glacial and post-glacial history consisting of shallow-water coastal lake, wetland, and dune sedimentation that began during, and continued after, the final stages of glacial retreat in the Great Lakes area (see Figures 4 and 5).

Unconsolidated deposits near the Facility are underlain by the Antrium Shale (Upper Devonian) and carbonate rock (Muscatatuck Group) of Devonian Age. Bedrock near the Facility ranges from 430 to 450 feet above mean sea level (amsl). The Antrium Shale consists of brown to black non-calcareous shale and overlies the Muscatatuck Group in the Facility area. The Muscatatuck Group consists of rocks that are predominately limestone and dolomite.

A 1977 United States Geological Survey (USGS) boring near the eastern portion of the Facility encountered bedrock (Antrium Shale) at 175 feet below ground surface (bgs). A second USGS boring on the western portion of the Facility encountered shale (Antrium Shale) at 182 feet bgs.

Hydrogeology

Surficial aquifers under the Facility consist of glacially-derived sediments associated directly or indirectly with the advance and retreat of the Lake Michigan ice lobe during the Wisconsinan glaciation. There are three major aquifers within the unconsolidated sediments at and near the Facility: Basal Sand, Subtill, and Surficial.

The most extensive aquifer around the Facility is the surficial aquifer and consists primarily of unconfined lacustrine and eolian sands. The surficial aquifer under the Facility is approximately 50 feet thick and groundwater flow in the surficial aquifer is primarily horizontal toward Lake Michigan. The saturated thickness ranges from 20 to 40 feet. The aquifer is recharged in the dune-beach complex (north of U.S. Route 12) and discharges into streams, ditches or ponded areas in the adjacent interdunal wetlands, including the western terminus of the Great Marsh. The Great Marsh is an expansive interdunal wetland formed as part of the broader dune system approximately 4,000 years ago. Historically, it consisted of a single open body of water comprised of one watershed. In the early twentieth century, the Great Marsh was impacted by urbanization and was divided into three watersheds. It is currently about 12 miles from west to east with the Cowles Bog Wetland Complex located at its far western edge.

Surface Water

Surface water within Area C is limited mostly to off-site wetlands within IDNP (discussed more below). Some of those water bodies are permanent features and some come and go with seasonal water fluctuations. On-site water bodies, settling ponds, are in Area B. These ponds were associated with the Facility's former wastewater management system for the coal-fired power generation. The Area A coal-fired unit is undergoing decommissioning, and these settling ponds no longer receive non-contact cooling water and are being closed under IDEM oversight consistent with the applicable regulations.

North and downgradient from the CCR disposal areas and settling ponds, there are a variety of surface water bodies present. As shown in Figure 6, the Central Blag Slough forms the northern edge of Area B and contains surface water depending on precipitation and groundwater elevations. The same is true for Little Lake and the Eastern Wetlands located within Area C, north of SWMU 15. A permanent surface water body known as Southeast Pond exists in the eastern part of Area C. The Cowles Bog Wetland Complex, located east of Area C, lies north of the Southeast Pond and extends to the east. Lake Michigan is located north of the IDNP. The Little Calumet River is located approximately 0.5 miles south of the Facility and discharges to Lake Michigan through Burns Ditch about 5 stream miles west of the Facility.

Ecological Setting

The Facility itself does not contain ecological habitat. The surrounding IDNP however, including Area C, is a globally significant ecosystem. IDNP is a “dune and swale” environment, which means a series of tall sandy ridges (dunes) parallel to the lake alternating with low-lying areas that form wetlands. This unique environment was created by the advance and retreat of the last glacier responsible for creating Lake Michigan. The biological diversity within the National Park is amongst the highest per unit area of all our national parks. There are over 1,100 flowering plant species and ferns and 350 species of birds. IDNP was the focus of the investigations for Area C and the remedies proposed in this document are designed to ensure the National Park is protected and minimally disturbed while also being restored.

SECTION III: SUMMARY OF ENVIRONMENTAL INVESTIGATION

The purpose of a Corrective Action Remedial Facility Investigation (“RFI”) is to determine whether hazardous waste or hazardous constituents were released into the environment at a Facility, and if so, to evaluate the significance of the releases in terms of risk to human health and the environment. The investigation is governed by a conceptual site model (“CSM”) which illustrates Site physical characteristics, sources of contaminants, their fate and transport, affected environmental media, and potentially exposed people and ecological receptors (plants and animals). Each RFI varies depending on Facility-specific details.

During the investigation phase, environmental media such as soil, groundwater, surface water, sediments, and biota are sampled and analyzed for contamination. Where contaminated media are found, subsequent sampling is usually completed to refine the CSM and define the extent of contamination (how far it may have traveled), and to collect enough information for analysis of exposure effects in risk assessments. After each sampling event or investigation phase, EPA evaluates the CSM to determine the adequacy of the data to support decision-making. If found to be inadequate, additional data collection is necessary. Due to the sensitive nature of the National Park and complicated hydrology of the area, this process took many years to complete for Area C.

Site Investigation Summary

NIPSCO conducted an extensive multi-phase, multi-media investigation in Area C. Soil, sediment, groundwater, surface water and plant samples have been collected to determine the nature and extent of the contamination. Studies were conducted to fully understand the makeup of the National Park and the various ecological interactions critical to the park. Over the course of several years and multiple, iterative studies, sufficient information was gathered to determine the impacts of contamination from the Facility on the National Park and how best to address them.

Under Corrective Action, two SWMUs (14 and 15) and two AOCs (9 and 10) as well as downgradient locations in IDNP were identified within Area C as needing investigation to determine whether they have released hazardous waste or hazardous waste constituents (See Figure 2). These areas were identified based upon waste handling history and potential contaminant fate and transport mechanisms. Groundwater, surface water, soil and sediment were characterized at the SWMUs and AOCs and at downgradient locations of potential concern (e.g., Great Marsh, Little Lake, Eastern Wetlands, Central Blag Slough and Northwest Blag Slough). Biological assessments were also conducted in order to fully characterize the impacts to the IDNP. Studies focused heavily on plants but also included amphibians, due to their sensitivity to contamination. Even low levels of contaminants pose a risk to the receptors within the National Park due to the receptors' sensitivity.

Over the course of the RFI, the following studies were performed to determine what the chemicals of concern were, where they were located and what risks they posed:

Soil Investigations

- test pit investigations to delineate the extent of known and suspected CCR in SWMU 14 and 15;
- soil borings and collection of over 450 soil samples to characterize soil lithology and identify areas of exceedances of screening criteria and/or background concentrations;

Groundwater & Hydrogeologic Investigations

- installation of over 50 groundwater monitoring wells on and off-site;
- quarterly groundwater, surface water and sediment sampling to identify exceedances of screening criteria and/or background concentrations;
- analysis of over 400 sediment samples, over 400 surface water samples, and over 600 groundwater samples;
- installation and quarterly measurement of staff gauges in the IDNP to identify vertical hydraulic gradients in low-lying wetland areas;
- testing and quarterly monitoring well gauging to identify horizontal hydraulic gradients;
- sampling of the Lake Michigan groundwater/surface water interface (GSI) within IDNP along the shore of the lake;

Ecological (Plant and Animal) Investigations

- investigation to characterize the fraction of vegetative stress in contaminated portions of IDNP;
- investigation to assess whether a relationship exists between the absence of IDNP vegetation in barren soil areas and presence of Facility-related constituents in soil;
- assessment of whether a relationship exists between observation of vegetative stress and the presence of Facility-related constituents in soil and plant tissue;
- amphibian survey to observe and evaluate the ecological receptors in IDNP wetlands downgradient from the Facility;
- amphibian surveys to further assess whether Facility-related constituents were impacting IDNP amphibian populations;
- amphibian toxicity study to determine whether some component of sediment in the IDNP exhibits toxicity to embryonic and/or larval amphibians;
- rhizome and soil testing to evaluate the potential for plant bioconcentration of metals and subsequent release back to soils; and
- plant toxicity study to assess whether Facility-related constituents were impacting plants in the IDNP

Investigations, such as the ones summarized above, collect data and compare those results to screening values. A contaminant found above its screening value is considered a constituent of potential concern ("COPC"). Those COPCs are then further evaluated during the risk assessment process to determine if they are causing any unacceptable risk to the receptor of concern (discussed more in the next section). The COPC's that were identified during the investigation are presented in the table below. See Figures 7, 8 and 9 to reference these investigation locations.

Constituents of Potential Concern SWMU 15		
Soil	**Sediment**	**Groundwater**
Arsenic	Not Applicable	Aluminum
Boron		Arsenic
Cadmium		Boron
Chromium		Molybdenum
Copper		Selenium
Lead		
Manganese		
Molybdenum		
Selenium		
Eastern Wetland		
Soil [1]	**Sediment [1]**	**Groundwater**
Arsenic	Arsenic	Aluminum
Boron	Barium	Boron
Cadmium	Boron	
Chromium	Cadmium	
Copper	Chromium	
Molybdenum	Copper	
Selenium	Lead	
	Manganese	
	Mercury	
	Molybdenum	
	Selenium	
Central Blag Slough		
Soil	**Sediment**	**Groundwater**
Not Applicable	pH	Aluminum
		Manganese
Northwest Blag Slough		
Soil	**Sediment**	**Groundwater**
Not Applicable	Not Required	Aluminum
Little Lake		
Soil	**Sediment**	**Groundwater**
Not Applicable	Not Required	Aluminum
		Manganese
Other Wetlands		
Soil	**Sediment**	**Groundwater**

Not Applicable	Not Required	Aluminum
		Manganese
SWMU - Solid Waste Management Unit		
Not Applicable - soil or sediment not present in sub-area.		
Not Required - sediment in this sub-area does not require investigation based on CSM.		
^{1} Only applies in Greenbelt at toe of SWMU 15 and potentially extending into the IDNL near IDNL-GW13.		

The contaminants listed above were found at concentrations above conservative screening values. Those screening values are very low and developed to overestimate impacts to ensure nothing is prematurely ruled out. The screening values for the Area C investigation included:

- Groundwater: Great Lakes Initiative values (GLI); plant screening values (Oak Ridge National Laboratory values); Piping Plover values developed by EPA for site-specific evaluation; and, background
- Surface Water: GLI; background
- Soil (ecological): EPA Ecological Soil Screening Levels (avian, mammalian, plant, invertebrates); EPA Region 5 Ecological Screening Levels; and, Oak Ridge National Laboratory values
- Soil (human health): IDEM RISC Industrial default closure level; EPA Regional Screening Level (industrial); and, background
- Sediment: EPA Region 5 Ecological Screening Levels; NOAA Screening Quick Reference Tables; and, background

Since completion of the Area C RFI (AMEC, 2011), NIPSCO conducted additional CMS investigations to better understand the horizontal and vertical distribution of CCR in SWMU 15, groundwater geo-chemistry and soil mineralogy, and hydrology. Detailed field and laboratory studies were conducted to quantify boron attenuation on aquifer solids, define the attenuation mechanisms (both temporary sorption and permanent fixation), and the capacity of the aquifer to remove boron from the dissolved phase. Findings from these investigations were used to refine the conceptual site model for groundwater flow and boron transport. Beginning in 2016, a series of CMS-focused investigative studies were conducted at SWMU 15 to examine the excavation, encapsulation, and ISS technology options that were evaluated for source control.

The SWMU 15 investigations included multiple, direct-push and hand-auger borings to better understand the distribution of fine CCR and the nature of underlying, native soils, particularly in central portions of the landfill. Sonic borings were subsequently advanced to better understand lithology at depths greater than 40 feet, the limit of direct-push borings. Samples of CCR were collected for chemical and geotechnical analysis, as well as bench-scale testing of various formulations to evaluate the ISS technology. Samples of sand and clay were also collected for geotechnical testing for consideration of additional design parameters.

The IDNP investigations were conducted primarily in groundwater downgradient of SWMU 15. Data were collected to determine the viability and mechanisms of natural attenuation and in support of potential remedial alternatives evaluated for IDNP groundwater. NIPSCO coordinated with EPA's Office of Research and Development to ensure any monitored natural attenuation evaluations were conducted in accordance with EPA's guidance[8]. Additional assessment was conducted in Cowles Bog and Little Lake to refine the conceptual site model (CSM) for groundwater flow. Parameters that were developed from the IDNP studies were incorporated into numerical models of groundwater flow and contaminant transport to perform a comparative analysis of the alternatives developed for IDNP groundwater.

The following is a summary of those additional investigations that have taken place since the RFI:

- groundwater geochemistry and soil mineralogy studies to quantify boron attenuation on aquifer solids;
- an aerial photograph study to understand the history and sequence of SWMU 15 development;
- supplemental SWMU 15 delineation and CCR characterization (including soil borings, soil and CCR sampling for analysis of chemical and geotechnical properties, and CCR sampling for leachability testing);
- deep soil boring program to assess clay continuity and the native lithology underlying SWMU 15;
- soil pH study in area of barren soil;
- hydraulic conductivity testing, groundwater/surface water transducer study, groundwater gauging, water elevation surveys, and Cowles Bog groundwater sampling to better evaluate the hydraulic conditions within the sensitive IDNP area.

Attachment B provides detailed information about the investigations that have taken place from about 2012 to present. These investigations have significantly impacted the selection of this proposed remedy and therefore are provided in an attachment for convenience. The information can also be found in the *Final Area C Corrective Measures Study* (2019).

SECTION IV: SUMMARY OF RISK EVALUATION

EPA uses risk assessments to evaluate the information and data collected during the investigation to determine whether the contamination present poses a risk to human health or the environment. This is done in a human health risk assessment (HHRA) and a baseline ecological risk assessment (BERA). Both types of risk assessments were conducted for Area C. Risk assessments are used to make a risk management decision as to whether a cleanup is necessary.

For human health risk assessments, EPA has developed a cancer risk range that it deems acceptable to protect the public. This range is identified through the risk assessment process and used to make risk management decisions. Cancer risk is often expressed as the maximum number of new cases of cancer projected to occur in a population due to exposure to the cancer-causing substance over a 70-year lifetime. For example, a cancer risk of one in one million means that in a population of one million people, not more than one additional person would be expected to develop cancer as a result of the exposure to the substance causing that risk. EPA utilizes the acceptable exposure level, or "risk goal" described in the National Contingency Plan (NCP) at 40 C.F.R. Part 300 for enforcement and cleanup decisions at both Superfund sites and RCRA facilities. The NCP defines the acceptable excess upper lifetime cancer risk as generally a range between $1\text{x}10^{-6}$ – $1\text{x}10^{-4}$ for determining remediation goals. See 40 C.F.R. 430 (e)(2)(i)(A). If the contaminants are noncancerous but could cause other health problems, then a hazard index quotient is used. To be acceptable to the EPA, the hazard index (HI) quotient for all

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[8] EPA, *Monitored Natural Attenuation of Inorganic Contaminants in Groundwater* (2007)

contaminants must be less than one. The hazard index is the ratio of the concentration of a contaminant to its human health screening value.

The constituents listed above in the COPC table were evaluated in both human health and ecological risk assessments. The Area C human health risk assessment evaluated potential exposures to current and future Facility workers, future construction workers, current and future trespassers, current and future park workers, park visitors and teen volunteers. The assessment concluded there are no unacceptable risks to people from Area C. All carcinogenic and noncarcinogenic risk estimates associated with potential exposures to all media in all exposure areas are below the target risk range of $1x10^{-6}$ and $1x10^{-4}$ and hazard index of 1. However, as discussed in the next section, cleanup criteria for the IDNP groundwater includes safe drinking water criteria (MCLs) in addition to the Great Lakes Initiates criteria. EPA's groundwater remediation policy includes restoration of aquifers to their maximum beneficial use[9]. Also, when a facility's contamination extends off-site onto neighboring property, the contamination must be addressed in a manner consistent with the off-site property's use. As a National Park, both ecological and human health receptors must be protected in such a way as to not limit future uses. Based on this policy, the off-site groundwater will be remediated to drinking water standards (discussed more in the next section).

A BERA was conducted to provide a comprehensive assessment of potential risks to populations of ecological receptors that may be exposed to contamination at or from Area C. The constituents listed in the COPC table above were evaluated in soil, surface water, sediment, and/or groundwater in seven habitat areas: Northwest Blag Slough, Central Blag Slough, Little Lake, Eastern Wetlands, SWMU 14 and SWMU 15, and Southeast Pond. Ecological receptors, including mammals, birds (one of which was the Federally endangered piping plover), amphibians, fish, soil invertebrates, benthic invertebrates, and terrestrial plants were assessed.

Contamination leaving the Facility in groundwater from SWMU 15 and entering the IDNP exceeds applicable ecological criteria (discussed more in the next section, also see Figure 10). Groundwater contamination is found in the surface waters of IDNP as a result of the groundwater and surface water being connected. Stressed vegetation has been observed and studied within the National Park. There is a complicated hydrogeologic cycle between the groundwater, surface water and sediment as it pertains to the bioavailability of certain metals. The most chronically exposed receptors to this cycling of contamination between groundwater, surface water, and sediment are the plants. Studies subsequently demonstrated Facility contamination within the plant tissue.

NIPSCO submitted the BERA to EPA in 2011 and concluded there were no risks to any receptors from any of the contamination. EPA, in consultation with the National Park Service, evaluated the methods used in the BERA and concluded it did not agree with NIPSCO's conclusion**.** Attachment C is the evaluation EPA conducted and provided to NIPSCO in early 2013. In general, EPA found the level of uncertainty associated with many of the studies too high to eliminate the possibility of unacceptable risk. The nature of the off-site environment, the National Park, requires the highest level of protection and conservatism. EPA's BERA comments in Attachment C provide specific details about receptors, areas, and risks posed. As a summary, EPA's conclusions included the following:

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[9] EPA, *Handbook of Groundwater Protection and Cleanup Policies for RCRA Corrective Action Sites* (2004)

- unacceptable risk to plants
- potential risk to benthic receptors and invertivorous birds
- potential risk to amphibians likely low, but uncertainty is too high to rule out
- potential risk to terrestrial invertebrates
- unacceptable risk to certain terrestrial wildlife in some areas

Due to the overwhelming multiple lines of evidence suggesting ecological risk to the National Park, EPA directed NIPSCO to proceed with a risk management decision without revising the BERA. A risk management decision refers to an action or set of actions that are developed and implemented to reduce risk to an acceptable level. In this case, EPA specified that an acceptable decision would include source control (SWMU 15), limited off-site remediation (in coordination with NPS), and long-term monitoring.

This Statement of Basis represents the conclusion of that risk management decision process. Although all COPCs were evaluated it was found that the boron groundwater plume extending into IDNP is of most significance. Boron exhibits the largest area of groundwater impacted and poses unacceptable risk to the National Park's plant life. Boron concentrations have been compared to the Great Lakes Screening values.

SECTION V: CORRECTIVE ACTION OBJECTIVES AND MEDIA CLEANUP STANDARDS

The proposed final remedy and associated remedial goals are designed to protect human health and the environment by mitigating risk to current and potential future receptors. They are also designed to restore IDNP without causing any further damage by the cleanup. EPA's long-term goals for the remedy being proposed are the following:

- Protect human health and the environment;
- Attain the applicable media (e.g., soil, water, etc) cleanup standards ("MCS" or "cleanup levels");
- Control the sources of the releases to the extent practicable; and
- Manage all remediation waste in compliance with applicable standards.

Presented in the following table are the cleanup objectives, or Corrective Action Objectives (CAOs), for the affected media and applicable cleanup standards. The CAOs are the overarching goals the remedy needs to achieve (prevent direct exposure, reduce inhalation risk, restore groundwater to most beneficial use, etc). Bear in mind that on-site cleanup standards are industrial/commercial because the reasonably anticipated reuse of the NIPSCO facility will be industrial/commercial use. Nonetheless, the off-site IDNP property will have no use restrictions. Consequently, the media cleanup standards for the off-site IDNP areas are equivalent to residential cleanup standards.

Environmental Media	Corrective Action Objectives				
	SWMU 15 On-Site	Greenbelt and Eastern Wetland	IDNP Off-Site	Cross-media Transfer	Resource Restoration
Groundwater	At downgradient points of compliance, groundwater will meet the lower of EPA's Great Lakes Initiative[10] (GLI) values or Maximum Contaminant Level (drinking water levels, MCLs)	The lower of EPA's Great Lakes Initiative (GLI) values or Maximum Contaminant Level (drinking water levels, MCLs)	The lower of EPA's Great Lakes Initiative (GLI) values or Maximum Contaminant Level (drinking water levels, MCLs)	Prevent the migration of contaminated groundwater from SWMU 15 impacting IDNP through source control	Restore groundwater in IDNP to GLI values by eliminating the source
Soil	Prevent direct exposure: IDEM Default Closure Levels (DCLs) for industrial soil and EPA Regional Screening Levels (RSLs) for analytes where IDEM has not published DCLs	Prevent direct exposure: IDEM Residential Direct Exposure Criteria and Migration to Groundwater	NA	Prevent CCR contamination in SWMU 15 from leaching to groundwater and entering IDNP soil through an engineered remedy	NA
Sediment	NA	EPA Region 5 Ecological Screening Levels, or site-specific background	NA	Prevent the cycling of contaminated groundwater to surface water or sediment by eliminating the source of contamination	Restore the sediment in IDNP to ecologically safe levels by eliminating the source of contamination.

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[10] Section 118(c)(2) of the Clean Water Act (CWA) (Pub. L. 92–500 as amended by the Great Lakes Critical Programs Act of 1990 (CPA), Pub. L. 101–596, November 16, 1990) required EPA to publish proposed and final water quality guidance on minimum water quality standards, antidegradation policies, and implementation procedures for the Great Lakes System. The GLI was established in order to develop a consistent level of environmental protection for the Great Lakes ecosystem (60 Fed Reg 15366-15425). The GLI methodologies were developed with the sensitivity of the Great Lakes resources in mind, including the lakes themselves, their connecting channels and all the streams, rivers, lakes and other bodies of water that are within the drainage basin of the Lakes. (60 Fed Reg 15367, 15388) (40 CFR 132.2). GLI values are derived from Criteria and Values for Selected Substances Calculated Using the Great Lakes Basin Methodologies (IDEM, 2002). Also, certain contaminants did not have designated MCLs and EPA used GLI limits because the GLI is specific to the region and highly conservative.

Environmental Media	**Corrective Action Objectives**				
	SWMU 15 On-Site	Greenbelt and Eastern Wetland	IDNP Off-Site	Cross-media Transfer	Resource Restoration
Surface Water	NA	NA	Due to the connection between the groundwater and surface water, the IDNP surface water will also attain GLI levels	Prevent the cycling of contaminated groundwater to surface water through source control	Restore the surface water in the IDNP by remediating the groundwater cycling to the surface to GLI values

The specific media cleanup standards for each constituent of concern that will achieve those corrective action objectives are as follows:

Analyte	Direct Contact (mg/kg)	Leaching from Unsaturated Soil (ug/L)	Groundwater MCS (ug/L)
ARSENIC	30 [1]	30	10 [3]
BORON	100,000 [2]	4,800	1,600 [4]
CADMIUM	980 [1]	15	5 [3]
CHROMIUM	100,000 [1]	300	100 [3]
COPPER	47,000 [1]	840	280 [4]
LEAD	800 [1]	45	15 [3]
MANGANESE	26,000 [2]	2,982	994 - 2,351 [5]
MOLYBDENUM	5,800 [2]	2,400	800 [4]
SELENIUM	5,800 [1]	13.8	4.61 [4]
Notes:			
[1] IDEM RISC Industrial Soil Default Closure Level			
https://www.in.gov/idem/cleanups/files/risc_screening_table_2018_a6.pdf			
[2] EPA Industrial Soil Regional Screening Level			
[3] MCL - Maximum Contaminant Level			
[4] GLI - Great Lakes Initiative			
[5] GLI hardness-adjusted range with background established as lower limit. Because hardness does not apply to SPLP results, the leaching-based soil standard for manganese was established as three times the background value for groundwater.			
GLI values derived from Criteria and Values for Selected Substances Calculated Using the Great Lakes Basin Methodologies (IDEM, 2002); boron value from IDEM Water Quality Standards Tier II 2004 update.			

The proposed MCS for unsaturated soil is derived by multiplying the proposed MCS for groundwater by a factor of 3. The MCS for soil is measured using the Synthetic Precipitation Leaching Procedure (SPLP).		
MCS - Media Cleanup Standard		

SECTION VI: PROPOSED FINAL REMEDY AND EVALUATION OF ALTERNATIVES

The process of developing a proposed final remedy often starts with a broad range of options that are evaluated and either retained for further consideration or eliminated based on disqualifying evidence. For Area C, technologies were eliminated if they did not protect human health and the environment by mitigating risk to receptors and address the source of contamination (SWMU 15). A summary of all the alternative technologies evaluated for the Facility are in the table below and detailed information about the proposed remedies follow. More information about all the cleanup options considered can be found in the Corrective Measures Study Report (2019). The proposed final cleanup remedies for Area C are shaded in the table below and described in greater detail below. The other alternative cleanups listed were not selected due to evidence indicating they would not work or would not work as well as the proposed remedies.

Alternatives Considered	SWMU 15	Greenbelt and Eastern Wetland	IDNP Groundwater	Previously Barren Soil Areas
1	Full Excavation and Off-Site Disposal of CCR	Full Excavation and Off-Site Disposal of CCR (presumptive remedy)	In Situ Remediation	Excavation and Off-Site Disposal with Soil Replacement
2	Full Excavation and On-Site Consolidation of CCR		Groundwater Pump & Treat	Soil Flushing/pH Adjustment
3	Full Excavation with On-Site Consolidation and Off-site Disposal of CCR		Source Control and Monitored Natural Attenuation Alternative Water Supply (if needed)	Source Control and Monitored Natural Attenuation Alternative Water Supply (if needed)
4	Partial Excavation with Off-Site Disposal and In-Situ Solidification/Stabilization of Remaining CCR		Alternative Water Supply (if needed)	
5	Partial Excavation with On-Site Consolidation and ISS of Remaining CCR			
6	In Situ Encapsulation			

The process of selecting a proposed remedy involves screening them against certain criteria and comparing them to each other. EPA has defined threshold and balancing criteria to compare remedial technologies at all facilities in a consistent manner. All remedies must meet the threshold criteria and the balancing criteria can be used to further refine the best possible technology based on site-specific factors. The remedies presented above were all compared to these criteria and the proposed remedies presented in this document represent the best possible options. See Attachment D for additional balancing criteria information.

EPA's three remedial Threshold Criteria are the following:

1) Protect human health and the environment based on reasonably anticipated land use(s), both now and in the future
2) Achieve media cleanup objectives appropriate to the assumptions regarding current and reasonably anticipated land use(s), and current and potential beneficial uses of water resources
3) Control the sources of releases to achieve elimination or reduction of any further releases of hazardous wastes or hazardous constituents that may threaten human health and the environment

The seven remedial Balancing Criteria are the following:

1) Long-term reliability and effectiveness (long-term effectiveness should consider reasonably anticipated future land uses)
2) Reduction of toxicity, mobility, and volume of waste
3) Short-term effectiveness
4) Implementability (technical feasibility and availability of services and materials)
5) Cost
6) Community acceptance of remedy
7) State/support agency acceptance

Proposed Final Remedy

The proposed remedies for each SWMU are described in more detail below followed by a table presenting the threshold and balancing criteria as they pertain to the proposed remedies.

SWMU 15: The corrective measures alternatives for SWMU 15 were developed to manage CCR and its impact on groundwater entering the IDNP. Six alternatives were evaluated. The alternative being proposed is Alternative 4: partial excavation and off-site disposal of CCR with ISS of CCR below the water table. Attachment E is a fact sheet that describes ISS, solidification and stabilization, in more detail.

Full excavation and off-site disposal was evaluated but was not selected as the proposed remedy for several reasons. Excavation of CCR below the water table presents certain risks and challenges. Excavation below the water table, particularly in a sandy environment, would require extensive de-watering. The volume of water that would need to be pumped out of the ground, in combination with the length of time it would be necessary, raises concerns over the sensitive hydrology of the IDNP and nearby wetlands. Minimizing damage to IDNP is a significant consideration.

In order to de-water an excavation as deep as SWMU 15, the soil would require shoring (such as sheet piling). The installation of sheet pile for wall stability and water management during excavation of CCR to the depths required at SWMU 15 would require large overhead equipment for positioning and driving the sheet pile. Driving sheet pile would not be allowed within a certain distance of energized power lines and would not be possible beneath the power lines (energized or de-energized). The high voltage lines are 138 kilovolts and require a clearance of 15 feet in accordance with OSHA[11]. The ISS option will not interfere with the high voltage power lines.

Many RCRA-regulated CCR surface impoundments across the country have been either closed in place or excavated for clean closure. This practice has identified a substantial hazard associated with the instability of wet CCR, including the loss of life in one situation. Full excavation of CCR from below the water table at SWMU 15 presents an extremely difficult and hazardous undertaking, which is a significant consideration for the recommended alternative of partial excavation of CCR from above the water table and solidification of CCR remaining below the water table.

The totality of issues associated with full excavation when compared with an equally effective option helped inform EPA's decision to propose Alternative 4. Approximate remedial quantities for SWMU 15 are summarized in the following table.

Area (acres)	**Perimeter (feet)**	**Volume (cubic yards)**	**Thickness of CCR (feet)**	**Thickness of Soil Cover (feet)**
16.6	4,500	227,000 – Total Volume (CCR & Soil) 178,000 – CCR • 86,000 below the water table • 92,000 above the water table	1 – 22	0 – 6

The proposed remedy includes excavation of CCR above the water table (92,000 cubic yards) at SWMU 15 and disposal at an off-site facility permitted to accept CCR. Remaining CCR below the water table (86,000 cubic yards) will be solidified in place by mixing in amendments designed to reduce the leachability of CCR contaminants through a reduction of both hydraulic conductivity and increased chemical fixation (also referred to as in-situ solidification and stabilization, ISS). As described in Attachment E, solidification binds the waste in a solid block of material and traps it in place. The stabilization component of ISS causes chemical reactions that make contamination less likely to be leached into the environment.[12] Upon completion of the work, the site will be backfilled and graded for proper drainage and restored to a condition that will more closely mimic surrounding dune topography compared to current conditions. This remedy will cut off the current source of groundwater contamination, allowing the groundwater plume to meet groundwater cleanup standards in a reasonable amount of time. Modeling suggests that timeframe will be around five years; however, cleanup timeframes are less precise when natural processes are involved.

Excavated CCR will be stockpiled and placed in trucks for transport to an off-site landfill. Truck traffic during this phase of the cleanup will increase temporarily. Low clearance equipment such as bulldozers would need to operate beneath the power lines to remove CCR with adequate clearance. An important consideration for CCR removal is the stability of the material. This alternative minimizes the concern relative to CCR stability by removing approximately one-half of the CCR from above the water table and solidifying the remaining CCR below the water table. This alternative also requires adequate dewatering below the working surface and shallow sidewall sloping.

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[11] https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.1408

[12] A Citizen's Guide to Solidification and Stabilization, EPA 2012

As discussed above, complete removal of the CCR would involve excavation to depths as great as 13 feet below the water table (22 feet below the land surface). These deeper excavations would require extensive dewatering to maintain water levels below the working surface and would present additional safety challenges due to excavation bottom and sidewall stability. Extracting that much groundwater would also have a potentially adverse effect on the IDNP wetland hydrology and sensitive ecological receptors. Due to those potential adverse effects, the practical technical difficulties, and the ISS' effectiveness in preventing contaminant migration, complete CCR excavation was rejected.

Other alternative cleanup technologies were also considered for SWMU 15. A series of technical memos from NIPSCO to EPA in Attachment F provides additional background on the process of selecting the proposed remedy[13]. In addition to studies specific to the proposed ISS technology, those memos also describe a remedy initially proposed by NIPSCO. In 2015, NIPSCO submitted to EPA a draft Corrective Measures Study that identified encapsulation with a slurry wall and cap as the proposed remedy. Due to concerns about the engineering of that technology, EPA requested NIPSCO to conduct a geotechnical investigation. Encapsulation requires barriers to completely surround the waste – sides, top and bottom - to prevent water from infiltrating into or through the waste and further contaminating groundwater. NIPSCO's investigation demonstrated encapsulation was not a feasible option because it required a thick clay bottom layer of soil, deep underground, beneath the entire SWMU 15. However, the geotechnical investigation discovered the bottom clay layer at SWMU 15 is not continuous and would not allow for a full encapsulation (additional information in Attachment F). NIPSCO subsequently reevaluated remedial options and demonstrated the proposed partial CCR removal and ISS proposed remedy in this SB is the best option for SWMU 15.

Greenbelt and Eastern Wetland: During the course of the investigation, CCR was discovered in a small area outside of SWMU 15 in the vicinity of the Greenbelt. It appears, based upon the location and limited quantity, the CCR was not placed or disposed of at this location but was accidently "dropped" or "spilled" during historic placement into SWMU 15. The area was delineated and consists of about 705 cubic yards of CCR and CCR-contaminated soil. The alternative being proposed for the Greenbelt and Eastern Wetland is Alternative 1. The proposed remedy of excavation and off-site disposal is the only remedial approach considered. For certain situations there are remedies that are proven to be effective; these are referred to as presumptive remedies. It is not necessary to evaluate multiple remedies if a presumptive remedy is proposed. EPA is proposing CCR removal and off-site disposal here because the CCR was not placed into the water table and the amount of CCR material is relatively minor.

The soil and CCR will be removed to a maximum depth of approximately 3.5 feet below grade based upon delineation sampling. Upon completion of the excavation, native dune sand and topsoil from an EPA-approved borrow pit will be imported for use as backfill. The backfilled area will then be re-vegetated with native species selected in consultation with the IDNP and monitored for 10 events over a period of 5 years, as part of the long-term stewardship plan.

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[13] The technical memos in Attachment F include only the text of the documents due to document sizes. The full memos can be found in the Administrative Record.

IDNP Groundwater: The corrective measures alternatives for IDNP groundwater were developed to address elevated concentrations of boron (the risk driver) in groundwater that comes from SWMU 15. Areas of groundwater exceedances are depicted on Figures 6.

The following corrective measures alternatives were developed and evaluated to address the Corrective Action Objectives for IDNP groundwater:

- IDNP Groundwater Alternative 1 – In-Situ Remediation by Permeable Reactive Barriers
- IDNP Groundwater Alternative 2 – Groundwater Pump & Treat
- IDNP Groundwater Alternative 3 – Monitored Natural Attenuation with Source Control

Each alternative includes a potable water supply if the need arises before the alternative achieves the media cleanup levels. Implementation of institutional controls (e.g., deed restrictions) on National Park property is not an acceptable method of groundwater exposure control. It is assumed that a potable water source exists within one mile of the area affected by boron in groundwater and can be used to serve that area, if need be. Each alternative includes the trench excavation and pipe installation required to provide this service.

The first two alternatives involve physical disruption to the National Park, Cowles Bog and nearby wetland habitat. The third alternative relies on the SWMU 15 source control and natural processes documented to be occurring by routine periodic monitoring. All three alternatives will have a groundwater monitoring network. In consultation with the NPS, the proposed remedy reflects the least amount of physical disruption to the National Park. The alternative being proposed for this area is Alternative 3.

As mentioned above, the primary risk driver in the IDNP groundwater is boron from the CCR source material at SWMU 15. The use of MNA as a component of a remedy requires source control, which is being proposed at SWMU 15. MNA is being proposed for the off-site plume that extends down gradient from SWMU 15 based upon extensive study conducted in accordance with EPA guidance. The processes of natural attenuation rely on natural mechanisms to reduce or eliminate contamination. Natural attenuation mechanisms include 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, sediment, or groundwater. In order to incorporate MNA into a cleanup remedy, an investigation is necessary to better understand the exact mechanisms and the viability of attenuation as a component of a remedy. EPA's guidance on MNA of inorganic contaminants identifies four tiers of activities that are required to use MNA as a component of a remedy:

- Tier I: Active Attenuation
- Tier II: Attenuation Mechanism
- Tier III: Attenuation Capacity
- Tier IV: Monitoring and Contingency

The MNA studies conducted in IDNP included an analysis of aquifer solids, mineralogical data and groundwater chemistry. Boron attenuation was demonstrated through two different extraction methods that demonstrated irreversible sorption processes occurring in IDNP. The observed feldspar weathering to clays in IDNP has increased the aquifer percentages of boron-sorbing material. In combination with SWMU 15 source control, MNA will have the capacity to remove the boron from IDNP.

Proposed Remedy Criteria Summary Table

Threshold Criteria	Evaluation
1) Protect human health and the environment	EPA's proposed remedies for the Facility protects human health and the environment by eliminating, reducing, or controlling potential unacceptable risk from the continued leaching of contamination from the CCR. Excavation will remove half the CCR from the Facility and place it in a regulated landfill. ISS will eliminate the risk from leaching CCR contamination to groundwater. During implementation, security fencing will be in place and dust control measures will be employed.
2) Achieve media cleanup objectives	EPA's proposed remedy meets the media cleanup objectives based on assumptions regarding current and reasonably anticipated land and water resource use(s). The remedy proposed in this SB is based on the current and future anticipated land use at the Facility as commercial or industrial. Dissolved metals concentrations will meet MCLs or GLI criteria in groundwater, and exposures to any remaining on-site soil contamination will be adequately controlled through land use restrictions.
3) Remediating the sources of releases	In all proposed remedies, EPA seeks to eliminate or reduce further releases of hazardous wastes and hazardous constituents that may pose a threat to human health and the environment. The Facility will meet this criterion by eliminating the source of groundwater contamination and eliminating the CCR present within IDNP. Therefore, EPA has determined that this criterion has been met.

Balancing Criteria	Evaluation
4) Long-term effectiveness	The long-term effectiveness of the proposed remedy, excavation and ISS, has been demonstrated. Eliminating the source of leachable material will allow uncontaminated groundwater to flow through IDNP and facilitate the remediation of the off-site groundwater.
5) Reduction of toxicity, mobility, or volume of the hazardous constituents	Pilot test information in Attachment F demonstrates the reduction in mobility of contaminants after ISS. Reduction of the volume of hazardous constituents in soil will be achieved by the excavation and off-site disposal of almost 100,000 cubic yards of CCR and contaminated soil. The reduction of toxicity will be

	demonstrated within the IDNP groundwater as MNA occurs.
6) Short-term effectiveness	EPA's proposed remedy will be partially effective in the short-term. The excavation and off-site disposal of CCR will exhibit the greatest short-term effectiveness. The short-term impacts of ISS will be more moderate since it's a remedy that relies on the immediate fixation of contamination to result in long-term benefits down gradient. The excavation and off-site disposal of the Greenbelt CCR will exhibit the greatest short-term effectiveness.
7) Implementability	EPA's proposed remedy is readily implementable. Once the proposed remedy is either selected or modified based on public comment, NIPSCO will be able to immediately plan for the implementation of the work.
8) Cost	The proposed remedy will cost over $20 million. A breakdown of the costs can be found in Attachment D.
9) Community acceptance	EPA will evaluate community acceptance of the proposed remedy during the public comment period, and it will be described in the Final Decision and Response to Comments. EPA recognizes many local stakeholders would prefer all CCR be removed and taken off-site; however, weighing safety, ISS effectiveness, and the impacts of dewatering to the IDNP wetlands during excavation influenced the selection of this proposed remedy.
10) State/support agency acceptance	It is anticipated that the State and local stakeholders will find this remedy acceptable.

Institutional Controls

Institutional Control ("IC") remedies restrict land or resource use at a Facility through legal instruments. ICs are distinct from engineered or construction remedies. ICs preclude or minimize exposures to contamination or protect the integrity of a remedy by limiting land or resource use through means such as rules, regulations, building permit requirements, well-drilling prohibitions and other types of ordinances. For an IC to become part of a remedy, there must be binding documentation such as land-use restrictions in a recorded environmental covenant, local zoning restrictions, or rules restricting private wells. There will be institutional controls consistent with Indiana Code 13-11-2-193.5 and 13-25-4-24 implemented at this Facility to prohibit interference with the remedy, prohibit the use of groundwater for drinking water and limit the future use of the Facility to a non-residential scenario, such as commercial or industrial.

Financial Assurance

NIPSCO must demonstrate a financial ability to complete corrective action, including constructing the proposed remedy and monitoring Facility conditions following remedy construction, as needed, by securing an appropriate financial instrument, consistent with the requirements of 40 C.F.R §§ 264.142 and 264.144. NIPSCO will develop a detailed cost-estimate as part of the corrective measures implementation work plan. NIPSCO may use any of the following financial mechanisms to make the demonstration: financial trust, surety bonds, letters of credit, insurance, and/or qualification as a self-insurer (corporate guaranty) by means of a financial test. After successfully completing the construction phase of the remedy, NIPSCO may request that EPA reduce the amount of the financial assurance to the amount necessary to cover the remaining costs of the remedy, including any yearly operation and maintenance costs. NIPSCO may make similar requests of EPA as the operation and maintenance phase of the remedies proceeds and ceases.

Long Term Stewardship

NIPSCO must ensure all controls and long-term remedies are maintained and operate as intended. NIPSCO will submit a Long-Term Stewardship (LTS) Plan. Components of a LTS Plan include: an Institutional Control Implementation and Assurance Plan (ICIAP), five-year remedy review procedures, operation, maintenance and monitoring details. An annual certification that all controls, including institutional controls, are in place and remain effective should be provided for in this plan. Long term remedies will be reviewed and inspected on a five-year basis to ensure the remedy is functioning as intended, the exposure assumptions, toxicity data, cleanup levels, and CAOs are still valid, and any information that comes to light that could call into question the protectiveness of the remedy is considered.

If any five-year review indicates that changes to the selected remedy are appropriate, EPA will determine whether the proposed changes are non-significant, significant, or fundamental changes to the remedy. EPA may approve non-significant changes without public comment. EPA will inform the public about any significant or fundamental changes to the remedy.

SECTION VII. PUBLIC PARTICIPATION AND INFORMATION REPOSITORY

EPA requests feedback from the community on this proposal to remediate the NIPSCO Bailly Generating Station. The public comment period will last forty-five (45) calendar days, from July 1, 2020 to August 15, 2020. In lieu of a public meeting, EPA will be posting a pre-recorded presentation on the site's webpage, located at: https://go.usa.gov/xvuqx. EPA invites you to view the presentation and submit your comments in one of the following ways:

- By confidential voicemail at 312-886-6015
- By fax to 312-697-2568
- By website, directly at: https://go.usa.gov/xvuqx
- By email to safakas.kirstin@epa.gov
- By mail to:
  Kirstin Safakas
  U.S. EPA Region 5
  External Communications Office
  77 W. Jackson Blvd
  Chicago, IL 60604-3590

We encourage community members to submit any comments regarding the proposed remedy in writing by August 15, 2020. Following the 45-day public comment period, EPA will prepare a Final Decision and Response to Comments document that will identify the selected remedy for the Facility. The Response to Comments document will address all significant comments sent to the EPA. EPA will make the Final Decision and Response to Comments document available to the public. If such comments or other relevant information cause EPA to propose significant changes to the currently proposed remedy, EPA will seek additional public comments on any proposed revised remedy.

The Facility Record contains all information considered when making this proposal and will include the Response to Comments document. The Facility Record may be reviewed at the website provided above or at these locations (please call for hours):

Local Document Repository Portage Public Library 2665 Irving Street Portage, IN (219) 763-1508	EPA Region 5 Office EPA Records Center 77 W. Jackson Blvd., 7th Floor Chicago, IL (312) 886-4253

If you have any additional questions, contact:
Michelle Kaysen (LR-16J)
77 W. Jackson Blvd
Chicago, IL 60604
(312) 886-4253
kaysen.michelle@epa.gov

Next Steps

Following issuance of the Final Decision and Response to Comments document, NIPSCO will prepare a Corrective Measures Implementation Work Plan. The Plan will identify any additional data collection needed to implement the corrective measures, along with the specifications for completing the selected corrective measures. The Plan will provide a detailed construction schedule. Based on the proposed corrective measures, it is anticipated that most of the remedial measures can be completed within two years of the Final Decision.

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Site Location

Northern Indiana Public Service Company

Bailly Generating Station
Chesterton, Indiana

Legend

- - - - Bailly Generating Station Property Line
— Roads
▨ Wetland
🟩 Natural/Forested Area
🟥 Urban

Location of Site

Notes and Sources

FIGURE 1

USGS DRG: March 2003
Courtesy of USA PhotoMaps
Cross Section: USGS Open File
Report 92-39, 1994

N

0 1,000 2,000
Feet

wood.
Wood Environment &
Infrastructure Solutions, Inc.
271 Mill Road
Chelmsford, MA 01824
(978) 692-9090

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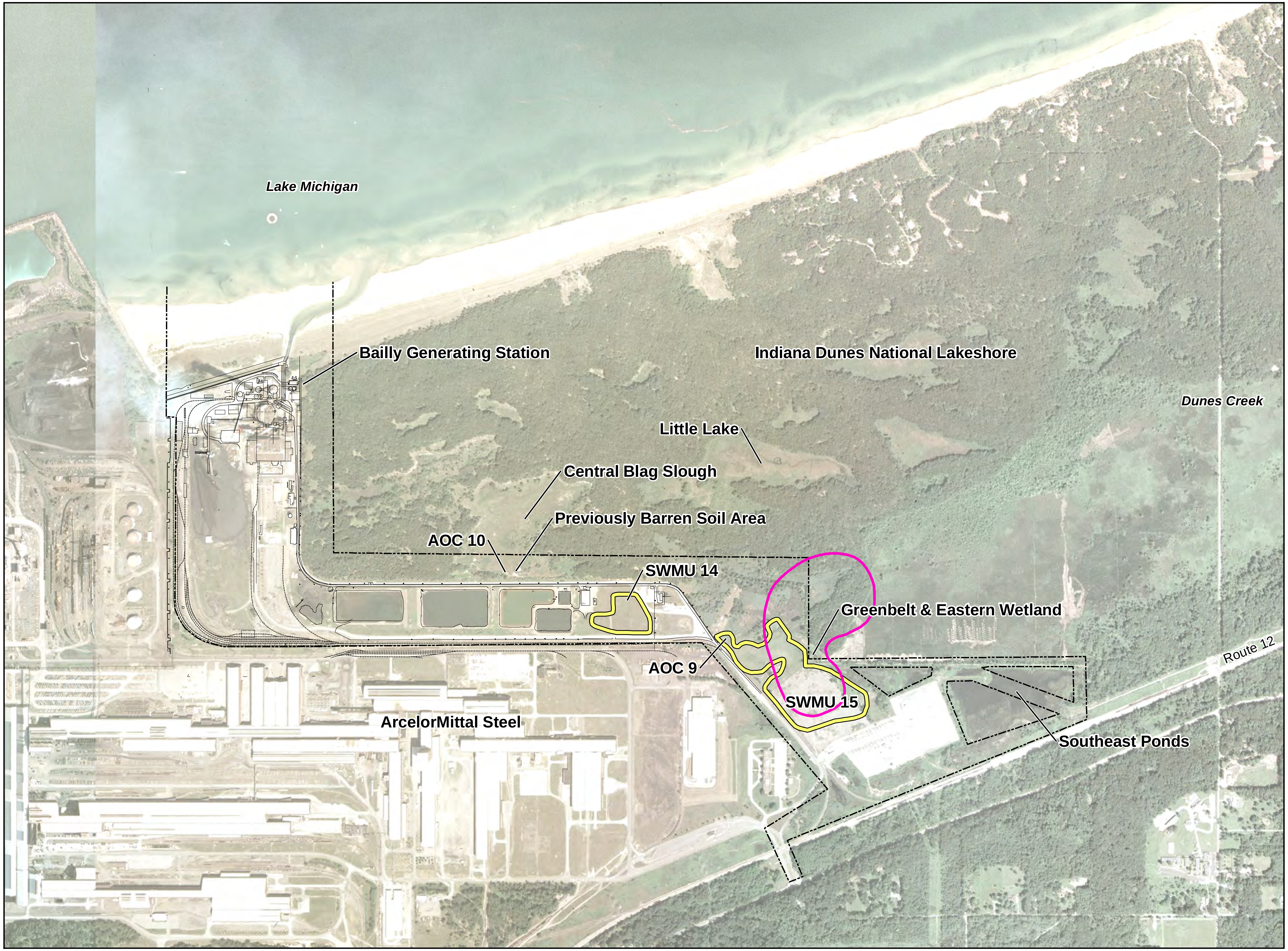

Sitewide Overview and Site Features

Northern Indiana Public
Service Company

Bailly Generating Station
Chesterton, Indiana

Legend

- -·-·- Bailly Generating Station Property Boundary
- ☐ Solid Waste Management Unit Boundary
- ☐ Extent of Groundwater Contamination Above Clean-up Standards Based on 2018 Results

Location of Site

Notes and Sources

FIGURE 2

Aerial Photo: March 2003
Courtesy of Indiana Spatial Data Portal

0 1,000
Feet

N

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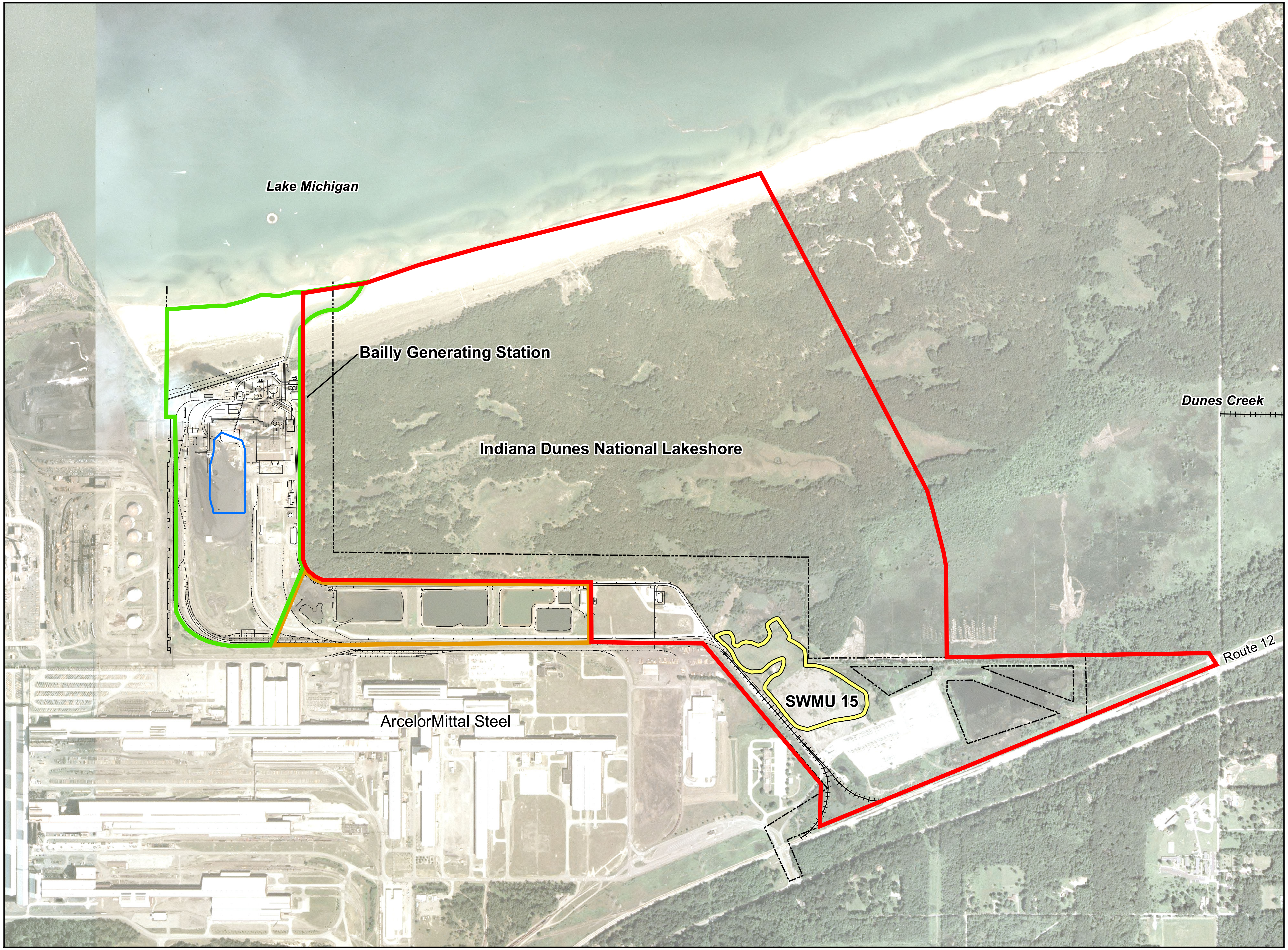

Sitewide Overview and Site Features

Northern Indiana Public
Service Company

Bailly Generating Station
Chesterton, Indiana

Legend

-·-·- Bailly Generating Station Property Boundary
— Approximate Slurry Wall Location
┼┼┼┼┼ Railroad
🟩 Area A
🟧 Area B
🟥 Area C
🟨 SWMU 15

Location of Site

Notes and Sources

FIGURE 3

Aerial Photo: March 2003
Courtesy of Indiana Spatial Data Portal

0 750 1,500
Feet

N

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Location of Geologic Cross Section A-A'

Northern Indiana Public Service Company

Bailly Generating Station
Chesterton, Indiana

Legend

A├─┤A' Cross Section Location
- - - Bailly Generating Station Property Line
▭ Roads
▨ Wetland
🟩 Natural/Forested Area
▨ Urban

Location of Site

Notes and Sources

FIGURE 4

USGS DRG: March 2003
Courtesy of USA PhotoMaps
Cross Section: USGS Open File
Report 92-39, 1994

N

0 1,000 2,000
Feet

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(978) 692-9090

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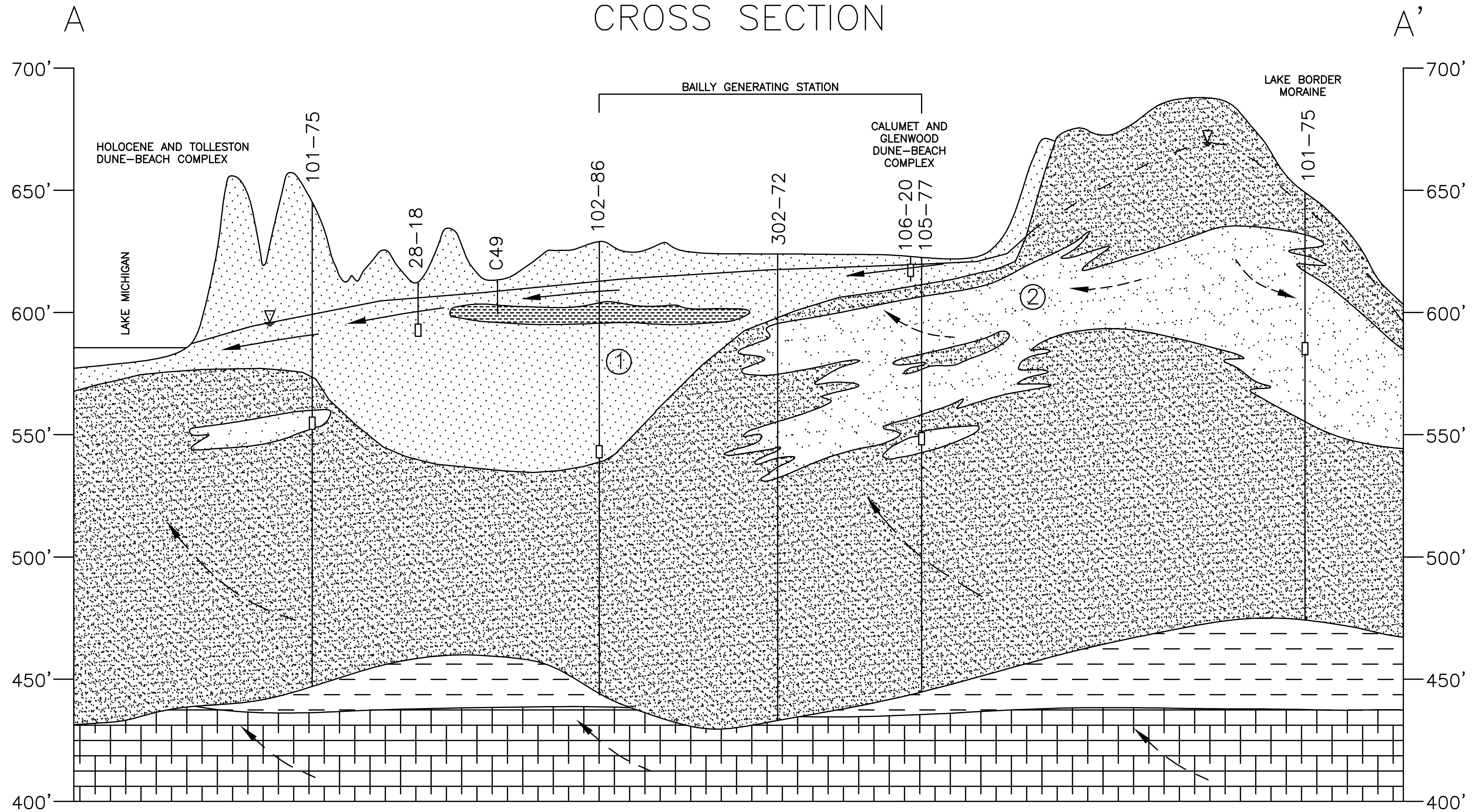


NOTES:

1. WATER LEVELS MEASURED BY AMEC PERSONNEL ON OCTOBER 12 THROUGH OCTOBER 26, 2010.
2. LAKE MICHIGAN WATER LEVEL IS AVERAGE FROM OCTOBER 12 THROUGH OCTOBER 26, 2010 AS MEASURED AT CALUMET HARBOR, LAKE MICHIGAN, IL.
3. 20 X VERTICAL EXAGGERATION.

SOURCE:
SHEDLOCK, R.J., COHEN, D.A., IMBRIGIOTTA, T.E., AND THOMPSON, T.A., 1994, HYDROGEOLOGY AND HYDROCHEMISTRY OF DUNES AND WETLANDS ALONG THE SOUTHERN SHORE OF LAKE MICHIGAN: U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT 92-139.

LEGEND:

▨ DUNE-BEACH AND LACUSTRINE SAND
▤ CALCAREOUS CLAY INCLUDES PLANT AND SHELL FRAGMENTS
▩ TILL AND GLACIAL-LACUSTRINE CLAY AND SILT
▨ GLACIAL LACUSTRINE SAND
▤ SHALE
▦ CARBONATE ROCKS
▽ WATER TABLE (INFERRED)
▽ WATER TABLE (KNOWN)
▯ OBSERVATION WELL
| CONTINOUS CORE

DIRECTION OF FLOW:

→ LOCAL FLOW SYSTEM
⇢ INTERMEDIATE FLOW SYSTEM
→ REGIONAL FLOW SYSTEM
① SURFICIAL AQUIFER
② SUBTILL AQUIFER

HORIZONTAL SCALE: 1" = 1000'
0 1000' 2000'
0 50' 100'
VERTICAL SCALE: 1" = 50'

CLIENT LOGO

CLIENT:
NORTHERN INDIANA PUBLIC SERVICE COMPANY

PROJECT
NORTHERN INDIANA PUBLIC SERVICE COMPANY
BAILLY GENERATING STATION
CHESTERTON, INDIANA

DRAWN BY: D. DEMPSEY
CHECKED BY: R. JOHNSON
DATUM: NONE
PROJECTION: NONE
SCALE: AS SHOWN

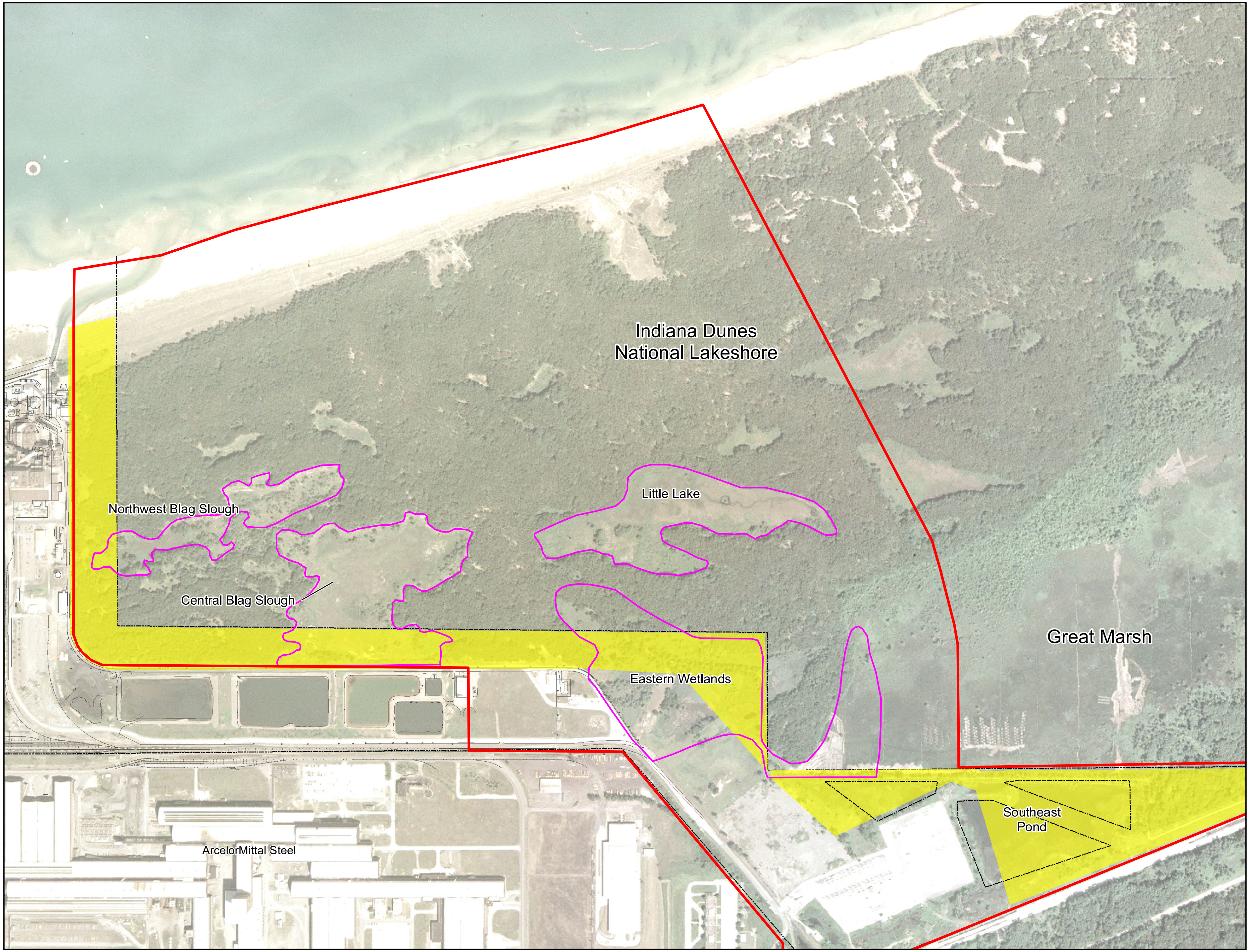
wood.

271 MILL ROAD
3RD FLOOR
CHELMSFORD, MA 01824

TITLE
REGIONAL GEOLOGIC CROSS SECTION A-A'

DATE: FEBRUARY 18, 2019
PROJECT NO: 3651180080
REV. NO.: A
FIGURE No. 5

P:\old_WFD-FS1_Data\Projects\NiSource\BaillyGeneratingStation\CAD\2015-03-16\SECTION A-A 2019-02-18.dwg - Layout1 - Nov. 26, 2019 8:20am - dana.dempsey



Indiana Dunes National Lakeshore Adjacent to Bailly Generating Station

Northern Indiana Public
Service Company

Bailly Generating Station
Chesterton, Indiana

Legend

▭	IDNL Wetland Habitat
-·-·-	Bailly Generating Station Property Line
▇	Approximate Greenbelt Area
▭	Area C

Location of Site

Notes and Sources

FIGURE 6

Aerial Photo: March 2003
Courtesy of Indiana Spatial Data Portal

N

0 400 800 Feet

Wood Environment &
Infrastructure Solutions, Inc.
271 Mill Road
Chelmsford, MA 01824
(978) 692-9090

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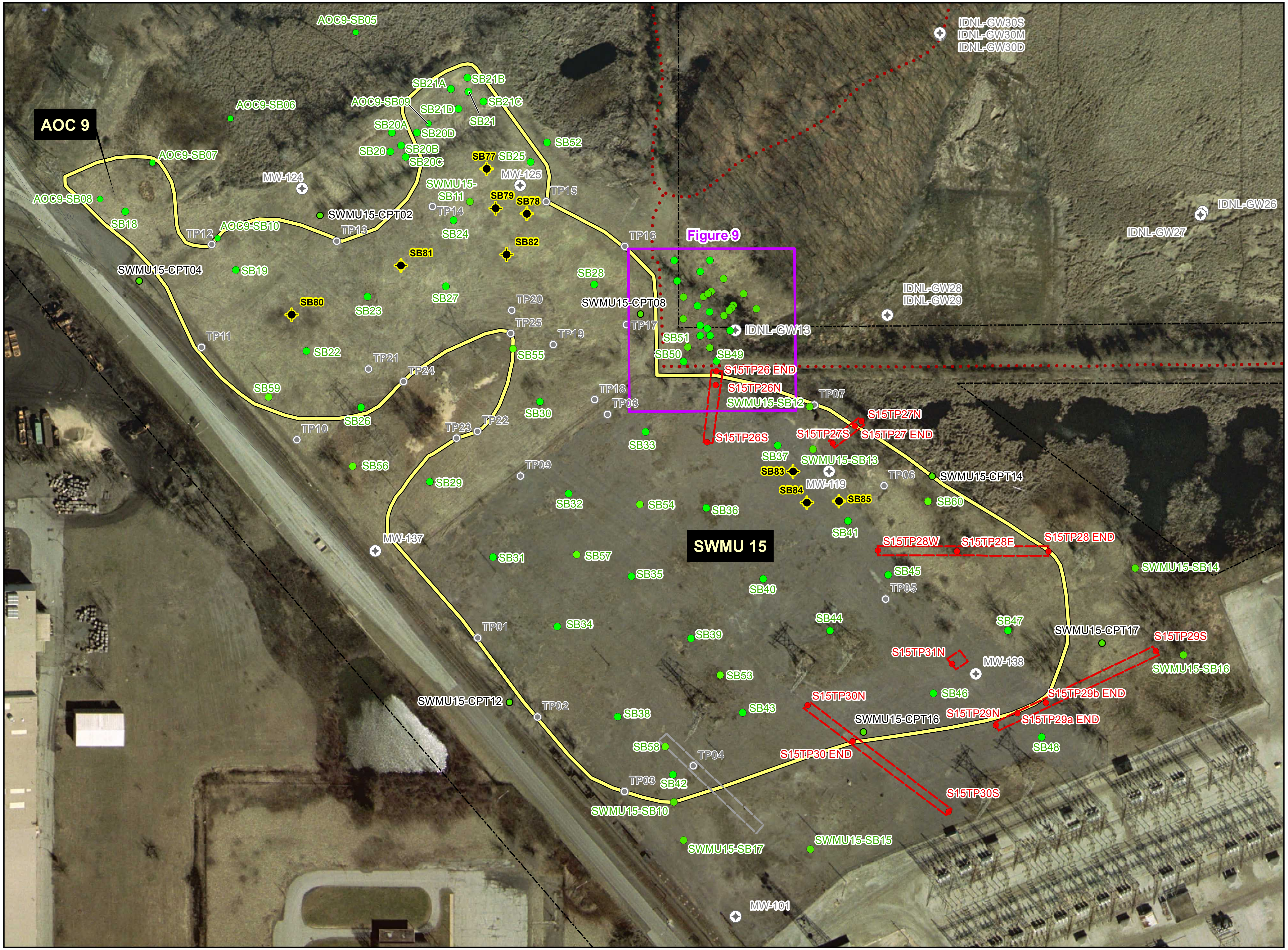

SWMU 15
Investigation Locations

Northern Indiana Public
Service Company

Bailly Generating Station
Chesterton, Indiana

Legend

- ◆ Soil Boring Location 2017
- ● Soil Boring Location
- ● Test Pit End Location 2009
- ◉ Test Pit End Location 2005
- ⊕ Monitoring Well Location
- ⋯ Trail
- -·- Bailly Generating Station Property Line
- ▭ Test Pit Location 2009
- ▭ Test Pit Location 2005
- ▭ Coal Combustion Residual Fill Area

Location of Site

Notes and Sources

FIGURE 7

Aerial Photo: 2005.
Courtesy of LizardTech, Inc.

- Area of SWMU 15 landfill is 16.56 acres.

-For abbreviated soil boring locations, the full location name is SWMU15-SB##.

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Infrastructure Solutions, Inc.
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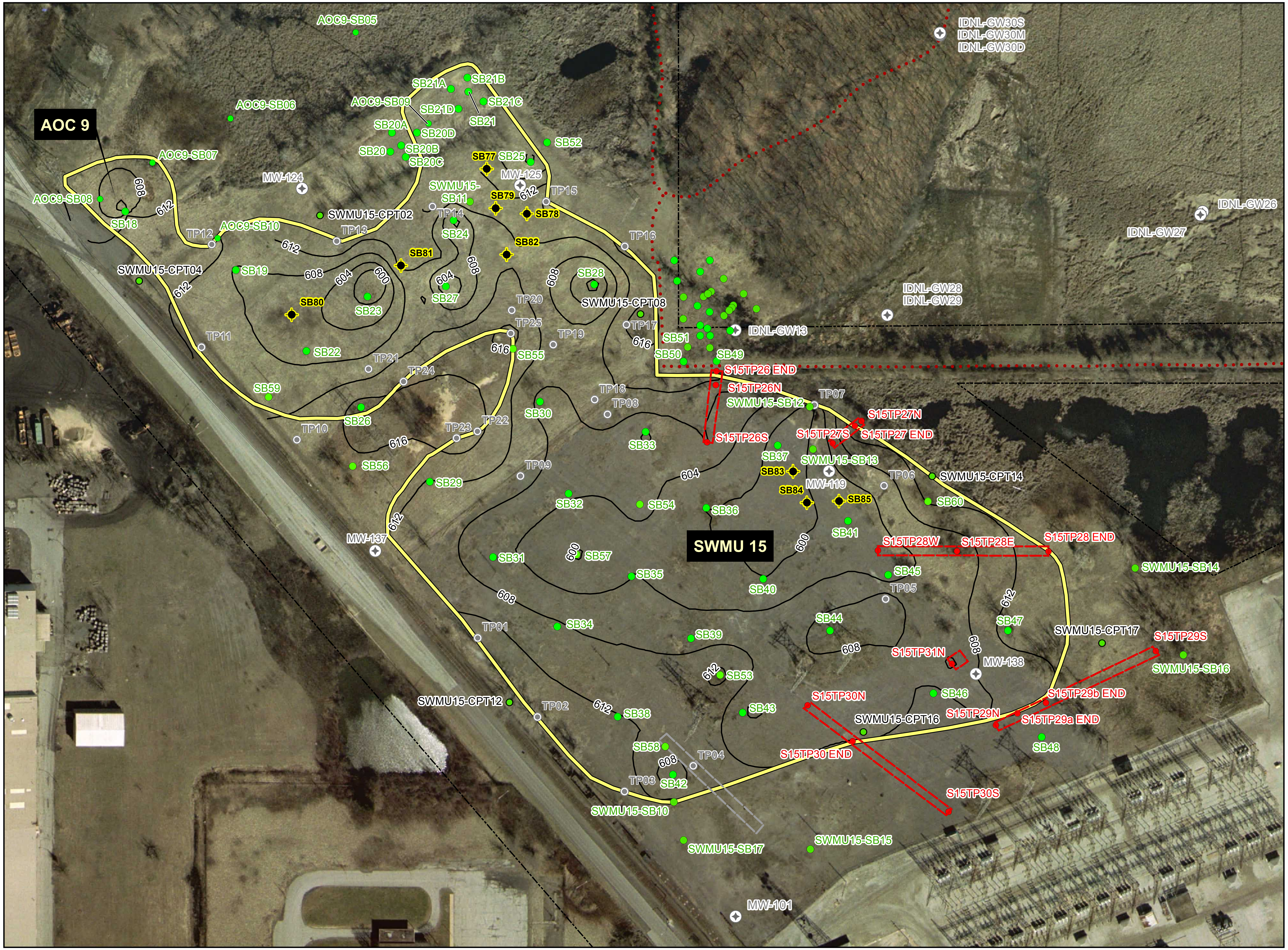
Chelmsford, MA 01824
(978) 692-9090

H:\NiSource\BaillyGenerating\Task81\MXD\Fig7_SWMU15ProposedDirectPushBorings_Sept2014 - 12.2.2014.mxd November 26, 2019 DWN: emily.gardiner CHKD: RAJ

SWMU 15
Bottom Elevation of Coal Combustion Residuals

Northern Indiana Public Service Company

Bailly Generating Station
Chesterton, Indiana



Legend

- ✦ Soil Boring Location 2017
- ● Soil Boring Location
- ● Test Pit End Location 2009
- ◉ Test Pit End Location 2005
- ⊕ Monitoring Well Location
- — Elevation Contour (4 foot)
- ⋯ Trail
- -·- Bailly Generating Station Property Line
- ▭ Test Pit Location 2009
- ▭ Test Pit Location 2005
- ▭ Coal Combustion Residual Fill Area

Location of Site

Notes and Sources

FIGURE 8

Aerial Photo: 2005.
Courtesy of LizardTech, Inc.

- Area of SWMU 15 landfill is 16.56 acres.

-For abbreviated soil boring locations, the full location name is SWMU15-SB##.

N

0 150 Feet

wood.
Wood Environment &
Infrastructure Solutions, Inc.
271 Mill Road
Chelmsford, MA 01824
(978) 692-9090

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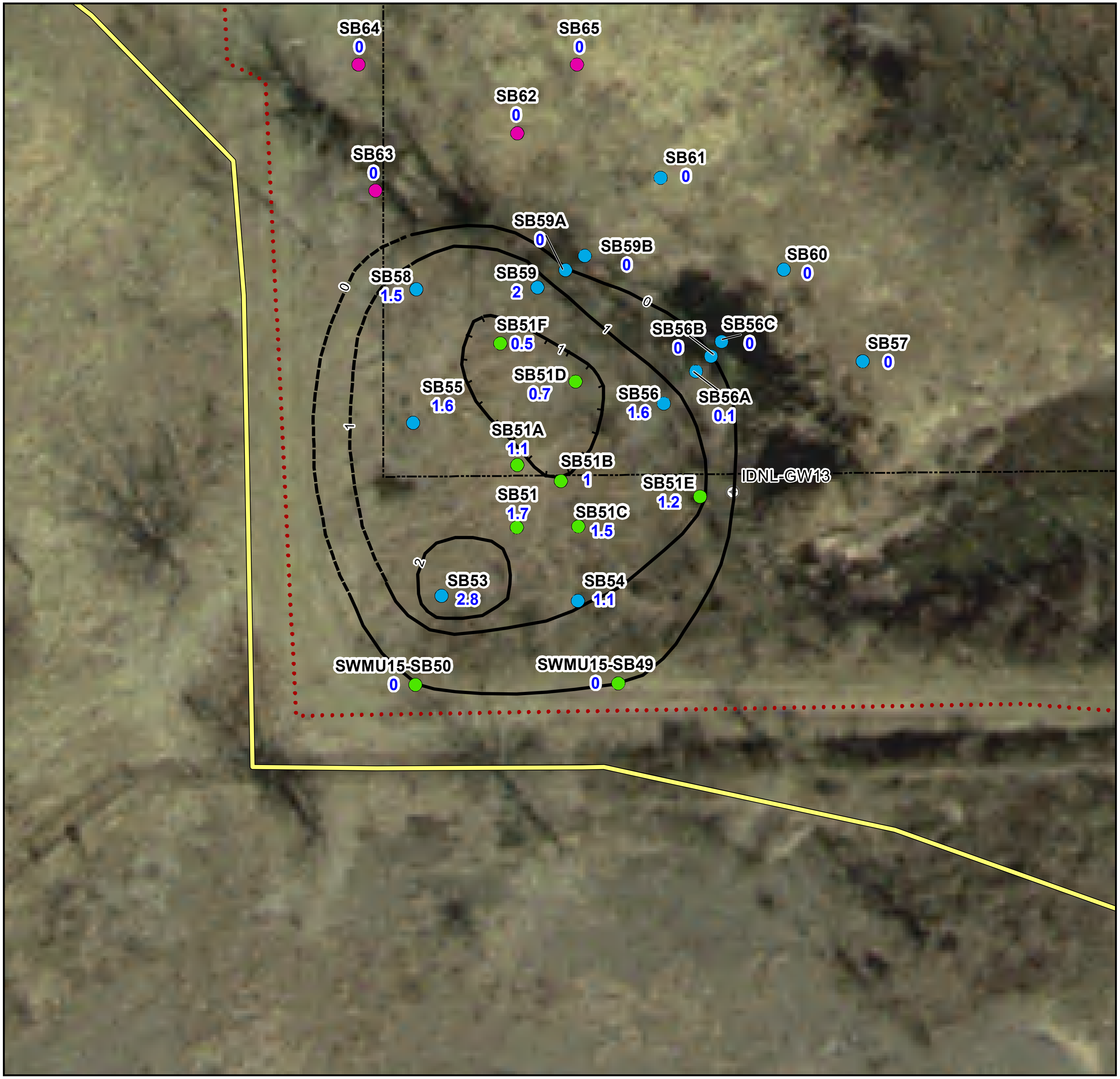

Greenbelt and Eastern Wetland

Northern Indiana Public
Service Company

Bailly Generating Station
Chesterton, Indiana

Legend

● October 2014 Soil Boring Location

● May & September 2014 Soil Boring Location

● March 2015 Soil Boring Location

1.7 CCR Thickness (feet)

— CCR Thickness Contour (dashed where inferred)

⊕ Monitoring Well Location

-·- Bailly Generating Station Property Line

••• Trail

▭ Approximate Boundary of SWMU 15

CCR - Coal Combustion Residuals

Location of Site

Notes and Sources

FIGURE 9

1) For soil boring locations, the full location name is IDNL-SB##.

2) CCR thickness contour interval is 1'.
Aerial Photo: 2005.
Courtesy of LizardTech, Inc.

0 17.5 35
Feet

N

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Infrastructure Solutions, Inc.
271 Mill Road
Chelmsford, MA 01824
(978) 692-9090

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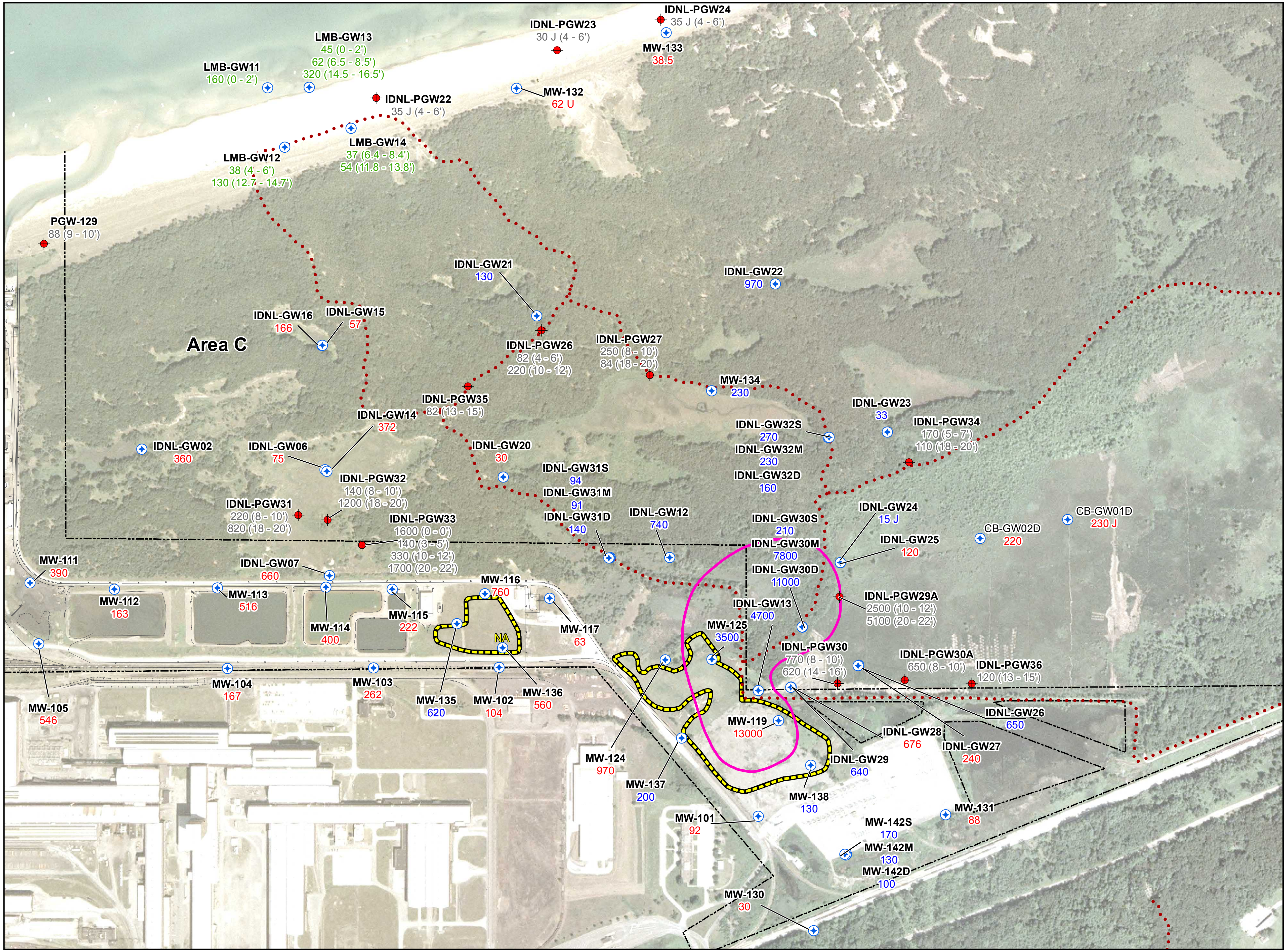

Area C
Boron Groundwater Results

Northern Indiana Public
Service Company

Bailly Generating Station
Chesterton, Indiana

Legend

Monitoring Well Sample Result (µg/L)

130	October 2018
5100	Last Time Sampled (Various Dates)
29 (14-16')	PGW - May and June 2006 Screening Sample Result (µg/L) and Depth (ft bgs)
160 (0-2')	LMB - September 2009 Screening Sample Result (µg/L) and Depth (ft bgs)
✦	Groundwater Monitoring Well
⌖	Direct Push Groundwater Sample Location
• • •	Trail
▭	Coal Combustion Residual Fill Area
▭	Extent of Groundwater Contamination Above Clean-Up Standards Based on 2018 Results

Location of Site

Notes and Sources

FIGURE 10

Aerial Photo: March 2003, Courtesy of Indiana Spatial Data Portal
- All concentrations are in ug/L.
- J = Estimated value.
- U = Non-detect at the reporting limit.

wood.

H:\NiSource\BaillyGenerating\Task88\MXD\Area C Boron Groundwater Results_2019.mxd November 25, 2019 DWN: emily.gardiner CHKD: RAJ

Table 1: Synthetic Precipitation Leaching Procedure Results for SWMU 15

Benchmark (mg/L)	Units	SWMU15SB18AA	SWMU15SB23AA	SWMU15SB25AA	SWMU15SB31AA	SWMU15SB31AB	SWMU15SB35AA	SWMU15SB38AA	SWMU15SB41AA
N/A	N/A	Fine CCR	Fine CCR	Fine CCR	Fine CCR	Fine CCR	Fine CCR	Coarse CCR	Fine CCR
N/A	N/A	1 - 2	1 - 2	1.2 - 2.2	1 - 4	1 - 4	3 - 4	1 - 2	3 - 4
N/A	N/A	8.47	9.53	7.52	10.03	10.03	9.26	11.11	9.63
0.14 [1]	mg/L	3.6	0.096 J	71	2.3 J	6.6 J	2.6	11	3.6
0.01 [2]	mg/L	0.089	0.066	1.5	0.039 J	0.078 J	0.11	0.015 U	0.11
N/A	mg/L	0.062	0.028	0.59	0.0063 UJ	0.05 J	0.0051 U	0.01 U	0.027
1.6 [3]	mg/L	0.58	0.77	1.2	0.26	0.37	0.42	0.082 U	0.46
N/A	mg/L	0.0024	0.002 U	0.04	0.002 U	0.0022	0.00089 J	0.002 U	0.0027
N/A	mg/L	0.022	0.004 U	0.51	0.004 UJ	0.019 J	0.004 U	0.0041	0.013
N/A	mg/L	0.02	0.0027 J	0.31	0.0051 J	0.021 J	0.0075 J	0.0044 J	0.018
N/A	mg/L	0.031	0.01 U	1.1	0.01 UJ	0.025 J	0.01 U	0.01 U	0.018
0.99 [1]	mg/L	0.028	0.0054	0.34	0.003 UJ	0.19 J	0.003 U	0.003 U	0.017
N/A	mg/L	0.0002 U	0.0002 U	0.0002 U	0.0002 U	0.00032	0.0002 U	0.0002 U	0.0002 U
0.8 [3]	mg/L	0.18	0.024	0.16	0.0081 J	0.017	0.022	0.01 U	0.06
0.00461 [3]	mg/L	0.025 U	0.017 J	0.017 J	0.056	0.055	0.1	0.025 U	0.034

Benchmark (mg/L)	Units	SWMU15SB26AA	SWMU15SB26AB	SWMU15SB42AA	SWMU15SB49AA
N/A	N/A	Sand	Sand	Sand	Sand (Trace CCR)
N/A	N/A	0.6 - 2.0	0.6 - 2.0	1.1 - 3.3	6 - 7
N/A	N/A	8.35	8.35	9.82	10.83
0.42	mg/L	0.53	0.46	5.3	1.5
0.03	mg/L	0.015 U	0.015 U	0.17	0.015 U
N/A	mg/L	0.024 U	0.017 U	0.015 U	0.021
4.8	mg/L	0.11 U	0.063 U	0.15 J	0.44
N/A	mg/L	0.002 UJ	0.002 UJ	0.002 UJ	0.002 U
N/A	mg/L	0.004 UJ	0.004 UJ	0.0014 J	0.0034 J
N/A	mg/L	0.01 U	0.01 U	0.005 J	0.0076 J
N/A	mg/L	0.01 U	0.01 U	0.0038 J	0.0033 J
2.8	mg/L	0.0032 J	0.012 J	0.00058 J	0.11
N/A	mg/L	0.0002 U	0.0002 U	0.0002 U	0.00022
2.4	mg/L	0.01 U	0.01 U	0.0065 J	0.15
0.014	mg/L	0.025 U	0.025 U	0.025 U	0.025 U

Aluminum, arsenic, and boron were identified as COPECs for both SWMU 15 and IDNL groundwater. Manganese was identified as a COPEC for IDNL groundwater. Molybdenum and selenium were identified as COPECs for SWMU 15 groundwater.

mg/L - milligram per liter; bgs - below ground surface; N/A - not applicable

Barium, cadmium, chromium, copper, lead, and mercury were initially identified as Contaminants of Potential Ecological Concern (COPECs), but there were no exceedances in IDNL groundwater downgradient of SWMU 15; therefore no benchmarks were established for these metals.

SPLP results for CCR are compared to benchmarks for groundwater with no dilution/attenuation factor because some CCR is below the water table.

[1] Background

[2] Maximum Contaminant Level

[3] Great Lakes Initiative (GLI) values derived from Criteria and Values for Selected Substances Calculated Using the Great Lakes Basin Methodologies (IDEM, 2002); boron value from IDEM Water Quality Standards Tier II 2004 update.

The SWMU 15 Media Cleanup Levels for unsaturated soil below CCR was derived by multipling the media cleanup level for groundwater by a dilution/attenuation factor of 3.

MCLs:

Barium	2	mg/L
Cadmium	0.005	mg/L
Chromium	0.1	mg/L
Copper *	0.28	mg/L
Lead	0.015	mg/L
Mercury	0.002	mg/L

* GLI for copper.

Qualifiers:
U - Not detected above the reporting limit.
J - Estimated value.

🟨 Indicates an exceedance of the benchmark; non-detects were shaded if one-half the reporting limit was greater than the benchmark.
🟦 For context only, blue shading indicates a reported SPLP value greater than an MCL.

Table 2: Summary of Physical Properties
SWMU 15 Coal Combustion Residuals

Location	**SWMU15-SB22**	**SWMU15-SB23**	**SWMU15-SB25**	**SWMU15-SB33**	**SWMU15-SB41**
Sample Interval (feet bgs)	0-8	5-12	5-12	5-12	5-11
Moisture Content (%)	23.2	20.4	27.9	18.4	37.6
Average Specific Gravity (at 20^{o} C)	2.86	2.78	2.68	2.83	2.79
Grain-Size Distribution					
Gravel (%)	0.76	8.16	0.04	0.29	0.69
Sand (%)	22.47	30.60	7.28	51.34	41.54
Silt & Clay (%)	76.77	61.24	92.68	48.38	57.76
USCS Classification	Silt with Sand	Sandy Silt	Silt	Silty Sand	Sandy Silt

Notes:
1. Samples summarized above were field classified as black, fine CCR.
2. All samples were determined by the laboratory to be non-plastic material.
3. Source: Geotechnics Project Number 2014-692-01, dated June 3, 2014.

Table 3: Summary of Physical Properties
SWMU 15 Native Soils

Location	**SWMU15-SB18**	**SWMU15-SB30**	**SWMU15-SB31**	**SWMU15-SB41**	**SWMU15-SB50**
Sample Interval (feet bgs)	28-35	10-18	21-28	28-35	22-29
Moisture Content (%)	17.6	19.2	19.8	15.7	17.5
Average Specific Gravity (at 20^o C)	2.68	2.70	2.71	2.79	2.72
Grain-Size Distribution					
Gravel (%)	0.70	1.2	1.44	0.69	2.02
Sand (%)	90.75	90.1	12.48	41.54	11.51
Silt & Clay (%)	8.55	8.7	86.08	57.76	86.47
USCS Classification	Poorly graded Sand with Silt	Poorly graded Sand with Silt	Lean Clay	Sandy Silt	Lean Clay

Notes:
1. Source: Geotechnics Project Number 2014-692-01, dated June 3, 2014.

Table 4: Untreated Material Physical Characterization
SWMU 15 Coal Combustion Residuals

TESTING PARAMETER	TEST METHOD	UNIT	SAMPLE
			SWMU-15 Composite
Moisture Content	ASTM D2216		
ASTM Moisture Content		%	20.92
Percent Solids		%	82.71
Bulk Density	ASTM D7263	pcf	130.2
Solid Specific Gravity	ASTM D854		2.77
Loss on Ignition (Organic Content)	ASTM D2974		
Average Moisture Content		%	21.22
Average Loss on Ignition			1.65
Particle Size with Hydrometer	ASTM D422		
Sample Description			Black sandy silt
Soil Classification	ASTM D2487		
Gravel		%	2.5
Sand		%	27.8
Silt		%	61.2
Clay		%	8.5
Atterberg Limits	ASTM D4318		
L.L.			NV
P.L.			NP
P.I.			NP

Notes:
Sample color determined by the Munsell Soil Color Chart
% = percent
pcf = pound per cubic foot
L.L. = Liquid Limit
P.L. = Plastic Limit
P.I. = Plasticity Index
NV = Non Viscous
NP = Non Plastic

Source: KEMRON Environmental Services, Inc., Project No. SH0549, December 19, 2014

Table 5: Untreated Material Analytical Results
SWMU 15 Coal Combustion Residuals

Analyte	Units	Benchmark	SWMU-15 Composite	MW-119 7/6/2011	IDNL-GW13 10/23/2014
			SPLP (1312/6010C)	Groundwater (6010B/6020)	
Arsenic	µg/L	10 [1]	203	480	16
Barium	µg/L	2000 [1]	151	36	37
Boron	µg/L	1600 [2]	723	29000	5100
Cadmium	µg/L	5 [1]	0.30 U	0.98	0.5U
Chromium	µg/L	100 [1]	2.10	4U	2.1J
Copper	µg/L	280 [2]	3.00	2U	10U
Lead	µg/L	15 [1]	3.30 U	5U	10U
Manganese	µg/L	994 [3]	2.60	16	340
Molybdenum	µg/L	800 [2]	110	3800	10
Selenium	µg/L	4.61 [2]	82.2	2.4	1U
Silver	µg/L	N/A	0.60 U	3U	6U
			SPLP (1312/7470A)	Groundwater (7470A)	
Mercury	µg/L	N/A	0.01 U	0.2U	0.2U

Notes:

SWMU 15 Composite - flyash sample collected from multiple borings from 9/8/14 through 9/11/14

MW-119 - the lastest groundwater sample results for this source well are included for comparison

IDNL-GW13 - the latest groundwater sample results for this downgradient well is included for comparison

Arsenic, boron, molybdenum, and **selenium** were identified as Contaminants of Potential Environmental Concern (COPECs) for SWMU 15 groundwater and **arsenic, boron** and **manganese** were identified as COPECs for IDNL groundwater.

µg/L = microgram per Liter

[1] Maximum Contaminant Level (MCL)

[2] Great Lakes Initiative (GLI)

[3] Background

Benchmark Exceedance

N/A - Not applicable; silver and mercury were not detected in IDNL groundwater

U = Analyte was not detected

J = Estimated value

ATTACHMENT A

U.S. ENVIRONMENTAL PROTECTION AGENCY

ADMINISTRATIVE RECORD
FOR THE

NIPSCO BAILLY GENERATING STATION
CHESTERTON, PORTER COUNTY, INDIANA
EPA ID NO: IND000718114

STATEMENT OF BASIS
JUNE 22 2020
SEMS ID: 955953

NO.	SEMS ID	DATE	AUTHOR	RECIPIENT	TITLE/DESCRIPTION	PAGES
1	953142	3/31/05	U.S. EPA	Maassel, M., NIPSCO Bailly Generating Station	Administrative Order on Consent (AOC), Docket No. RCRA-05-2005-0005	18
2	954805	4/13/05	NIPSCO Bailly Generating Station	U.S. EPA	Current Conditions Report	87
3	951442	4/21/05	NIPSCO Bailly Generating Station	U.S. EPA	Sampling Rationale Spreadsheet	1
4	951443	5/19/05	Sullivan, D., NiSource and Haney, M., AMEC	Majack, M., U.S. EPA	Technical Memorandum - Supplement to the Current Conditions Report	9
5	954813	5/25/05	AMEC	NIPSCO - Northern Indiana Public Service Company	RCRA Facility Investigation Work Plan (Redacted)	121
6	953145	7/1/05	Sullivan, D., NiSource and Haney, M., AMEC	Majack, M., U.S. EPA	Technical Memorandum 05-02 - Test Pit Program Summary of Findings	33

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7	951444	7/13/05	Sullivan, D., NiSource and Haney, M., AMEC	Majack, M., U.S. EPA	Technical Memorandum re: 5/3/05 Technical Memorandum	3
8	951479	3/31/06	AMEC	U.S. EPA	NIPSCO Responses to EPA Review of the Evaluation of the Nature and Extent of Compounds in Soil	7
9	954819	2/21/07	Sullivan, D., NiSource and Haney, M., AMEC	Majack, M., U.S. EPA	Technical Memorandum 07-01 - Summary of Findings from Fall 2006 Soil and Plant Sampling	73
10	953146	3/1/07	AMEC	NIPSCO - Northern Indiana Public Service Company	2007 Sampling and Analysis Plan	31
11	954820	7/27/07	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	Human Health Risk Assessment	212
12	953147	8/30/07	Nisource	NIPSCO Bailly Generating Station	RFI Report Tables	29
13	954804	8/30/07	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	RFI Report Figures	53
14	954809	4/10/09	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	2009 IDNL Vegetation Survey Plan	50
15	954810	7/16/09	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	2009 IDNL Vegetation Survey Plan and Related Investigations, Rev 1	54
16	954837	4/30/10	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	2010 Amphibian Toxicity Study Plan (Redacted)	74

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17	954821	6/21/10	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	2010 Plant Toxicity Study Plan - Final	63
18	954811	11/17/10	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	Final 2010 Amphibian Toxicity Study Report	160
19	955890	11/22/10	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	Final 2009 Amphibian Survey Report	333
20	951481	1/14/11	AMEC	U.S. EPA	Rhizome and Soil Testing Results	8
21	954814	2/18/11	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	RFI Appendix F - Validated Area C Groundwater Analytical Data	1117
22	955891	2/18/11	AMEC Earth & Environmental, Inc.	NIPSCO - Northern Indiana Public Service Company	RFI Area C - Appendices I-J - Charts, Tables, Maps	41
23	954838	4/29/11	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	Human Health Risk Assessment for Area C	213
24	954835	4/29/11	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	Baseline Ecological Risk Assessment for Area C	188
25	954812	4/29/11	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	Baseline Ecological Risk Assessment for Area C - Appendices I-M	447
26	954853	4/29/11	AMEC Earth & Environmental, Inc.	NIPSCO - Northern Indiana Public Service Company	RCRA Corrective Action Program - RCRA Facility Investigation Report for Area C	143

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27	954807	4/29/11	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	RCRA Corrective Action Program - RCRA Facility Investigation Report for Area C - Figures	60
28	954854	4/29/11	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	RCRA Corrective Action Program - RCRA Facility Investigation Report for Area C - Tables	353
29	955887	4/29/11	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	RFI Area C Appendices A - C	2546
30	954815	4/29/11	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	RFI Area C Appendix D - Boring Logs	129
31	955880	4/29/11	AMEC	NIPSCO - Northern Indiana Public Service Company	SWMU 14 and 15 - 3D Model of Subsurface Conditions (Re-issued Appendix K)	16
32	953143	7/9/12	Guerriero, M., U.S. EPA	NIPSCO - Northern Indiana Public Service Company	Final Decision/Response to Comments	36
33	953149	7/30/13	AMEC	NIPSCO - Northern Indiana Public Service Company	Risk Assessment for SWMU 14	29
34	954808	7/30/13	AMEC Earth & Environmental, Inc.	NIPSCO Bailly Generating Station	Final Corrective Action Program - SWMU 14 Attachment	54
35	953150	9/16/13	Johnson, R. and Cooke, D., AMEC	Kaysen, M., U.S. EPA	Memo - Baseline Ecological Risk Assessment - SWMU 14 Revised Calculations	27
36	951483	9/26/13	Johnson, R., AMEC Foster Wheeler	Kaysen, M., U.S. EPA	Memo - Corrective Measures Study for Area C - Central Blag Slough pH Measurements	19

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37	953151	11/6/13	AMEC	U.S. EPA	Area C Corrective Measures Study Conceptual Corrective Actions - IDNL	30
38	951474	2/28/14	Johnson, R. and Miller, G., AMEC	Kaysen, M., U.S. EPA	Memo - Corrective Measures Study for Area C - SWMU 15 Supplemental Landfill Delineation	7
39	951476	2/28/14	Johnson, R. and Miller, G., AMEC	Kaysen, M., U.S. EPA	Memo - Corrective Measures Study for Area C - IDNL Investigation Work Plan	12
40	953144	4/3/14	Johnson, R. and Cooke, D., AMEC	Kaysen, M., U.S. EPA	Memo - SWMU 14 Groundwater Plume Evaluation and Exposure Parameters - Baseline Ecological Risk Assessment	23
41	951475	5/8/14	Johnson, R. and Miller, G., AMEC	Kaysen, M., U.S. EPA	Memo - Corrective Measures Study for Area C - Revised IDNL Investigation Work Plan	12
42	953152	6/17/14	Johnson, R., AMEC	Kaysen, M., U.S. EPA	Memo - NIPSCO Response to EPA Comments on the Area C Human Health Risk Assessment	19
43	953153	7/10/14	Johnson, R. and Cooke, D., AMEC	Kaysen, M., U.S. EPA	Memo - Corrective Measures Study for Area C - Proposed Media Cleanup Standards	16
44	951477	9/26/14	Johnson, R., AMEC and Sullivan, D., NIPSCO	Kaysen, M., U.S. EPA	AMEC Memo - Corrective Measures Study for Area C - Revised Work Plan Addendum - SWMU 15 Supplemental Landfill Delineation	5
45	954799	9/30/14	Johnson, R., AMEC and Sullivan, D., NIPSCO	Kaysen, M., U.S. EPA	AMEC Memo - Proposed Additions and Reductions - October Annual Sampling Event	35
46	954839	12/4/14	AMEC Environment & Infrastructure, Inc.	NIPSCO Bailly Generating Station	Revised Risk Assessment for SWMU 14	121

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47	954800	12/4/14	Johnson, R., AMEC and Miller, G., Geochemical LLC	Kaysen, M., U.S. EPA	AMEC Memo - Geochemistry of Groundwater and Aquifer Solids Related to Boron Attenuation Observed at IDNL in May 2014: Demonstration of Monitored Natural Attenuation Tier I	36
48	953154	4/20/15	Johnson, R., AMEC Foster Wheeler and Miller, G., Geochemical LLC	Kaysen, M. and Ford, R., U.S. EPA	AMEC Foster Wheeler Memo - Response to Comments - Review of Initial MNA Evaluation Corrective Measures Study	20
49	953136	5/11/15	Johnson, R., AMEC Foster Wheeler and Miller, G., Geochemical LLC	Kaysen, M. and Ford, R., U.S. EPA	AMEC Foster Wheeler Memo - Irreversible Sorption of Boron in Sediments, Soils, and Aquifer Materials	9
50	954803	5/11/15	Johnson, R., AMEC Foster Wheeler and Miller, G., Geochemical LLC	Kaysen, M. and Ford, R., U.S. EPA	AMEC Foster Wheeler Memo - Analysis of Boron Breakthrough Curves - Wells IDNL-GW02 and MW-134	25
51	955886	6/1/15	AMEC Foster Wheeler Environment & Infrastructure, Inc.	NIPSCO - Northern Indiana Public Service Company	Appendix J - Numerical Modeling of Boron Fate & Transport in Groundwater Remedial Alternatives Analysis	44
52	951446	6/15/15	Johnson, R., AMEC Foster Wheeler	Kaysen, M., U.S. EPA	Memo - Response to EPA Comments Corrective Measures Study for Area C Proposed Media Cleanup Standards	12
53	954841	6/24/15	AMEC	NIPSCO Bailly Generating Station	Corrective Measures Study Area C - Appendix F - Previously Barren Soil Areas pH Analysis	21
54	954802	7/1/15	AMEC	NIPSCO Bailly Generating Station	Draft Corrective Measures Study Report Appendix K - Summary of Cost Estimate	20
55	951473	8/13/15	Kaysen, M. and Moore, T., U.S. EPA	NIPSCO Bailly Generating Station	Documentation of Environmental Indicator Determination - Interim Final	12

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56	954840	8/14/15	AMEC Environment & Infrastructure, Inc.	NIPSCO Bailly Generating Station	Area C Corrective Measures Study	117
57	953137	8/14/15	AMEC	NIPSCO Bailly Generating Station	Final Corrective Measures Study Report Tables	28
58	954801	8/14/15	AMEC Foster Wheeler	NIPSCO Bailly Generating Station	Final Corrective Measures Study Figures	38
59	951482	2/4/16	Kaysen, M., U.S. EPA	Johnson, R., AMEC Foster Wheeler	E-mail Response - Groundwater Flow and Boron Transport Modeling	2
60	951445	6/30/16	Johnson, R., AMEC Foster Wheeler	Kaysen, M., U.S. EPA	AMEC Foster Wheeler Memo - SWMU 15 Geotechnical Investigation	8
61	954842	1/23/17	Guerra, P. and Johnson, R., AMEC Foster Wheeler	Kaysen, M., U.S. EPA	Memo - SWMU 15 Geotechnical Investigation Summary - Corrective Measures Study for Area C	125
62	951478	6/2/17	Guerra, P. and Johnson, R., AMEC Foster Wheeler	Kaysen, M., U.S. EPA	Memo - Revised Costs for SWMU 15 Corrective Measures Study for Area C	22
63	951447	9/18/17	Johnson, R., AMEC Foster Wheeler	Kaysen, M., U.S. EPA	Memo - Response to EPA Comments Revised Costs for SWMU 15 Corrective Measures Study for Area C	8
64	954806	12/21/17	Delano, T. and Johnson, R., AMEC Foster Wheeler	NIPSCO Bailly Generating Station	Treatability Study Work Plan - SWMU15	47
65	951480	12/21/17	Johnson, R. and Delano, T., AMEC Foster Wheeler	Kaysen, M., U.S. EPA	Memo - Response to EPA Comments - Corrective Measures Study for Area C - Treatability Study Work Plan	9

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66	954852	7/9/19	Johnson, R. and Delano, T., Wood Environment & Infrastructure Solutions, Inc.	NIPSCO - Northern Indiana Public Service Company	Final Area C Corrective Measures Study	1633
67	955889	7/19/19	AMEC Foster Wheeler	NIPSCO - Northern Indiana Public Service Company	Corrective Measures Study Area C - Appendix H - Groundwater Chemistry	49
68	955952	6/22/20	U.S. EPA	File	Statement of Basis for Area C	155

Attachment B

Investigation Summary

Since completion of the Area C RFI (2011) several additional investigations have been conducted to better understand the horizontal and vertical distribution of CCR in SWMU 15, groundwater geo-chemistry and soil mineralogy, and hydrology, particularly near Cowles Bog and Little Lake. Detailed field and laboratory studies were conducted to quantify boron attenuation on aquifer solids, define the attenuation mechanisms (both temporary sorption and permanent fixation), and the capacity of the aquifer to remove boron from the dissolved phase. Findings from these investigations were used to refine the CSM for groundwater flow and boron transport. Beginning in 2016 a series of studies were completed at SWMU 15 to assist in the selection of the proposed remedy. Each investigation is described in the following subsections.

Aerial Review: Development of SWMU 15

A series of aerial photographs (included in this attachment) were reviewed to better understand the history of SWMU 15 development. An annotated photograph from 1938 shows conditions prior to development of the Facility and includes a trace of the dike (labeled “Berm”) that now separates the site from the IDNP. The photograph includes Cranberry Marsh, of which only a remnant remains north of SWMU 15. The Dune Acres Substation was constructed over a portion of the historic Great Marsh. A drainage feature is clearly visible in the bottom of Little Lake, which is still evident today during extended dry periods.

An aerial from 1961 shows early construction activities. For the SWMU 15 area, a light-colored area presumed to be sand is noted where the Dune Acres Substation was eventually constructed. Just to the north is a paddle-shaped, light-colored feature that runs approximately east west and appears to have been constructed of sand for the electric transmission line towers (Tower Set #1). Further north, a second paddle-shaped feature that trends southwest to northeast was constructed for Tower Set #3. In between the two paddles is what appears to be the top of a natural dune used to support Tower Set #2.

A 1963 oblique-angle aerial photograph (looking southeast) shows the Dune Acres Substation, the two paddles for Tower Sets #1 and #3, and the natural dune used to support Tower Set #2. The substation and transmission towers have not yet been constructed. Although not obvious in the aerial, subsequent information indicates that there were low-lying areas between the substation and each tower set. The dike that is present today was not yet constructed.

The 1977 oblique-angle aerial was taken facing northwest towards Lake Michigan and shows the three tower sets and the dike. Visible also are Little Lake in the right-central portion of the photograph, the settling ponds in the left central portion of the photograph, with Central Blag Slough beyond the settling ponds. The land surface is now almost completely flat between the Dune Acres Substation (just off the photograph to the lower right) and Tower Sets #1 and #2. The sand paddle of Tower Set #1 is no longer distinguishable from the filled areas, and just the top of the dune can be seen at Tower Set #2.

A 1979 aerial clearly shows the Dune Acres Substation and dike that separates the Southeast Ponds and SWMU 15 from the Cowles Bog Wetland Complex. The dike also separates four numbered ponds from what remains of Cranberry Marsh. The sand paddle for Tower Set #3 separates Ponds #2 and #3. Pond #4 was an area where CCR was placed and appears to be filled in this photo. The rectangular feature adjacent to and just north of Pond #4 was not filled and is a now a vegetated, low-lying area that was included in the SWMU 15 investigations. Ponds #1, #2, and #3 were not filled, and are currently densely-vegetated, shallow water bodies.

SWMU 15 CCR Delineation and Characterization

The SWMU 15 CCR delineation and characterization was completed in three mobilizations. The investigations were performed in accordance with the Revised SWMU 15 Supplemental Landfill Delineation work plan dated May 8, 2014, which proposed 34 soil borings to clay (see **Figure 7**). The plan focused mainly on the vertical dimensions of the landfill interior (i.e., thickness of CCR, relative position of CCR to the water table, thickness of sand above clay, and depth to clay). In addition to investigation activities within the interior portion of the landfill, three borings (SWMU15-SB49, SWMU15-SB50, and IDNL-SB51) were proposed between SWMU 15 and the IDNP, near monitoring well IDNL-GW13. The purpose of those three borings was to determine if CCR might extend into the area near or in IDNP. Borings SB49 and SB50 were proposed within the dike that separates SWMU 15 from the surrounding land, and SB51 was proposed northeast of the dike, in the direction of INDL-GW13.

Delineation and Characterization Summary

Investigation activities were initiated on May 12, 2014 but were hindered when rainfall made portions of the landfill and Greenbelt inaccessible. As a result, 15 out of the 34 proposed borings were completed using a direct-push drill rig, including borings at SB49 and SB50, which were advanced to 35 and 30 feet bgs, respectively. The dike materials were verified as largely comprised of sand underlain by clay; no CCR was encountered at boring SB50, whereas trace amounts (i.e., <5%) of coarse CCR were encountered in the upper 6.5 feet of boring SB49. The remaining 13 soil borings were advanced to refine the extent of CCR in SWMU 15, improve understanding of site stratigraphy, and collect samples for analysis of soil chemistry and physical properties. Nine soil samples were collected, including one duplicate, for analysis of metals following the Synthetic Precipitation Leaching Procedure (SPLP) at TestAmerica in Amherst, NY. Ten soil samples were submitted to Geotechnics in Raleigh, NC for physical characteristics.

The boring program was resumed in September 2014. As discussed during a July 16, 2014 site walk with EPA, NIPSCO and NPS, boring SWMU15-SB52 was added in the northeast portion of SWMU 15. This boring was positioned on the dike to investigate materials used to construct the dike and to establish the northeast boundary of SWMU 15. DLZ Industrial, LLC (DLZ) performed a survey on September 5, 2014 to acquire horizontal and vertical positions of the land surface at each of the borings advanced during the May mobilization, and to stake the proposed locations for the September mobilization (i.e., survey-determined horizontal locations). The land surface elevation at each of the proposed boring locations was also surveyed. The horizontal precision of the survey is 0.1 foot and the vertical precision is 0.01 foot.

A total of 17 soil borings (i.e., 16 of the remaining 18 proposed borings and SB52) were advanced in September 2014 using a Geoprobe direct-push drill rig. It was not possible for the GeoProbe rig to access locations SB20 and SB21 in the northeast, low-lying portion of SWMU 15. Here, hand-auger borings were advanced 10 feet bgs with relative ease. Therefore, a series of hand-auger borings (SB20A through SB20D and SB21A through SB21D) were also advanced to 10 feet bgs around the two proposed borings. Two soil samples were collected from sand below CCR at direct-push borings SWMU15-SB26 and SWMU15-SB42 for analysis of metals following the SPLP at TestAmerica in Amherst, NY. One 6-gallon, composite sample of fine CCR was collected from four direct-push borings within SWMU 15 (including SWMU15-SB27, SWMU15-SB28, SWMU15-SB32 and SWMU15-SB45) and submitted to Kemron Environmental Services (Kemron) for bench-scale testing of various formulations to evaluate the In-Situ Solidification and Stabilization (ISS) technology.

Stratigraphic data obtained from the 33 direct-push borings advanced in May and September 2014 (excluding IDNL-SB51 located outside the SWMU 15 footprint) were entered into the Environmental Visualization System (EVS) Software 3D model to evaluate potential data gaps. Transmission tower plans and historic aerial photographs from the 1960s and 1970s (discussed above) were also reviewed to better understand the sequence of tower construction and CCR disposal at SWMU 15. The information reviewed suggested that the towers were constructed on an existing dune in the northern portion of SWMU 15 and that earthen material may have been imported prior to tower construction in the southern portion of SWMU 15. Based on this information and the updated EVS 3D model, eight additional borings (SWMU15-SB53 through SWMU15-SB60) were positioned to address identified data gaps related mainly to the stratigraphy and presence/absence of CCR near the towers.

A 3D model of SWMU 15 was developed using visualization software to help integrate all the data collected. The model includes diagrams depicting the horizontal and vertical distribution of the CCR, peat and sand units, and can be manipulated by the user to change the viewing angles and zoom in on areas of interest. **Figure 8** provides a plan-view map of SWMU 15, including contours developed by the EVS model depicting the bottom elevation of the deepest (and most often the thickest) CCR interval. The surface of SWMU 15 ranges from 615 feet to 618 feet NAVD88 (North American Vertical Datum 1988). Elevations are lower at the perimeter ranging from 613 feet to 614 feet NAVD88. There are shallower intervals of CCR, but these are typically thinner than the deepest CCR interval and separated by sand or peat intervals. In some areas the CCR was deposited as a continuous interval from depth to the land surface. The deepest areas of CCR would therefore have the lowest bottom elevations shown in **Figure 8**. For example, CCR extends to depths of 22 feet, 20 feet, and 18 feet bgs at borings SWM15-SB23, SWMU15-SB28 and SWMU15-SB36, respectively. The EVS model was also used to develop volume estimates for the corrective action alternatives evaluated for SWMU 15.

SPLP Results

Table 1 provides results for CCR and soil samples collected at SWMU 15 and analyzed using the SPLP method. The plan anticipated collecting six samples of CCR for SPLP analysis and 12 samples of unsaturated (dry) sand from below CCR for SPLP analysis to determine if the underlying soils had become a secondary source. The boring program, however, revealed that there were very few places were unsaturated soil was present below CCR. At most locations, CCR extended below the water table. Only two samples were collected from unsaturated soil below CCR within the SWMU 15 footprint: SWMU15-SB26 collected from 0.6 to 2.0 feet bgs and SWMU15-SB42 collected from 1.1 to 3.3 feet bgs.

A third sample of unsaturated soil was also submitted for SPLP analysis from dike boring SWMU15-SB49. The interval targeted at boring SWMU15-SB49 (6-7 feet bgs) includes a pocket of sand with a small amount of coarse CCR and trace slag.

The top portion of **Table 1** presents SPLP results for the seven CCR samples collected (six proposed, one additional collected), whereas the bottom row presents SPLP results for unsaturated sand. For context, SPLP results for CCR are conservatively compared to screening levels that are developed from proposed media cleanup levels for SWMU 15 and IDNL Groundwater. No dilution/ attenuation factor (DAF) is included for the comparison of CCR to these screening levels, as a large proportion of the CCR is in direct contact with groundwater. Exceedances of the groundwater screening levels are shaded yellow. (Note that the CCR is the source material to be eliminated or controlled by the Corrective Action.) Also, for context CCR SPLP results are compared to the Maximum Contaminant Levels (MCLs) for barium, cadmium, chromium, copper, lead and mercury as these metals do not have media cleanup levels because the frequency of detection in IDNL groundwater was so low. The bottom portion of **Table 1** compares SPLP results for the underlying sand to these screening levels after applying a DAF of three (calculated in accordance with EPA guidance). Non-detects are identified as possible exceedances if one-half the reporting limit was greater than the screening level benchmark. **Table 1** results show that:

Aluminum concentrations in the SPLP samples are higher for CCR than sand and all reported values for CCR and sand exceed the screening levels of 0.14 and 0.42 mg/L, respectively. Note that the field measurements of pH for the CCR and soil samples selected for SPLP analysis ranged from 7.52 to 11.11 standard units, whereas the SPLP test simulates precipitation having a pH of 4.2. The actual pH of the SPLP effluent was not measured. Aluminum is very sensitive to pH, the solubility of aluminum increases as pH either increases or decreases from neutral conditions (i.e., having a pH between 6.5 and 7.5). The SPLP results indicate that CCR has a higher potential to leach aluminum than sand; however, groundwater data show that there have been no exceedances of the site-specific background level for aluminum in IDNL groundwater at wells located immediately downgradient of SWMU 15.

Arsenic was detected in all fine CCR samples above the reporting limit, ranging from 0.066 to 1.5 mg/L. Arsenic was not detected in the one sample of coarse CCR. All the arsenic detections for CCR exceed the screening level (which is the MCL). Arsenic was detected above the reporting limit in one of four sand samples at 0.17 mg/L, almost 10-fold lower than the maximum result for CCR. The one arsenic detection for sand exceeds the screening level.

Selenium was detected in six of eight CCR samples, and all reported values (including one-half the reporting limit for the two non-detect values) exceed the media cleanup level for selenium, which is the GLI value. Selenium was not detected in the SPLP effluent for the sand samples, and one-half the reporting limit is below the SWMU15 media cleanup level.

Physical Properties

Five samples of CCR, three samples of underlying sand, and two samples of fines (i.e., silt- and clay-sized particles) at depth in the aquifer were collected in May 2014 and submitted to Geotechnics in Raleigh, NC for physical characteristics. **Table 2** presents the physical properties for the CCR samples, all of which include a high percentage of fines, ranging from 48 to 93 percent. The next most abundant grain-size category is sand, with minimal gravel-sized material. The higher percentages of sand-sized particles indicate the mixing of fine CCR with coarse CCR and/or native sands. Moisture content ranges 18.4 to 37.6 percent and the specific gravity is similar to and slightly denser than quartz.

Table 3 presents physical properties for native materials underlying the fine CCR, all of which were collected from the saturated zone. Samples SWMU15-SB18 and SWMUSB–SB30 were comprised of over 90% sand, whereas one sample (SWMU15-SB41) was characterized as sandy silt, containing 42% sand and 58% silt and clay. Samples SWMU15-SB31 and SWMU15-SB-50 were collected from the confining unit that defines the lower boundary of the surficial aquifer and contained over 86% silt and clay.

Bench-Scale Testing

One six-gallon, composite sample of fine CCR was collected from four direct-push borings within SWMU 15 (including SWMU15-SB27, SWMU15-SB28, SWMU15-SB32 and SWMU15-SB45) between September 8 and 11, 2014, and submitted to Kemron for bench-scale testing of various formulations to evaluate the ISS technology. **Table 4** summarizes the untreated physical properties of the composite CCR sample. The moisture content and specific gravity of the composite sample fall within the range of results for the individual CCR samples. The grain-size distribution for the composite CCR sample is also very similar to that for the individual CCR sample results, with a silt- and clay-sized fraction of approximately 70%, and a sample description of “black sandy silt”.

Table 5 presents the SPLP results from the untreated CCR. The purpose of these SPLP data for untreated material (i.e., fine CCR) was to establish baseline conditions for comparison with various ISS formulations. Note that the solidified CCR samples were crushed to create a granular material prior to the SPLP analysis, so the results likely over-estimate the actual leachate generation from a solidified mass. Groundwater benchmarks and groundwater results from source-area well MW-119 and well IDNL-GW13, located immediately downgradient of SWMU 15, were included in the table for context and to allow the following remarks:

Arsenic (203 ug/L) and selenium (82.2 ug/L) are the only metals in the SWMU 15 composite sample that had SPLP leachate concentrations greater than the benchmarks of 10 ug/L (MCL) and 4.61 ug/L (GLI), respectively. Arsenic was also detected in groundwater above the benchmark in source-area well MW-119 (480 ug/L) and downgradient well IDNL-GW13 (16 ug/L). Although arsenic exceeds the groundwater benchmark by a small margin at IDNL-GW13, there is more than a 10-fold decline compared to the composite sample results and source-area well MW-119, indicating rapid attenuation of arsenic in groundwater. Selenium was not detected at downgradient well IDNL-GW13, which also indicates rapid attenuation.

For the identified site constituents, the most concentrated SPLP result is for boron (723 ug/L), followed by arsenic (203 ug/L), molybdenum (110 ug/L), selenium (82.2 ug/L), and manganese (2.60 ug/L). Similarly, the three highest concentrations in source-area well MW-119 are boron (29,000 ug/L), molybdenum (3,800 ug/L), and arsenic (480 ug/L).

Boron persists in groundwater during transport and was detected at a concentration of 5,100 ug/L in downgradient well IDNL-GW13. Arsenic, molybdenum, and selenium are rapidly attenuated in the aquifer, and were detected in groundwater from IDNL-GW13 at concentrations that are 10-fold (or more) less concentrated than the composite sample results and source-area well MW-119. Conversely, the concentration of manganese in groundwater collected from IDNL-GW13 (340 ug/L) is substantially higher than either the composite sample SPLP results (2.6 ug/L) or source-area well MW-119 (16 ug/L). SWMU 15 was eliminated as a source of manganese to groundwater in the IDNL due to concentration gradients and source material concentrations.

Barium, cadmium, chromium, copper, and lead were either non-detect in the SWMU 15 composite sample results or had SPLP concentrations well below the benchmarks. The same is true for source-area well MW-119 and downgradient well IDNL-GW13, which justifies the exclusion of these five metals as constituents in groundwater for SWMU 15 and the IDNL.

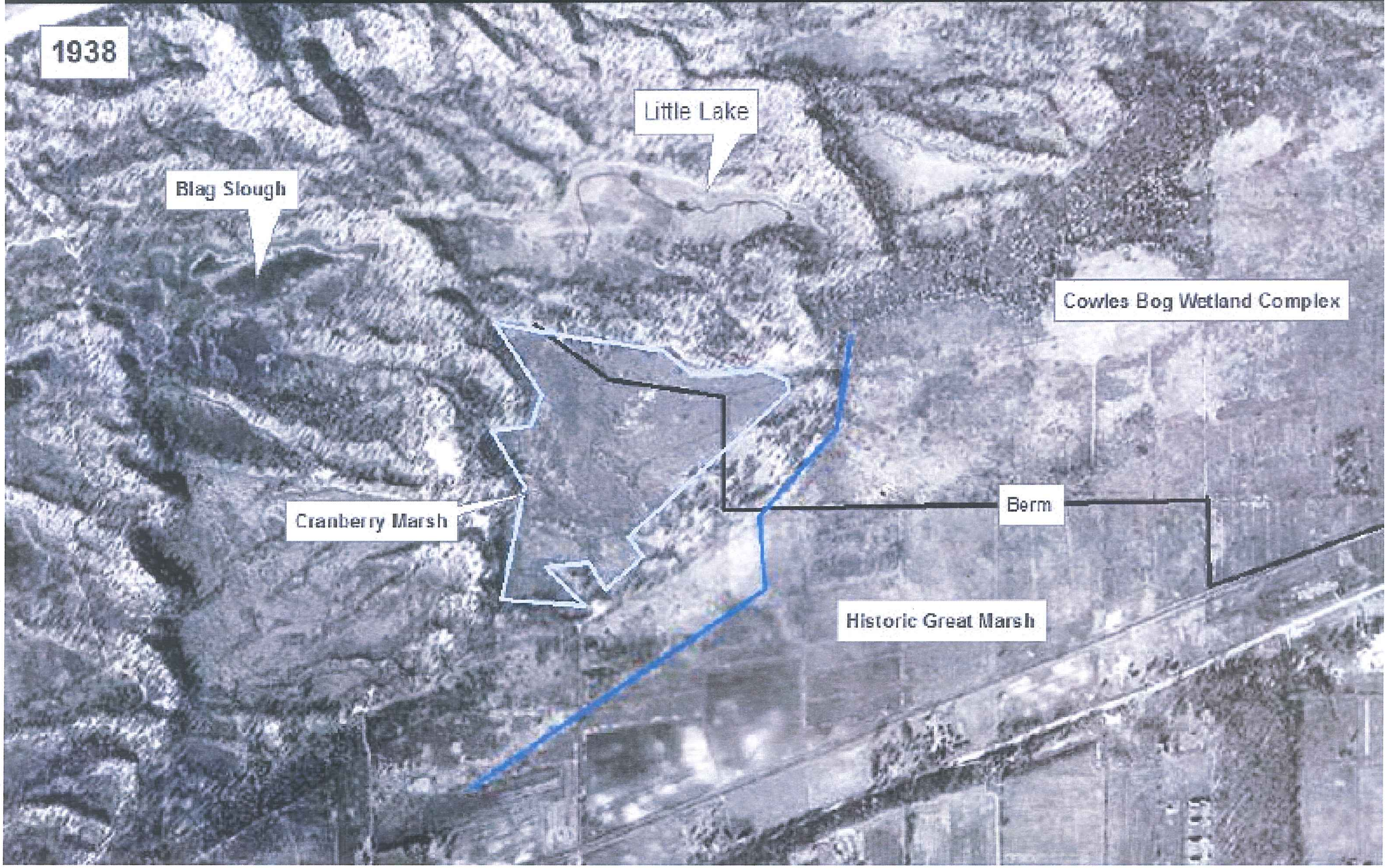
As summarized below, additional treatability testing was performed since the initial study summarized above was completed, using a more advanced EPA approach for assessing the leachability of solidified CCR called the Leaching Evaluation Assessment Framework (LEAF).

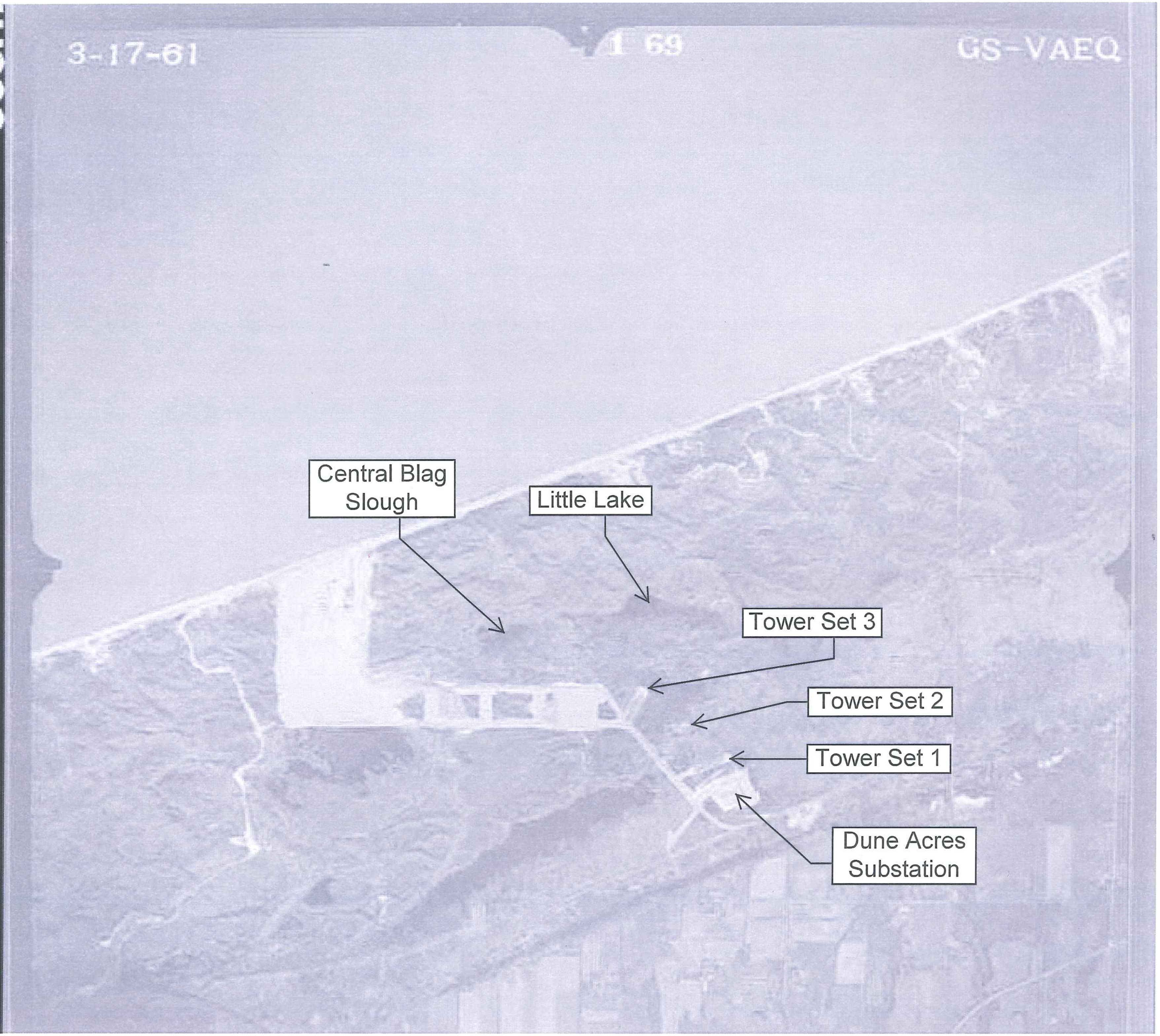
Additional SWMU 15 Remedy Evaluation Studies
On March 18, 2016, a draft proposed remedy was submitted to EPA by NIPSCO, which recommended encapsulation of CCR in SWMU 15. The conceptual design for encapsulation included a perimeter slurry wall keyed into underlying clay and an engineered, impermeable cover. EPA requested additional information to confirm the conceptual design would work prior to officially proposing the remedy to the public. A geotechnical investigation was conducted between July and September 2016 to address that request. The primary objective of that investigation was to better understand the presence and depth of the clay layer(s) underlying SWMU 15, particularly along the potential slurry-wall path. Findings from that investigation were documented in a memo to EPA dated January 23, 2017. The investigation findings had significant cost implications on the encapsulation remedy for SWMU 15 because the depths to clay were greater than assumed and the clay layers encountered were thin or discontinuous. NIPSCO proposed to revise the conceptual design and associated costs for encapsulation, full excavation, and partial excavation with ISS in a separate memo to EPA so that an informed decision could be made on a recommended remedy for SWMU 15.

Revised costs were presented in a memo to EPA dated June 2, 2017. As detailed in that memo, based on the geotechnical investigation findings and the cost re-evaluation, NIPSCO changed its prior recommendation of encapsulation to partial excavation with ISS for SWMU 15. EPA recommended that NIPSCO perform ISS feasibility evaluations to better evaluate ISS effectiveness and determine the dominant mechanism in leachate retardation (i.e., geochemical stabilization or physical solidification). A Treatability Study Work Plan for SWMU 15 was prepared for EPA review and approval, and the final was filed on December 21, 2017. Based on the initial testing of unconsolidated CCR collected from three areas within the SWMU 15 footprint, the most representative material was solidified using five mix designs and tested using LEAF monolith leach testing procedures. Resulting data were used to evaluate the reduction in mass flux from the solidified monoliths, which showed that Portland Cement (6%) generally performed well, having the lowest hydraulic conductivity value and passing the durability tests for wet/dry and freeze/thaw. Additional detail on the treatability study can be found in the November 16, 2018 memo submitted to EPA by NIPSCO.

Indiana Dunes National Lakeshore
Figure 1

National Park Service
U.S. Department of the Interior




3-17-61
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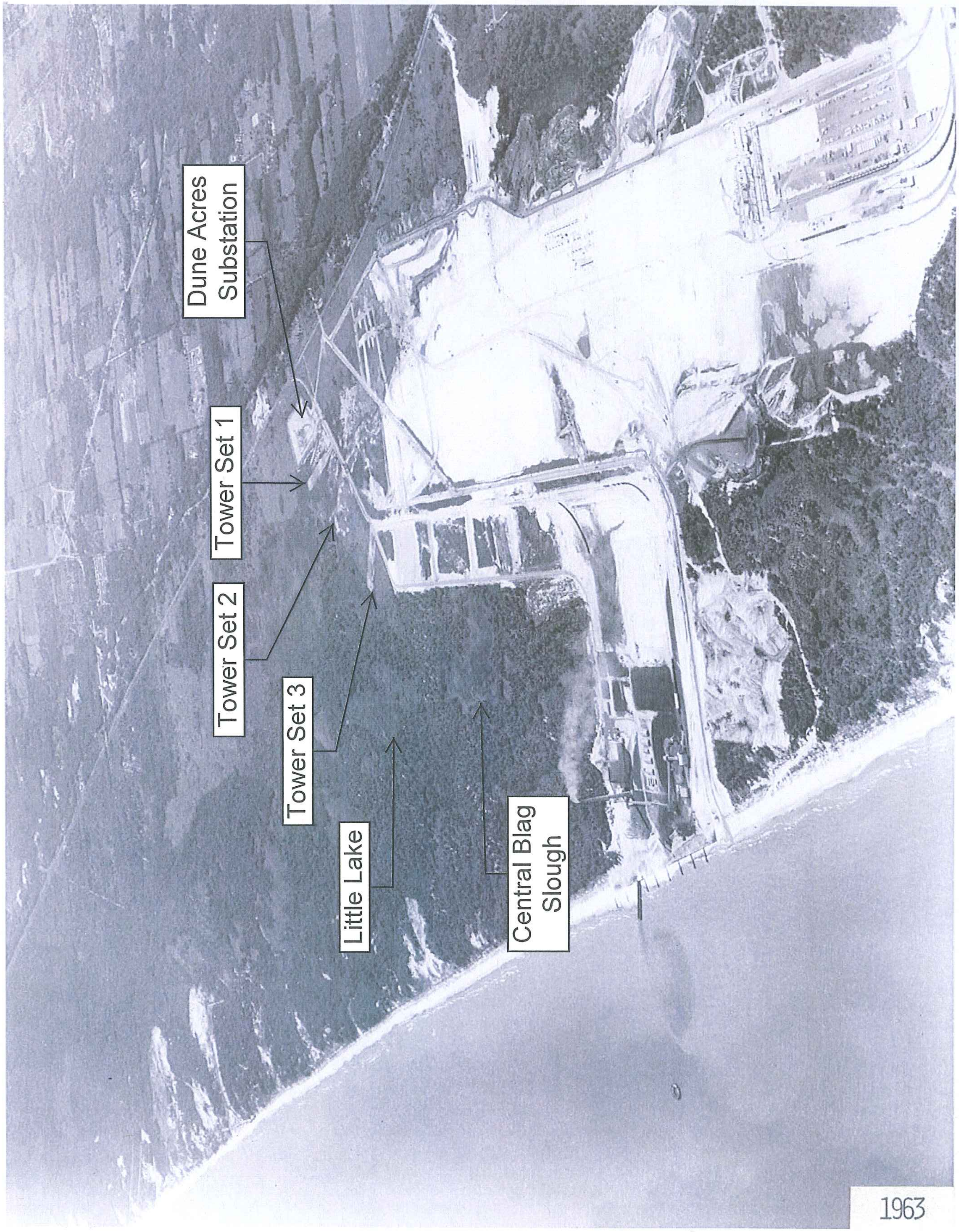
GS-VAEQ
Central Blag Slough
Little Lake
Tower Set 3
Tower Set 2
Tower Set 1
Dune Acres Substation


Dune Acres Substation
Tower Set 1
Tower Set 2
Tower Set 3
Little Lake
Central Blag Slough

1963

Aerial photograph from 1977

Source: Pavlovic, et. al., 2009


NOV 4 1979
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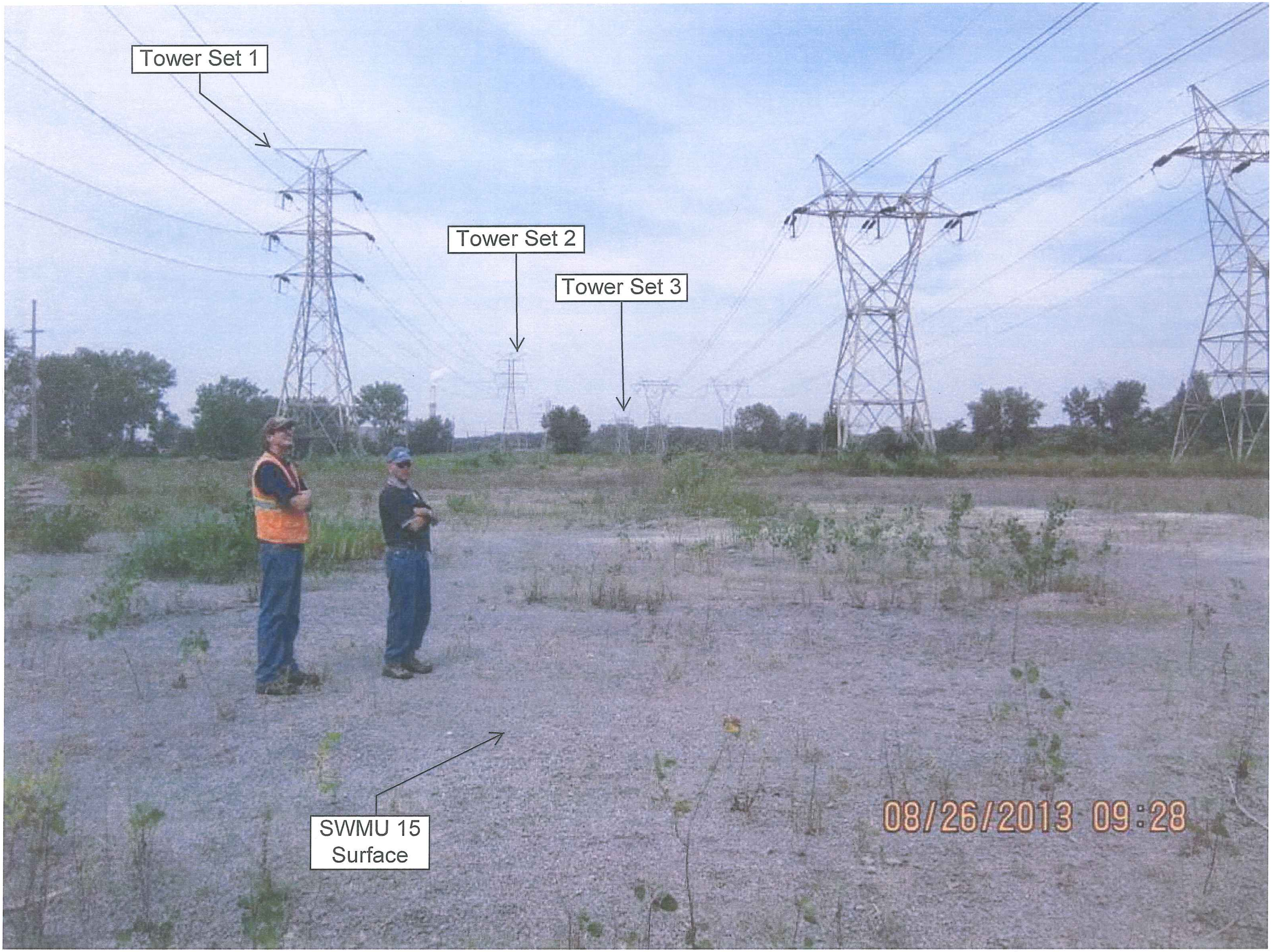
Tower Set 1
Tower Set 2
Tower Set 3
SWMU 15
Surface
08/26/2013 09:28

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

March 15, 2013
Via Email

Dan Sullivan
Northern Indiana Public Service Company
NIPSCO Bailly Generating Station
246 Bailly Station Road
Chesterton, Indiana

RE: NIPSCO Bailly Generating Station
EPA Area C BERA Comments
EPA ID: IND 000718114

Dear Mr. Sullivan:

US EPA has completed its review of NIPSCO's Area C Baseline Ecological Risk Assessment (BERA). EPA conferred with the National Park Service (NPS) during our review. The attached comments present concerns and conclusions from both Agencies.

In general, we do not concur with NIPSCO's conclusions in the BERA. NIPSCO concluded that there are no unacceptable risks to any receptors in any area of study. We believe, and have outlined in our comments, that through a "multiple lines of evidence" approach there exists an abundance of uncertainty associated with the potential ecological risks in Area C. We have also identified specific areas within the BERA's methodologies where potential risk was likely underestimated.

In addition to our BERA comments, attached you will find a recent report on a study of the vegetation found in the Cowles Bog complex (*Potential Impact of Fly-ash Groundwater Contamination on Vegetation of Cowles Bog, Indiana Dunes National Lakeshore, 2011*). The study presents findings that suggest boron, specifically, is causing adverse effects to the affected area of Cowles Bog. In combination with other lines of evidence, this report suggests that damages have occurred within the National Park and to the National Natural Landmark as a result of on-site sources. EPA and NPS believe there is enough evidence and uncertainty to demonstrate that there is unacceptable ecological risk within Area C.

EPA looks forward to discussing these comments with you; however, we will not be requesting a revised BERA. In order to mitigate risks, control sources, and proceed with the corrective action process, we believe the appropriate next step is to collaborate on a risk management decision.

An acceptable risk management decision would include source control, limited off-site remediation, and long-term monitoring. EPA and NPS anticipate working closely with you to achieve these goals. We believe the 2009 Eastern Landfill Pre-Design Investigation prepared by NIPSCO is a good starting point.

We recognize there are potential technical challenges to implement a remediation of this kind and look forward to working with you to find an acceptable solution. In an effort to keep the corrective action process moving forward, please propose a date to discuss these comments and the path forward.

Please feel free to contact me with any questions.

Thank you,

Michelle Kaysen

Michelle Kaysen
US EPA
LCD RRB CAS2
(312) 886-4253

cc: Jennifer Dodds, US EPA
Reginald Pallesen, US EPA
Charles Morris, National Park Service
Robert Daum, National Park Service
Gia Wagner, National Park Service
Dan Mason, National Park Service
Dan Sparks, US Fish and Wildlife Service
Liz McCloskey, US Fish and Wildlife Service
Dale Helmers, NiSource
Russ Johnson, AMEC

Attachments: NIPSCO Area C BERA Comments, EPA and NPS

EPA review of recent vegetation study as it applies to the BERA

Potential Impact of Fly-ash Groundwater Contamination on Vegetation of Cowles Bog, Indiana Dunes National Lakeshore, Paul E. Rothrock, Ph.D. and George C. Manning, August 2011

US Environmental Protection Agency
Review of NIPSCO Area C BERA
March 15, 2013

I. General Comments:

1. Overall, EPA does not agree with the conclusion drawn in the BERA that there are no risks for any receptors in any of the evaluated areas. In particular, the amount of uncertainty surrounding many of the studies (Ex: plant toxicity study, amphibian toxicity study, amphibian survey) and corresponding results, leads EPA to conclude that unacceptable risks to ecological receptors are possible based upon a multiple lines of evidence approach. Below is a brief summary of our conclusions based on review of the BERA and other information. Detailed rationale for our conclusions is provided in the Specific Comments section.
    a. Plants: For plants in at least some parts of the Indiana Dunes National Lakeshore (IDNL) (e.g., Central Blag Slough [CBS]), the weight of evidence suggests that risks are unacceptable and negative impacts may be occurring. This conclusion is based on: (1) soil and/or groundwater concentrations that exceed plant toxicity reference values (TRVs), (2) the presence of barren soil at CBS that has been linked to low pH and elevated metals concentrations, and (3) our analysis of the 2010 plant survey data, which suggests that plant community composition is impacted at some of the site-related areas in comparison to reference areas. As presented in the BERA, the results of the plant toxicity study provides the only line of evidence that conflicts with the above three lines of evidence. However, our review of the plant toxicity study shows that the study was performed with relatively uncontaminated soils and had poor reference area plant survival. We therefore consider the toxicity test results to be highly uncertain and not a supportive line of evidence for a lack of plant impacts. Our detailed reasons are discussed in the specific comments on Appendix G. Additionally, the attached study conducted on Cowles Bog area vegetation appears to contradict this particular line of evidence.
    b. Benthic Invertebrates and Wildlife in Aquatic Habitats: In most of the aquatic habitats in the IDNL, the BERA does not evaluate risks to benthic invertebrates or risks to wildlife through aquatic food web pathways. These are major gaps in the assessment, and we have conducted some preliminary calculations for key chemicals and areas to fill these gaps (detailed in Specific Comment 15). The results of our calculations indicate potential risk to benthic receptors and to invertivorous birds.
    c. Amphibians: Based on the available data and current analyses, the weight of evidence suggests that risks to amphibian receptors may be low. However, we believe that the amphibian assessment is not "definitive", as characterized in the BERA, and that there are important uncertainties that should have been acknowledged in the BERA and carefully considered by risk managers. Also, additional analyses of the amphibian survey data

may change the conclusions of the survey. Refer to comments on Appendices C and E.

d. Terrestrial Invertebrates: The only available line of evidence for terrestrial invertebrates is the comparison of soil concentrations to TRVs or screening values. The results of this comparison do suggest potential for risk in some areas: SWMU 14 and 15 from arsenic, boron, manganese; Little Lake from chromium, manganese; and Eastern Wetland from boron, manganese. It's also noted that although CBS did not demonstrate exceedances of the TRVs, the position that HQs in CBS are lower than the reference area HQs is not appropriate. This risk should not be dismissed based solely on suggestions that screening values are highly conservative or uncertain. Note that the low pH soils in much of the study area may tend to increase the toxicity of some metals in comparison to soils used in standard laboratory tests.
e. Wildlife in Terrestrial Habitats: While risks for most wildlife receptors exposed through the terrestrial food web pathway may be lower than risks for other receptors in the IDNL, there are risks to receptors like shrews and robins that should not be dismissed without additional evaluation or further justification. We also are concerned that the use of literature-derived bioconcentration factors (BCFs) may be resulting in underestimated exposures at this site (refer to Specific Comment 23 and Attachment 3). In addition, note that we recalculated risks to robins for key areas/metals in order to incorporate many of the changes recommended in the comments below (see further discussion in General Comment 5, and complete calculations in Attachment 2). Based on our recalculated risks, hazard quotients (HQs) for robins are as high as 5.8 for boron in the Eastern Wetland (EW) and 14 for cadmium in solid waste management unit (SWMU) 14/15.

2. This assessment could have been greatly strengthened through the collection and evaluation of additional tissue residue data, which is normally an important component of a BERA. Currently, tissue residue data are only available for plants, and these data suggest that uptake in the IDNL study area is greater than uptake predicted by standard literature-based BCFs (refer to Specific Comment 23 and Attachment 3), perhaps due to low soil pH in the study area. This causes concern that modeled concentrations in other organisms may also be underestimated. Collection and analysis of tissue residue samples for terrestrial invertebrates, benthic invertebrates, amphibians, small mammals, and/or bird eggs is typically a component of a BERA, especially in such an ecologically sensitive area.
3. For receptors with no or limited mobility, such as plants and invertebrates, a spatial evaluation of the risk in the risk characterization section would have reduced uncertainty and been more accurate. In contrast to wildlife receptors that are exposed to contaminants over their entire home range (and so, a 95 percent upper confidence limit on the mean [95% UCL] may more accurately represent

exposures to individuals), plants and invertebrates are exposed to very localized concentrations.

4. Given the importance of boron and molybdenum as contaminants of potential ecological concern (COPECs) in the Area C BERA, and the relative paucity of toxicological data available for these two metals, we believe NIPSCO should have prepared detailed toxicological profiles to be included as attachments to the BERA. We noted that the BERA does include references to primary literature for some of the toxicity values used for these metals, but it is unclear how comprehensive the literature search was or how any given study was selected for use in TRV derivation. Additionally, there are some data gaps in TRVs and BCFs for these metals, and it is unclear whether a literature search was conducted in an attempt to fill these data gaps. These data gaps are important uncertainties in the BERA.

5. The specific comments below recommend numerous changes to exposure parameters and toxicity reference values for the wildlife risk calculations. Risks to some receptors in some areas are sufficiently low (e.g., all HQs are less than 0.01) that recalculation is not needed. We do believe, however, that the recommended changes will impact conclusions for some receptors in some areas. To illustrate, we recalculated risks to robins in SWMUs 14/15 and the EW. A summary of results is presented in the table below, and complete calculations are presented in **Attachment 2**. As shown below, our calculated HQs for many analytes are appreciably greater than HQs presented in the BERA

Area	**Analyte**	**Robin HQ from BERA Appendix L**	**Recalculated Robin HQ**
Eastern Wetland	Arsenic	0.25	0.5
	Boron	**2.84**	**5.7**
	Cadmium	0.23	**5.4**
	Chromium	0.16	0.6
	Manganese	**1.13**	**2.1**
	Molybdenum	0.5	**1.0**
	Selenium	0.41	**1.3**
SWMU 14/15	Arsenic	0.68	**1.5**
	Boron	0.66	**11**
	Cadmium	0.1	**14**

II. Specific Comments:

Page 3-3, Section 3.4.1, Refined Selection of contaminants of potential ecological concern (COPECs) in Soil

6. This section does not include any discussion regarding the adequacy of detection limits for nondetected chemicals, and detection limits are not reported in Table 3-

1. EPA guidance (USEPA 1997) recommends retaining nondetected chemicals as COPECs if detection limits are greater than screening values. This comment is also applicable to other media discussed in later text sections (i.e., surface water, groundwater and sediment).
7. The second paragraph that discusses aluminum should have been expanded to include some of the discussion presented in the RFI Section 6.5.2.2, to expand upon a weight-of-evidence approach. Although soil pH data are graphically represented in the RFI, they should have been tabulated in the BERA as an important line of evidence in the ecological risk evaluation.
8. EPA does not agree with the statement, "glyphosate is acutely toxic to both plants and amphibians, and can be considered a contributing factor..." Although some laboratory studies have been provided to EPA which support the conclusion that glyphosate can be acutely toxic, without more site specific studies, it is more accurate to state that glyphosate... "may be" a contributing factor to any observed impacts at NIPSCO.

Page 3-4, Section, 3.4.2, Refined Selection of COPECs in Surface Water and Groundwater

9. This section describes the derivation of the surface water screening value for aluminum. However, the screening value identified in the text (i.e., 750 µg/L) is inconsistent with the screening values listed in Tables 3-3 and 3-5 (i.e., 87 µg/L).
10. This section should have included rationale for using trivalent chromium screening values only, and excluding screening values for hexavalent chromium. If no data on the valence state of chromium in site-specific waters are available, then screening values for hexavalent chromium should have been included. This represents an area of uncertainty. See also Table 3-4.

Page 3-7, Section 3.4.3, Refined Selection of COPECs in Sediment

11. This section indicates that selenium was not selected as a COPEC in the Southeast Pond, but Table 3-6 indicates that selenium was selected as a COPEC in the Southeast Pond. Note that we do not concur with the justification provided for excluding selenium from the Southeast Pond, and we recommend retaining selenium as a COPEC in Southeast Pond sediment. The lack of detection of dissolved selenium in surface water does not preclude the possibility that selenium in sediment could cause toxicity either directly to benthic invertebrates or indirectly through foodweb exposures to wildlife because pore water concentrations of selenium are likely to be greater than surface water concentrations.

Page 3-9, Section 3.5.2, Habitat Areas

12. This section omits discussion of the "Other Wetlands," for which assessment and measurement endpoints are listed in Table 3-12.

Page 3-11, Section 3.5.2.2, Indiana Dunes National Lakeshore (IDNL) Habitats

13. Figure 3-4 is referenced and includes soil/sediments invertebrates as one of the ecological receptor groups for Northwest Blag Slough (NBS), CBS, Little Lake, and the EW. However, the text appears to omit the benthic invertebrates when listing the ecological receptors and feeding guilds in the four IDNL wetland areas. They are however, included as ecological receptors for the Southeast Pond.

    Additionally, in previous correspondence (i.e., letter from NIPSCO to EPA dated February 13, 2009), NIPSCO agreed to evaluate additional receptors in the IDNL (e.g., benthic invertebrates). These receptors do not appear to have been added to the BERA, and we maintain that additional receptors would have been appropriate to reduce uncertainty of risk. Specifically, benthic invertebrates should have been evaluated in <u>all</u> of the evaluated aquatic habitats at the IDNL. During the meeting on June 23, 2011, NIPSCO noted that benthic invertebrates were not evaluated because of the ephemeral nature of most of the Area C wetlands in the IDNL. We do not concur with this rationale, as many invertebrates are adapted to ephemeral pools and wetlands. If hydroperiods are sufficiently long to support larval amphibian development, then hydroperiods are also sufficiently long to support benthic invertebrate development.

    Also, evaluation of a representative invertivorous and/or omnivorous bird and mammal that would forage in aquatic habitats would have been appropriate and would have further reduced uncertainty. Based on personal communication with Randy Knutson (wildlife biologist at IDNL), wildlife species that have been observed in the NIPSCO-affected areas of the IDNL include the Virginia rail, sora, sandpipers (which are most commonly observed at the Lake Michigan shoreline, but sometimes venture inland), mallard, sandhill crane, great blue heron, raccoon, and muskrat. (Note that this list is not intended to be comprehensive.) Breeding populations of Virginia rail and sora occur at the IDNL. Based on this information, the Virginia rail, which feeds by probing in sediments, would have been appropriate and protective of other shorebird species. In areas where sediment concentrations for some metals are greater than soil concentrations (e.g., cadmium in CBS, molybdenum and selenium in EW), an herbivorous bird or mammal should have been selected for evaluation.

    To better understand the possible impacts of the addition of these receptors to the BERA, we conducted risk calculations for benthic invertebrates and the Virginia rail for a few selected analytes/areas (see summary in table below and more detailed information in **Attachment 1**). We attempted to include the analytes/areas that were most likely to result in the greatest risk. We also selected analytes that appeared to be present in the site-impacted areas at concentrations that exceed background concentrations.

Area	Analyte	Sediment EPC from Table 6-2 of the BERA (mg/kg)	Benthic Invertebrate TRV (mg/kg)*	Benthic Invertebrate HQ	Virginia Rail HQ**
Central Blag Slough	Cadmium	24.59	0.99	**25**	**9.1**
	Chromium	19.42	43.4	0.4	0.8
	Molybdenum	42.59	NA	NA	>0.4
Eastern Wetland	Arsenic	47.14	9.79	**4.8**	**3.0**
	Boron	28.65	NA	NA	>0.03
	Chromium	20.98	43.4	0.5	0.9
	Molybdenum	139.4	NA	NA	**>1.2**
	Selenium	4.304	2	**2.2**	**6.6**
Northwest Blag Slough	Chromium	31.75	43.4	0.7	**1.3**
	Mercury	0.658	0.174	**3.8**	0.7 to **52**
	Molybdenum	73.64	NA	NA	>0.6

*TRVs for cadmium, arsenic, chromium and mercury are Region 5 Ecological Screening Levels for sediment. TRV for selenium is from Lemly (2002) and was developed to protect both benthic invertebrates and wildlife. Benthic invertebrate TRVs for boron and molybdenum are not readily available from standard sources, and a literature search should have been conducted for benthic invertebrate toxicity data.
**Virginia rail HQs for mercury were calculated using TRVs for both inorganic mercury (HQ=0.7) and methylmercury (HQ = 52) to bracket the range of possible mercury risk. The HQs for boron and molybdenum are based on sediment ingestion only; prey ingestion should have been incorporated into the calculation in the BERA. Refer to Attachment 1 for additional information on these calculations.

Also note that the HQs for boron and molybdenum do not include the ingestion of contaminated prey, and include ingestion of sediment only, due to the lack of chemical-specific uptake factors into prey. Risks from prey ingestion could be 2-10 times greater than HQs from sediment ingestion, and prey ingestion should have been incorporated into the calculation in the BERA (refer also to General Comment 5 regarding data gaps for molybdenum and boron).

As shown in the table above, HQs for both benthic invertebrates and the Virginia rail exceeded 1 for several analytes in multiple areas, with highest HQs substantially greater than 1. These results confirm that it is important to quantify risks to these receptors in the BERA, and that risks to these receptors may be unacceptable for some analytes. Note that the table above is for illustration purposes only; the BERA should have included all COPECs in all areas, and should not have been limited to the analytes/areas included above. This represents a significant uncertainty in the risk.

14. If data are available, additional information about the hydroperiod for CBS, EW, NBS, and Little Lake should have been provided in this section.

Page 3-12, Section 3.5.2.3, Southeast Pond Habitat Area

15. Rather than just fish, this section should specify "fish and aquatic invertebrates" as receptors in this area. Also, it is unclear whether other avian species may have been needed in the Southeast Pond. NIPSCO should have clarified what bird species have been observed or are expected to occur in the Southeast Pond. If any wading birds or dabbling ducks are likely to occur, then a representative receptor should have been selected and evaluated.

Page 4-5, Section 4.1.3, IDNL Plant Toxicity Study

16. This section states, "For each Study Area and Reference Area wetland, sampling locations with the highest metals concentrations were selected in order to obtain the most conservative (i.e., worst case) toxicity testing results." However, it appears that locations with highest metals concentrations were not actually used; in fact the soils used had metals concentrations that were more similar to those in the reference areas. Refer to the discussion and table in the specific comments on Appendix G. We assume that locations with higher concentrations were omitted from the plant toxicity study because they were inundated at the time of sampling. This is an important uncertainty, and should have been highlighted in this section as well as Sections 7 and 8 and Appendix G.

Page 6-5, Section 6.2.1.1, Soil EPCs

17. It is unclear whether the depth-weighted averaging approach described in this section is appropriate. In cases where COPEC concentrations in the 0.5 to 2 ft interval are greater than concentrations in the 0 to 0.5 ft depth interval, then the depth-weighted approach may be needed to ensure protection of plants with deeper root systems. However, if COPEC concentrations are typically greater in the 0 to 0.5 ft depth interval, data from this depth interval alone should be used to ensure protection of plants with shallow root systems and to better characterize exposure for other receptors (e.g., invertebrates and wildlife). Risks to many receptors now have an added layer of uncertainty from not using the 0 to 0.5 ft data set.

Page 6-6, Section 6.2.1.2.1, Surface Water Outlier Samples

18. Additional analysis would have been appropriate to show that the concentrations designated as outliers are impacted by suspended sediment solids and are not representative of a truly elevated concentration. If high hits are due to suspended sediment, then most metals in the water sample should be elevated, not just one or two metals. With the exception of the April 2007 SW-07 sample, it is not clear that the outliers identified in this section should be removed from the dataset.

Page 6-8, Section 6.2.1.6, Dietary Component EPCs

19. This section should have specifically listed the dietary items and areas where concentrations were measured, rather than modeled (e.g., CBS plants). Also, Tables 3-7 through 3-12 should have indicated when tissue concentrations were measured rather than modeled.
20. In general, Section 6.2.1.6 and Table 6-3 do not provide enough information to allow reviewers to verify the acceptability of the BCFs used in the ERA. The following questions and comments illustrate the degree of uncertainty associated with this issue:
    - Were site-specific soil-to-plant BCFs used in all areas except SWMU 14/15? What was the rationale for using literature-derived soil-to-plant BCFs in preference to site-specific BCFs?
    - It appears as if water-to-plant bioconcentration factors were omitted; where these values exist, particularly for significant COCs such as boron (DOI, NIWQP Report #3, 1998), why were water-to-plant BCFs not considered?
    - How were reference area plant concentrations determined (metals for which measured concentrations were used)? References should have been provided to indicate where Reference Area plant data were tabulated. We could not find ProUCL output for Reference Area plants in Appendix J.
    - What soil concentrations were used in the calculation of the literature-derived plant BCF values? (For most metals, these values are calculated based on an equation that is dependent on the soil concentration.) Area-specific 95% UCL soil concentrations should have been used to calculate area-specific BCFs (i.e., literature-derived plant BCFs should vary by exposure area).
    - What wet weight-to-dry weight conversion factors were used?
    - Were water-to-aquatic invertebrate BCFs used exclusively in the Lake Michigan Beach area?
21. In order to better understand the differences between site-specific uptake factors and literature-derived uptake factor for plants, we tabulated soil-to-plant BCFs from three different sources: (1) Ecological Soil Screening Level (Eco-SSL) guidance documents (USEPA 2007), (2) literature-derived BCFs used by NIPSCO (from Table 6-3 of the BERA), and (3) site-specific BCFs (from Table 6-3 of the BERA). These values appear in Table 1 of **Attachment 3**. As shown in this table, the Eco-SSL BCFs and the literature-derived BCFs used in the BERA are generally fairly similar. However, the site-specific BCFs are often considerably different (usually greater) than the literature-derived BCFs. Of particular concern are the site-specific BCFs for boron and cadmium, which are about an order of magnitude greater than the literature-derived BCFs. These results suggest that the use of literature-derived BCFs may not be providing conservative estimates of exposures at the site.

In Table 2 of Attachment 3, we also tabulated plant concentrations for CBS, as calculated using the three different BCFs discussed above. For comparison, we included in Table 2 the plant concentrations that NIPSCO actually used in the wildlife risk calculations (from BERA Appendix L). As shown in Table 2, the plant concentrations used in wildlife risk calculations were different from (and usually less than) any of the plant concentrations that we calculated using the three different BCFs. It is unclear how NIPSCO determined these plant concentrations.

22. For aquatic exposure pathways, Table 6-3 includes only BCFs based on uptake from water. In general, depending on local chemistry, metals can partition more to sediments than surface water, and uptake to aquatic prey often should be estimated based on biota-sediment accumulation factors (BSAFs). (Note, however, that we concur that water-to-aquatic invertebrate BCFs should be applied to groundwater at Lake Michigan Beach.) A few good sources of information for BSAFs include Bechtel Jacobs (1998), USACE (2000), and USEPA (2000).

    Unfortunately, to our knowledge there are no comprehensive compilations of BSAFs for metals in fish. Our suggested approach would be to first use the Bechtel Jacobs (1998) reference to calculate metals BSAFs for benthic invertebrates. The USEPA (2000) reference can then be reviewed for fish BSAFs and to determine whether there is potential for biomagnification of any given metal in aquatic systems (refer to the "Food Chain Multipliers" sections under the "Aquatic Organisms" headings in the appendices of this document). In general, USEPA (2000) indicates little potential for biomagnification of most metals. For metals with little potential for biomagnification, fish concentrations can be estimated using the higher of values calculated using: (1) surface water concentrations and water-to-fish BCFs, and (2) sediment concentrations and Bechtel Jacobs (1998) BSAFs for benthic invertebrates. The latter calculation essentially assumes that fish concentrations will be equivalent to benthic invertebrate concentrations. Other ERAs we have reviewed have used primary literature sources to develop fish BSAFs for metals. For selenium, a useful reference is Lemly (2002). A more comprehensive literature review may be needed for any metals that may biomagnify (e.g., mercury).

23. For soil-to-plant, soil-to-earthworm, and soil-to-deer mouse BCFs, EPA's preferred source of literature-derived uptake factors is the Eco-SSL guidance document (Attachment 4-1) (USEPA 2007). Section 6.2.1.6 indicates that this source was used, but based on Table 6-3, it appears that it was not used for all constituents (cadmium, copper, and selenium).

24. Based on Table 6-3, NIPSCO used soil-to-earthworm BCFs for boron and molybdenum that are based on the geometric mean of other available metal BCFs. Considering the importance of these two metals at this site and the high site-

specific plant BCF that was calculated for boron (i.e., BCF of 34, from Appendix K and Table 6-3), this uncertainty is cause for concern. A literature search to determine whether any soil-to-earthworm BCFs for these metals are available would have been appropriate. The collection and analysis of tissue samples for terrestrial and benthic invertebrates as well as other potential receptors would have allowed for more site-specific data to be generated. This is a substantial data gap and area of uncertainty.

Page 6-12, Section 6.2.2.2, Habitat Use Factors

25. The application of Seasonal Use Factors (SUFs) for robins, woodcocks, and hawks at this site is not appropriate. An SUF should only be used in cases where the receptor is absent during the breeding season (the most toxicologically sensitive lifestage) and the toxicity studies on which the TRVs are based used exposure durations that are longer than the exposure durations experienced by receptors at the site. All three of these species (and other species within the same guild) occur locally during the breeding season. Also, it is likely that most of the toxicity studies used to derive TRVs employed relatively short exposure durations (i.e., from a few days to a few months). For example, a review of the avian data included in the Eco-SSL dataset for cadmium indicates that none of the 50 test results for reproduction, growth, and survival endpoints was based on exposure durations greater than 3 months. SUFs should have been omitted from the BERA, or an SUF of 1 should have been used for all receptors. Risks have likely been underestimated and this represents an uncertainty.

Page 6-14, Section 6.3.2, Mammalian TRVs

26. This section indicates that allometric scaling was used to derive mammalian TRVs. Refer to Allard et al. (2010) for a recent discussion of methods for interspecies extrapolation of toxicity data and reasons why allometric scaling is no longer recommended. Section 6.3.2, Table 6-9, and affected tables and text sections are not acceptable due to the use of allmostric scaling and represent an area of uncertainty.

Page 6-15, Section 6.3.3.3, Terrestrial and Wetland Plant TRVs

27. It appears that the molybdenum TRVs derived from the McGrath et al. (2010a, as cited in the BERA) study may not be adequately protective of plants in Area C. First, NIPSCO derived TRVs based solely on data from the Zegveld area. The molydbdenum ED10 values (i.e., doses causing 10% inhibition) for the Zegveld area (i.e., 1502 to 3476 mg/kg) are markedly greater than the ED10 values for any of the other nine tested locations (i.e., 3 to 330 mg/kg) (McGrath et al., 2010a). Based on a comparison of soil properties in Table 1 of McGrath et al. (2010b, as cited in the BERA) and those included in Table 3 of the plant toxicity study report (Appendix G) and Tables 4 through 24 of Appendix I, the Zegveld soils do not

appear to be adequately similar to IDNL study area soils to justify the use of the Zegveld data for TRV development. For example, pH in Zegveld soils is 4.4, while pH in the IDNL study area is higher (typically 5 to 7) in all areas except the southern portion of CBS. Also, the organic carbon content in Zegveld soils (30.7%) is greater than organic carbon in IDNL soils, based on data in BERA Appendices G and I. In Table 3 of the plant toxicity study report (Appendix G), total organic matter measurements range from 1.2% to 7.3% in IDNL study area soils. Total organic matter (based on data included in Appendix I) ranges from 7% to 26% for soils in the IDNL study area. Although grain size data are not presented in the BERA for IDNL study area soils, the text in Section 6.3.3.3 indicates that the grain size distribution in IDNL soils is different from Zegveld soils.

Taken together, this information indicates that the Zegveld soils are not similar to IDNL study area soils, and should not be used to derive TRVs in the Area C BERA. Summary statistics for available soil properties parameters (including grain size distribution, pH, organic matter content, and other relevant parameters) for the IDNL study area should have been tabulated by area to facilitate comparisons with soils tested by McGrath et al. and to more rigorously support the selection of a molybdenum TRV for plants.

Also, we do not agree that TRVs should be derived by calculating the geometric mean of ED10 values for the four species tested by McGrath et al. (2010). Considering the paucity of available toxicity data for molybdenum, it appears that very little is known about the relative species sensitivity of plants to molybdenum. When data are only available for such a small number of species (i.e., four species tested by McGrath et al.), it is more appropriate to use the lowest value for all species tested, particularly for use in a protected area like the IDNL study area. To the extent possible, the TRV should be derived using a methodology that attempts to protect all plant species at the IDNL study area and that minimizes the likelihood that risks are underestimated. That does not appear to have been done in the BERA and represents significant uncertainty.

Page 7-1, Section 7.1, Approach to Risk Characterization

28. In general, we advise against the BERA's approach to using reference area data in the risk characterization, in which reference area HQs are calculated using 95% UCL concentrations and compared to HQs in site-related study areas (as described in this section). This approach may not be appropriate if population distributions in site-related study areas are different from distributions in reference areas. To avoid this problem, risks should be characterized based primarily on: (1) site-related study area HQs and (2) a statistical comparison of study area and reference area media concentrations, rather than a direct comparison of study area and reference area HQs. Refer to EPA guidance (USEPA 2002) for detailed recommendations regarding statistical methodologies.

Using this alternative approach, the risk characterization can then discuss risks calculated based on study area HQs, but can qualify these risks by indicating which chemicals are present at concentrations comparable to reference area concentrations and which are present at concentrations exceeding reference area concentrations.

Page 7-3, Section 7.2, Risk Characterization Findings

29. This section states, "For food chain exposure models, because no site-specific tissue samples had been collected, all prey item tissue concentrations were modeled using highly conservative literature based BCFs." However, site-specific plant tissue samples were collected and site-specific soil-to-plant BCFs are derived in Appendix K and summarized in Table 6-3. This section, and other later sections that make similar statements, are inaccurate. Also, text describing the literature-derived BCFs as "highly conservative" is not appropriate (refer to Specific Comment 16).

Page 7-5, Section 7.2.1.2, Risk Characterization of Potential Exposures of Plants

30. The statement that the SWMU14/15 habitat area is on the industrial Facility property and therefore the NOAEL-based HQs may have overestimated the risk is not acceptable. One of the modes of contaminant migration is GW from SWMU 14/15 migrating into the IDNL. According to EPAs Superfund Ecological Risk Assessment Guidance (ERAGs), the National Landmark status of the IDNL and its designation as a National Park means NOAEL-based HQs are acceptable for estimating risks from COCs in this area. ERAGs considers this type of environment as one that merits special protections along the same lines as a T&E species. Provided the hydrologic connection between the source area, SWMU 14/15, and the receptor, IDNL, NOAEL-based HQs are appropriate for purposes of estimating risk.

31. Although HQs exceed one for several metals in SWMU 14/15, this section concludes, "Because of the levels of conservatism used in this BERA (see Section 7.2), the HQ results do not indicate that the SWMU 14/15 Upland Successional Meadow poses any risk to the survival, growth and viability of conservative plant communities." Without additional lines of evidence or further justification, we do not concur with this conclusion. A more appropriate conclusion might be, "The HQ results indicate a potential for risk to plant communities, but the uncertainty associated with these HQs is high." Below is a list of NIPSCO's arguments for this conclusion (in italics) and our responses to these arguments.
    - *EPCs overestimate exposure concentrations over much of the habitat and EPCs are biased toward higher values because the sampling approach was intentionally biased toward areas with greater potential impact.* A spatial approach to risk characterization for plants (e.g., a map delineating

areas with HQs>1) would allow risk managers to better understand the spatial extent of the potential risk.

- *Screening levels are based on no-effects levels and are more conservative than TRVs.* Efroymson et al. (1997, as cited in the BERA) screening levels are developed based on low-effect levels, not no-effect levels. Similarly, Eco-SSLs for plants and invertebrates are typically derived from low-effect levels, maximum acceptable toxicant concentrations, and EC20 values. Statements characterizing all screening levels as no-effect levels are inaccurate throughout the BERA, which frequently cites the conservatism of "NOAEL-based" screening values. Additionally, these screening levels are not necessarily any more conservative than TRVs, and the basis for this statement is unclear. In the absence of any other information, risks should not be dismissed due solely to the fact that they were calculated based on a screening value or a no-effect level. Further, the conceptual site model presents an on-site area of contamination directly up-gradient and in hydrologic communication with the off-site National Park and National Natural Landmark. The National Park Service has expressed an expectation that their land will not be impacted from site-related constituents above background levels in an effort to avoid damages to the Park. As such, conservative screening levels were deliberately selected as an appropriate risk measurement endpoint towards the protection of the National Park. This comment is applicable throughout the risk characterization section of the BERA.
- *Screening levels based on only a few toxicity studies (and characterized as "low confidence screening levels") can be disregarded.* These data are the best available data, and cannot be dismissed in the absence of other data. A screening value based on a small dataset is not necessarily a conservative value; rather, a small dataset could bias a screening value either high or low (depending on the available data). Determining whether the bias is high or low will vary from chemical to chemical, and cannot be determined without a detailed review of the data on which each screening value is based (an effort that may be outside of the scope of the BERA). This comment is applicable throughout the risk characterization section, which dismisses risks multiple times because of low confidence screening values.
- *Boron risks to plants from groundwater (HQ of 26) can be dismissed because the screening level (1 mg/L) is based on "unspecified toxic effects on plants".* Efroymson et al. (1997, as cited in the BERA) also summarized results from another study in which 35-45% decreases in root and leaf weights were observed at a test concentration of 5.4 mg/L. Risks calculated based on this other study's effect level (which should be considered under-protective due to the 35-45% reductions) would still result in an HQ of approximately five. This risk cannot be dismissed, particularly in light of the additional line of evidence provided by the recent study of vegetation (Attached).

Page 7-9, Section 7.2.2.3.2, Plant Toxicity Study Results

32. There are multiple issues with the plant toxicity test and the interpretation of the results. These issues are well articulated in the contractor's comments. Based on all these issues, this line of evidence should not be the primary measurement endpoint used to assess the level of protection of the survival, growth, and viability of conservative plant communities in the IDNL. In addition to the issues articulated in the contractor's comments, the NPS has also reviewed the data and expressed similar concerns with the study and the interpretation of its results. In particular, the NPS notes the lack of natural botanical diversity in areas within or directly adjacent to the most heavily contaminated soils. Those areas are dominated by exotic and invasive species while adjacent habitats maintain a more natural assemblage of plants. In addition, the NPS noted the lower level of plant fitness in restoration plantings within Cowles Bog versus other areas. At this time, the plant toxicity study cannot be used to point to metals as the definitive cause of poor survival and fitness in some of the wetland plants, therefore its overall usefulness is in question.

33. The BERA states, "it is likely that other wetland plants...would have shown better survival and growth rates". EPA had requested that a wetland species of plant be used as part of the plant toxicity study and was met with much resistance for numerous reasons. A compromise was reached to use the red clover, which survived and grew better in both the study and reference areas. However, it is clear that the use of a wetland species would have proved invaluable in this study and would have rendered the results more useful. Overall, the plant toxicity test is not a strong line of evidence and represents uncertainty in this area.

Page 7-12, Section 7.2.2.4.2.2, 2009/2010 Amphibian Survey Results

34. We do not concur with this section's conclusions, particularly the following statement, "The assessment endpoints have been conclusively addressed to demonstrate that BGS- related metals are not impacting amphibians in the IDNL." Refer to comments on Appendix C for rationale. This comment is also applicable to risk characterizations for other IDNL areas.

Page 7-13, Section 7.2.2.4.3, Amphibian Toxicity Study Results

35. This section states, "Toxicity study results are a definitive indication that Northwest Blag Slough sediments pose no BGS-related risk to amphibians in the IDNL." The use of the word "definitive" is inappropriate. Uncertainty associated with the toxicity tests should be acknowledged. Refer to comments on Appendix E. This comment is also applicable to risk characterizations for other IDNL areas.

36. EPA questions the validity of the test results given the statistically significant differences in length and width of the test species exposed to NBS sediment samples as compared to those exposed to the lab control. All of the test species exposed to reference area sediment samples measured statistically significant differences in length and in the case of REF-07, width as well. Because of these issues, EPA does not consider the amphibian toxicity study results reliable and their usefulness as a measurement endpoint is in question. This comment is also applicable to all of the other areas sampled in the study; the CBS, the EW, and Little Lake all reported statistically significant differences in length of the test species exposed to site sediments as compared to those exposed to the lab control, while reporting no differences when compared to the reference areas.

Page 7-15, Section 7.2.2.5, Overall Northwest Blag Slough Risk Conclusion

37. EPA does not agree with the conclusion as stated. This statement is not supported by the available data and is further called into question through the comments provided above.

Page 7-17, Section 7.2.3.3.1, Hazard Quotients for Plants

38. This section omits discussion of plant HQs for selenium in soil. Any HQs greater than one should be noted.

Page 7-19, Section 7.2.3.3.3, Assessment of Barren Soil and Vein Clearing

39. Refer to Appendix I comments regarding conclusions related to the Vein Clearing and Barren Soil Report. Also, this section states that there was "a slight elevation of molybdenum and cadmium in the barren soils relative to reference area rooting zone soil". Based on Figure 9 of Appendix I, these differences should not be characterized as "slight" elevations, as molybdenum concentrations in the barren soils were as much as 50 times greater than concentrations in the reference soils, and cadmium concentrations in the barren soils appear to be about four times greater than concentrations in the reference soils. Finally, the last sentence of this section, "The concentrations of COPECs in soil and groundwater do not pose any BGS-related risk to the survival, growth and viability of conservative plant communities in Central Blag Slough", is not supported by the available data (refer to Appendix I comments).

40. At one point in this discussion, low pH in surface soil was closely linked to the low fertility of the soil and therefore the barren areas in the CBS. However, later in the discussion, a USGS report is cited stating, "that the pH of the soil has increased an order of magnitude…improving growing conditions". In addition, the Vein Clearing and Barren Soil Report, as found in Appendix I, lists two NIPSCO-related historical sources, the formerly unlined surface impoundments, as possible causes for the low soil pH. The issue of pH and the low fertility of the

soil in CBS should have been discussed further. Given these data gaps, the statement that "concentrations of COPECs in soil and groundwater do not pose any BGS-related risk to...plant communities in CBS", is not valid and should be removed. Further, it should be noted, that NIPSCO's 2007 Corrective Measures Proposal concluded, "low pH levels in soil may pose an unacceptable potential risk to plants in localized areas..." Based on the weight of evidence presented, EPA concludes that there is unacceptable risk to plants in the CBS.

Page 7-23, Section 7.2.3.4.4, Conclusion for Risk Characterization of Amphibians

41. EPA does not agree with the conclusion that surface water and sediment in CBS ephemeral pools poses no BGS-related risk to the survival, growth reproductive success and population sustainability of the amphibian community in the IDNL. This statement is not supported by the available data and is further called into question through the comments provided above.

Page 7-24, Section 7.2.3.5, Summary of Central Blag Slough Risk Characterization

42. This section states, "None of the HQs for plants exposed to COPECs in soil or groundwater exceeded 1 for any COPEC." This statement is not accurate, as HQs for aluminum and selenium exceeded 1 (Table L-38).

43. Paragraph 3 states "the naturally low soil pH levels in the greenbelt portion of the CBS may pose risk to terrestrial and wetland plant in this small portion of CBS". There is not enough evidence presented to determine that the low pH levels found in this area of the CBS are "naturally" low. In fact, as mentioned above, the Vein Clearing and Barren Soil Report, as found in Appendix I, lists two NIPSCO-related historical sources as possible causes for the low soil pH. Again, NIPSCO's own 2007 Corrective Measures Proposal states, "The low pH values measured in settling pond surface water in the 1970s (Hardy, 1981) suggest the historic seepage may have contributed acidity to southern Central Blag Slough barren soils."

Page 7-25, Section 7.2.3.5, Overall Central Blag Slough Risk Conclusion

44. EPA does not agree with the overall CBS risk conclusion of no risk to wildlife, invertebrates, plants or amphibians. The evidence provided does not support such a conclusion. NIPSCO's own 2007 report does not support such a conclusion, as it concluded remediation was necessary in CBS to reduce the acidity of soil.

Page 7-30, Section 7.2.4.4.1, Comparison of Surface Water COPEC Concentrations to Amphibian Screening Values

45. Given EPA's above mentioned concerns with the amphibian field survey and amphibian toxicity study, the screening level comparisons of manganese in surface water must be weighted more heavily than other lines of evidence. Therefore, EPA does not agree with the statement that the HQ results do not indicate that surface water from Little Lake poses any risk to the survival, growth, reproduction, and population sustainability of amphibians. The evidence provided, an HQ of 68 for manganese, does not support such a conclusion. This comment applies to Section 7.2.4.4.4 as well.

Page 7-32, Section 7.2.4.4.3, Amphibian Toxicity Study Results

46. Given EPA's above mentioned concerns with the amphibian toxicity study, EPA does not agree with the statement that "toxicity study results are a definitive indication that Little Lake sediment poses no BGS-related risk to amphibians in IDNL".

Page 7-34, Section 7.2.4.5, Overall Little Lake Risk Conclusion

47. EPA does not agree with the conclusion as stated. This statement is not supported by the available data and is further called into question through the comments provided above.

Page 7-45, Section 7.2.5.6, Terrestrial and Wetland Plants

48. EPA does not agree with the plant toxicity testing being weighted more heavily than the other lines of evidence. Given the flaws inherent in the study, primarily the lower survival and growth weights of the plants due to the study not including a wetland species of plant for testing in the wetland soils and the resultant compromised study results, this line of evidence must be weighted less heavily than the others.

Page 7-45, Section 7.2.5.6, Overall Eastern Wetland Risk Conclusion

49. EPA does not agree with the conclusion as stated. This statement is not supported by the available data and is further called into question through the comments provided above.

Page 7-49, Section 7.2.6.5, Overall Southeast Pond Risk Conclusion

50. EPA does not agree with the conclusion as stated. A statement of low risk or acceptable risk would be more accurate than stating there is no risk.

Page 8-1, Section 8.0, Uncertainty Analysis

51. This section presents a very cursory discussion of the uncertainties in this risk assessment, and highlights only areas that may have overestimated risks. A more balanced and detailed discussion would have been appropriate, as number of additional uncertainties have been identified in these comments.

Table 6-4

52. It appears that the food ingestion rates used in Table 6-4 are not conservative estimates. For example, NIPSCO has selected a food ingestion rate for the robin of 0.89 kg diet ww/kg bw-d, but the Wildlife Exposure Factors Handbook (USEPA 1993, as cited in the BERA) lists two food ingestion rates, 0.89 kg diet ww/kg bw-d and 1.52 kg diet ww/kg bw-d. It is unclear why NIPSCO has selected the lower of these two values. Similarly, if an ingestion rate for the robin is calculated based on an allometric equation (from USEPA 1993), the resulting value is considerably greater than the value used by NIPSCO (see Attachment 2). Additionally, the food ingestion rates used for the shrew and the mourning dove are considerably less than the ingestion rates used in the development of the Eco-SSLs (USEPA 2007). The risk to applicable receptors has likely been underestimated and this represents an area of uncertainty.

Tables 6-6 and 6-7

53. Rather than using TRVs for inorganic mercury only, mercury risks to wildlife should be calculated using both inorganic mercury TRVs and a methylmercury TRVs, in order to bracket the range of possible mercury risks. Refer to Attachment 1 for example calculations.

Appendix C, 2010 Amphibian Survey Report for Area C

54. In general, we do not concur with conclusions that the amphibian surveys and toxicity tests have "conclusively addressed [assessment endpoints] to demonstrate that BGS-related metals are not impacting amphibians in IDNL". We consider the amphibian survey to be a very weak line of evidence in this BERA, and little weight should be placed on it in the weight-of-evidence evaluation. This comment discusses reasons why we believe the amphibian surveys are a highly uncertain piece of evidence.

    First, the Survey Report made no attempt to quantify the effectiveness of the sampling effort. The results often include observations of only one individual of a given species in a given wetland, which is an indication that the sampling effort may have been inadequate to capture true species richness (Colwell and Coddington, 1994, as cited in Werner et al., 2007).

Next, consistent with literature on amphibians in a similar metacommunity of ponds and wetlands (e.g., Werner et al., 2007), the results of the amphibian survey indicated that natural variability plays an important role in the dynamics of amphibians at the IDNL. Werner et al. (2007) reported that pond hydroperiod, surface area, and forest canopy cover were the most important variables in determining the presence or absence of a species in each pond/wetland. As noted in the Survey Report, the presence or absence of fish in ponds/wetlands also greatly affects amphibians. This effect can occur not only via predation, as noted in the Survey Report, but also via selection of oviposition sites by adult amphibians (i.e., adults of some species avoid ovipositing in ponds/wetlands with fish).

In the context of this study, these natural variables are confounded factors that will tend to obscure any potential toxicological effects of elevated metals concentrations. NIPSCO has not attempted to control these confounded factors, and it is not surprising that correlations were low between metals concentrations and amphibian metrics using a univariate statistical approach in this multivariate system. Conclusions have been drawn exclusively from these very simplistic regression analyses, which are insufficient to support the conclusion quoted above. Considering our concerns regarding sampling effectiveness and the variability in this dynamic system, it's not clear that conducting a more detailed statistical analysis of these data would produce any more reliable conclusions.

We also note that the analyses provided do indicate possible impacts in the EW, based on Sorensen's Quantitative Index at all EW locations except EW-01. Results for the Shannon Index are similar. These results should not be entirely dismissed based on the results at EW-01, which are different from results in the rest of EW.

It has also been noted the lack of discussion regarding visual observations of frog abnormalities as a potential uncertainty associated with the multiple lines of evidence approach. EPA was present in the field during some survey work and also observed these abnormalities.

Appendix E, Final 2010 Amphibian Toxicity Study Report, Section 4.0, Uncertainties, Pages 19-20

55. A number of important uncertainties have been omitted from this discussion. One of the key uncertainties in the amphibian toxicity study is uncertainty about the relative sensitivity of the test species, *Rana pipiens*, in comparison to other amphibian species at the IDNL. No information about relative species sensitivity has been provided in either Appendix E or Appendix D (2010 Amphibian Toxicity Study Plan). The most useful information that we have found regarding relative species sensitivity of amphibians to metals is a book chapter by Birge et al. (2000), who conducted a series of toxicity tests with numerous chemicals and

amphibian species. As summarized by Birge et al. (2000), amphibian species sensitivity varied by metal. Relative to other amphibian species, *R. pipiens* was tolerant of mercury. For several other metals (e.g., cadmium, copper, selenium), *R. pipiens* was among the more sensitive species, but *R. pipens* LC50 (50% lethal concentration) values were 2-3 times greater than LC50s for some other species (including species present at the IDNL wetlands) (Birge et al., 2000). Considering these indications that other amphibian species may be more sensitive to some COPECs than *R. pipiens*, coupled with the fact that this assessment is of a federally protected area with special status species, this uncertainty is critical for risk assessors and managers to consider.

Another important uncertainty is related to the fact that the test exposure duration was relatively short, and only larvae were exposed. Review of tabulated data in Sparling et al. 2000 (as cited in the BERA) indicates that, for some chemicals, amphibian embryos may be more sensitive than tadpoles. For example, a study that exposed *R. pipiens* tadpoles to mercuric chloride reported an LC50 of 1,000 µg/L, but tests using the same chemical and embryos of the same species reported LC50s of 7.3-10 µg/L (refer to Table 7-6 in Sparling et al. 2000). Note that, in some amphibian species (e.g., leopard frog, spotted salamander), eggs are often deposited on, or sink to, bottom substrates.

Another important uncertainty in the conduct of amphibian toxicity tests is that dietary exposures of metals are not included in the tests.

Additionally, although the uncertainty section notes that sediment sample manipulation and water quality characteristics of the laboratory water used can alter the toxicity of sediments in the tests (in comparison to toxicity that might actually occur in the field), the text does not discuss the direction of these possible impacts. For example, will oxidation of sediments tend to increase or decrease metals bioavailability in the toxicity test? Was the water hardness in the lab water higher than in the site surface waters, thereby decreasing bioavailability in the toxicity tests?

56. The last sentence of this section states, "Laboratory toxicity studies with amphibians yield a highly conservative measure of potential risk". In light of the factors discussed above, it is not clear that these tests are "highly conservative", and appear to represent a significant level of uncertainty.

Appendix G, 2010 Plant Toxicity Study Report

57. We believe that the usefulness of the plant toxicity study is compromised by the poor survival observed in ISBSP-11 and ISBAD-10. As noted in the study report, it does seem clear that some factor(s) other than metals must be a major contributor to the poor survival observed in at least some of the locations. The study report states that the variability in survival and growth responses is likely

related to the test species' ability to adapt to the sandy wetland soils used in the tests. Ultimately, it is impossible to know whether any toxicity may have been observed if a plant species better suited to the site's soils had been used for this particular test (see attached study on IDNL vegetation). All that can be concluded from this study is that metals-related toxic effects could not be differentiated from effects that likely occurred due to soil type. As a result, the report's conclusions, "...there are no BGS-related impacts apparent to IDNL vegetation community", are overstated and fail to reflect the important limitations of this study. See also Specific Comment 65 below regarding analyte concentrations in the tested samples. This is another critical limitation of this study that should have been made transparent in the study conclusions.

58. The Plant Toxicity Study Report does not provide information to allow reviewers to determine whether the tested locations adequately represent the study areas in terms of contaminant concentrations. In general, it is advisable to conduct tests at locations that span the range of concentrations observed in the study areas. We reviewed data presented in Table 3 of the Plant Toxicity Study Report (i.e., measured chemical concentrations in the toxicity test soil samples) and Tables 3-1 and 6-2 of the BERA (i.e., maximum and exposure point concentrations reported for soil in the BERA). The results of this review are concerning, as it appears that none of the samples used in the toxicity tests had contaminant concentrations that were similar to the maximum concentrations or, even more importantly, the EPCs in the study areas. In some cases, the BERA EPCs were more than an order of
59. magnitude greater than the concentrations in the toxicity test samples. Results for a few chemicals in CBS and the EW are listed in the table below for illustration. In addition, comparison of the maximum soil concentrations used in the plant toxicity study with reference area concentrations provided in Table 6-2 of the BERA indicates that many of the maximum analyte concentrations are close to or even below the reference area concentrations (e.g., maximum CBS molybdenum in plant toxicity tests was 2.6 mg/kg; reference area EPC for molybdenum was 2.7 mg/kg).

Area	Analyte	Maximum Concentration in the Plant Toxicity Study Soil Samples (mg/kg)	Maximum Concentration from Table 3-1 of the BERA (mg/kg)	EPC from Table 6-2 of the BERA (mg/kg)
Central Blag Slough	Arsenic	2.6	34	9.9
	Cadmium	1.9	29.3	5.5
	Copper	3.5	63.4	25.4
	Molybdenum	2.6	694	145.2
Eastern Wetland	Arsenic	10.8	200	34.1
	Boron	15.9	253	47.4
	Copper	7.6	63.4	21.5
	Manganese	889	23,600	3,078
	Molybdenum	2.7	804	75.7

The lack of toxicity tests at the upper end of the concentration range detected at the site appears to be a major source of uncertainty in the risk assessment for plants.

60. Table 5 presents and Section 3.6 discusses results of the plant species surveys that were conducted within 20-ft x 20-ft areas immediately surrounding the toxicity study soil sample locations. The analysis of these data is very cursory in the Plant Toxicity Study Report, and the report simply notes that plant species with high coefficients of conservatism were present (or, in some cases, dominant) in study area and reference area locations with low *Lolium* and/or *Trifolium* survival. These plant survey data could be more useful, and may yield different results, if subjected to a more comprehensive analysis. As noted by Charles Morris during the meeting on June 23, 2011, a simple visual inspection of the data in Table 5 does suggest that there may be important differences between study area and reference area locations. For example, the common invasive species Autumn olive (*Elaeagnus umbellata*) was frequently observed in survey plots but was never observed in reference area plots. In addition, for each of the samples in the Reference Areas, CBS and EW, we calculated a mean coefficient of conservatism (Mean C) and a Floristic Quality Index (FQI) using equations and coefficients from Rothrock (2004, as cited in the BERA). Mean C results are tabulated below; FQI results were similar to Mean C results and are not tabulated here. We calculated values for the CBS and EW samples because metals concentrations are highest in these two areas.

Reference Areas		**Central Blag Slough**		**Eastern Wetland**	
Sample Number	Mean C	Sample Number	Mean C	Sample Number	Mean C
ISBAD-08	3.5	AOC10-SB03	2.8	AOC9-SB04	0
ISBAD-010	3.6	IDNL-SD05	1.9	IDNL-SD15	1.7
ISBSP-11	3.3	IDNL-SD09	3.0	IDNL-SO13	1.8

Clearly, based on the limited dataset that is available, the above table shows that Mean C values in the Reference Areas tend to be higher than values in CBS and, particularly, EW. These results indicate that important differences in the plant communities may exist between the CBS and EW communities and those in reference areas, and it is not appropriate to conclude that no effects are occurring at this time. Also, Table 5 presents only presence/absence data from the surveys, but it appears that data regarding the relative abundances of each species within each plot are also available. These data should have been presented in Table 5. Finally, note that the concerns regarding the limited concentration range in the tested sample locations are also applicable to these plant survey data. Any conclusions drawn from these data must be qualified by the fact that sampled locations had relatively low concentrations of metals in comparison to the soil EPCs used in the ERA.

61. It would be useful if Tables 1 and 2 included some measure of the variability around the mean (e.g., standard deviation or standard error) for each of the endpoints to give reviewers some indication of the variability among replicates for each sample. Based on a cursory review of Appendix D, it appears that variability among replicates for any given sample was often quite high. This information should have been discussed more specifically in the uncertainty section, which included a paragraph about precision.

Appendix I, Vein Clearing and Barren Soil Report

62. This report concludes that barren areas in the southern portion of CBS are linked to low pH. Although not stated in the conclusions section, the report also describes two NIPSCO-related historical sources that may have caused the low pH. The report also concludes that metals concentrations in soils and plants are not good predictors of vein clearing. However, cadmium and molybdenum are elevated in barren soil rooting zones compared with reference area soils, and slight elevations of the same metals were found in soils of vein clearing vegetation compared with non-vein clearing vegetation collected from CBS. The report conclusions are not clear regarding the possible linkage of vein clearing to low pH and the possible linkage of metals concentrations to barren soil areas. In addition, the report does not attempt to explore the possible effect of low pH on metals availability as a cause, or contributing cause, of barren soil and/or vein clearing. This interaction may be important and could have been appropriately explored through multivariate statistical analyses.

    In general, the presentation of the data makes it difficult to evaluate possible relationships between metals/pH and barren soil/vein clearing. It would have been very useful to present box-and-whisker plots for some of the key metals and pH. For example, a series of box-and-whisker plots (e.g., showing median, 5th percentile, 25th percentile, 75th percentile, 95th percentile values) could be presented on a single page for molybdenum, including one box-and-whisker plot for concentrations in each of the following media: barren soil, vein clearing soil, reference area soil, vein clearing dewberry tissue, non-vein clearing dewberry tissue, reference area dewberry tissue, and so on for other plants.

63. This report concludes that areas of barren soil and vein clearing comprise 1-2% of the total area in CBS, and that this area is sufficiently small to assume that population-level risks to plants are acceptable. The data and analyses included in this report do not adequately support this conclusion. It is important to recognize that barren soil is a very severe effect (i.e., 100% mortality of all plant species). If severe effects are present in small areas, one must also be concerned that less severe, unmeasured effects (e.g., reduced density, changes in species composition) may be occurring over larger areas. Results from the 2010 plant survey (Appendix G) are suggestive that species composition may also be

affected (see Specific Comment 66). Conclusions should be reconsidered in light of these important points.

Appendix L, Hazard Quotient Calculation Tables

64. We were generally unable to replicate and verify hazard quotient calculations because Appendix L tables are inadequately annotated to facilitate verification. Refer to Attachments 1 and 2 for examples of how risk calculations can be presented to allow reviewers to verify calculations. Also note that in these attachments, there is very little need for wet weight/dry weight conversions because ingestion rates (from USEPA 1993, as cited in the BERA) are given on a dry weight basis and literature-derived bioaccumulation factors are typically given on a dry weight basis.

65. Based on review of Table L-26, amphibian exposures have been calculated by multiplying surface water exposure concentrations by a Water Use Factor (WUF) of 0.25. This methodology is not technically sound. The TRVs used in the HQ calculations are derived based on short-term (i.e., typically 10 days or less) toxicity studies in which amphibian embryos or tadpoles are exposed to water. A WUF would only be needed if amphibians at the site are normally exposed to water for less time than the amphibians exposed in the toxicity tests used to derive the TRVs. Clearly, with test exposure durations of 10 days or less, that is not the case here. Additionally, all of the wetlands and ponds evaluated in this BERA hold water (in at least some years) for sufficient time for amphibians to complete their larval development. Consequently, risks calculated based on measured surface water concentrations (without the application of a WUF) accurately represent risks in years that are hydrologically favorable to amphibians. It might be appropriate to note that risks due to toxics will be lower in years that are unfavorable hydrologically, but it is not appropriate to apply a WUF that would result in underestimated risks in the wetter years.

III. References

Allard, P. et al. 2010. Recommendations for the development and application of wildlife toxicity reference values. Integrated Environmental Assessment and Management. 6:28-37.

Bechtel Jacobs Company. 1998. Biota Sediment Accumulation Factors for Invertebrates: Review and Recommendations for the Oak Ridge Reservation. BJC/OR-112. U.S. Department of Energy.

Birge, W.J., A.G. Westerman, and J.A. Spromberg. 2000. Comparative Toxicology and Risk Assessment of Amphibians. In: D.W. Sparling, G. Linder, and C.A. Bishop, editors. *Ecotoxicology of Amphibians and Reptiles.* Pensacola, Florida: SETAC Press. p. 727-791.

Lemly, A.D. 2002. Selenium Assessment in Aquatic Ecosystems: A Guide for Hazard Evaluation and Water Quality Criteria. Springer-Verlag. New York. Pages 21 through 23.

Schumacher, B.A. 2002. Methods for the Determination of Total Organic Carbon (TOC) in Soils and Sediments. U.S EPA, Office of Research and Development, National Exposure Research Laboratory. NCEA-C- 1282. www.epa.gov/esd/cmb/research/papers/bs116.pdf

USACE. 2000. Biota-Sediment Accumulation Factor Database. U.S. Army Corps of Engineers. http://el.erdc.usace.army.mil/bsafnew

USEPA. 2007. Guidance for Developing Ecological Soil Screening Levels. Attachment 4-1: Exposure Factors and Bioaccumulation Models for Derivation of Wildlife Eco-SSLs. OSWER Directive 9285.7-55. Office of Solid Waste and Emergency Response, Washington, D.C. Revised April 2007. http://www.epa.gov/ecotox/ecossl/SOPs.htm

USEPA. 2002. Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites. September 2002. EPA 540-R-01-003. OSWER 9285.7-41.

USEPA. 2000. Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment. Status and Needs. U.S. Environmental Protection Agency. EPA-823-R-00-001. February 2000. http://www.epa.gov/ost/cs/biotesting

USEPA. 1997. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments.* EPA 540-R-97-006. US Environmental Protection Agency, Edison, NJ.

Werner, E.E., K.L. Yurewicz, D.K. Skelly, R.A, Relyea, R.A., Amphibian species richness across environmental gradients. Oikos 116:1713-1725.

ATTACHMENT 1

Virignia Rail: Risk Calculations for Selected Analytes and Areas

Food Ingestion Rate (FIR)	0.00817	kg/day (dry wt)
Proportion Sediment in Diet	0.18	Based on data for western sandpiper (USEPA 1993, as cited in the BERA)
Sediment Ingestion Rate (SIR)	0.00147	kg/day (dry wt)
Dietary Composition	100%	Benthic Invertebrates
Body Weight (BW)	0.049	kg (wet wt) from Cornell Lab of Ornithology, www.allaboutbirds.org, accessed October 7, 2011
Area Use Factor	1	

Analyte	Sediment EPC[1] (mg/kg)	BSAF[2]	Benthic Invertebrate Prey Concentration (mg/kg dw)	Sediment Dose (mg/kg-d)	Prey Dose (mg/kg-d)	Total Dose (mg/kg-d)	Toxicity Reference Value[3] (mg/kg-d)	Hazard Quotient[4]
Central Blag Slough								
Cadmium	24.59	3.073	75.6	0.738	12.6	13.3	1.47	**9.1**
Chromium	19.42	0.468	9.09	0.583	1.52	2.10	2.66	0.79
Molybdenum	42.59	NA	NA	1.28	NA	NA	3.5	0.37
Eastern Wetland								
Arsenic	47.14	0.675	31.8	1.41	5.31	6.72	2.24	**3.0**
Boron	28.65	NA	NA	0.860	NA	NA	28.8	0.03
Chromium	20.98	0.468	9.82	0.630	1.64	2.27	2.66	0.85
Molybdenum	139.4	NA	NA	4.18	NA	NA	3.5	**1.2**
Selenium	4.304	2.5	10.76	0.129	1.79	1.923	0.29	**6.6**
Northwest Blag Slough								
Chromium	31.75	0.468	14.86	0.953	2.48	3.43	2.66	**1.3**
Mercury (using MeHg TRV)	0.658	2.868	1.89	0.0197	0.315	0.334	0.0064	**52**
Mercury (using inorganic Hg TRV)	0.658	2.868	1.89	0.0197	0.315	0.334	0.45	0.74
Molybdenum	73.64	NA	NA	2.21	NA	NA	3.5	0.63

[1] Sediment EPCs are from Table 6-2 of the BERA.

[2] Biota-to-Sediment Accumulation Factors (BSAFs) for cadmium, arsenic, chromium, and mercury are 90th percentile values from Bechtel Jacobs (1998). The BSAF for selenium is from Lemly (2002). All BSAF units are mg/kg dw tissue / mg/kg sediment. BSAFs for boron and molybdenum were not available from standard sources and prey doses were not calculated.

[3] TRVs are from Table 6-6 of the BERA. The methylmercury (MeHg) TRV is from Sample et al. (1996, as cited in the BERA) and is included to bracket the range of mercury risk.

[4] HQs for boron and molybdenum are based on incidental sediment ingestion only. HQs for these metals in the revised BERA should incorporate prey doses, which should be calculated based on measured, site-specific benthic invertebrate tissue residue concentrations (preferably) or BSAFs developed from a comprehensive literature review.

Equations:

FIR (kg/day dw) = $0.0582 * (BW)^{0.651}$ (from EPA 1993, as cited in the BERA)

ATTACHMENT 1

Virignia Rail: Risk Calculations for Selected Analytes and Areas

SIR (kg/d dw) = FIR (kg/d dw) * Proportion soil in diet
Benthic Invertebrate Prey Concentration (mg/kg dw) = Sediment EPC (mg/kg) * BSAF
Sediment Dose (mg/kg-d) = [Sediment EPC (mg/kg) * SIR (kg-d dw) * AUF]/BW (kg ww)
Prey Dose = [Prey Concentration (mg/kg dw) * FIR (kg/d dw) * AUF]/BW (kg ww)
Total Dose = Sediment Dose + Prey Dose
HQ = Total Dose/TRV

ATTACHMENT 2
American Robin: Risk Calculations for Selected Analytes and Areas

Food Ingestion Rate (FIR)[1]	0.01668 kg dw/day	[FIR (g dw/day) = $0.398*(BW)^{0.850}$ (from USEPA 1993 as cited in the BERA), converted to kg/day by dividing by 1,000]
Proportion Soil in Diet	0.104	From BERA Table 6-4
Dietary Composition	49%	Plants
	51%	Invertebrates
Soil Ingestion Rate (SIR)	0.00173 kg dw/day	[SIR (kg/d dw) = FIR (kg/d dw) * Proportion soil in diet]
Plant Ingestion Rate (IR_p)	0.00817 kg dw/day	[IR_p = FIR * 0.49]
Invertebrate Ingestion Rate (IR_i)	0.00850 kg dw/day	[IR_p = FIR * 0.51]
Body Weight (BW)	0.081 kg (ww)	from BERA Table 6-4
Area Use Factor	1	

Analyte	C_{soil} (mg/kg)	Soil-to-Plant BCF (dry wt basis)	C_{plant} (mg/kg dw)[2]	Soil-to-Earthworm BCF or Equation (dry wt basis)[3]	$C_{earthworm}$ (mg/kg dw)	Soil Dose (mg/kg-d)	Plant Dose (mg/kg-d)	Earthworm Dose (mg/kg-d)	Total Dose (mg/kg-d)	TRV (mg/kg-d)	HQ
	From Table 6-2	Site-Specific BCFs from Table 6-3	= C_{soil} * Soil-to-Plant BCF	From Eco-SSLs and Table 6-3	Based on equations in Soil-to-Earthworm BCF column	=(SIR*Soil EPC*AUF) /BW	=(IR_p*C_{soil} *AUF)/BW	=(IR_e*C_{soil} *AUF)/BW	=Soil Dose + Plant Dose + Earthworm Dose	From Table 6-6	=Total Dose /TRV
Eastern Wetland											
Arsenic	34.11	0.056	1.9	ln(Ce) = 0.706*ln(Cs)-1.421	2.92	0.730	0.193	0.306	1.23	2.24	0.5
Boron	47.4	34	1612	Ce = Cs * 0.144	6.83	1.01	163	0.717	164	28.8	**5.7**
Cadmium	1.055	6.0	6.33	ln(Ce) = 0.795*ln(Cs)+2.114	8.64	0.0226	0.639	0.907	1.57	0.290	**5.4**
Chromium	26.16	0.048	1.26	Ce = Cs * 0.306	8.00	0.560	0.127	0.841	1.53	2.66	0.6
Manganese	3078	0.96	2955	ln(Ce) = 0.682*ln(Cs)-0.809	106.6	65.9	298	11.2	375	179	**2.1**
Molybdenum	75.69	0.094	7.11	Ce = Cs * 0.144	10.9	1.62	0.718	1.14	3.48	3.50	**1.0**
Selenium	2.334	0.67	1.56	ln(Ce) = 0.733*ln(Cs)-0.075	1.73	0.0500	0.158	0.181	0.389	0.290	**1.3**
SWMU 14/15											
Arsenic	97.87	0.056	5.48	ln(Ce) = 0.706*ln(Cs)-1.421	6.14	2.10	0.553	0.645	3.29	2.24	**1.5**
Boron	87.67	34	2981	Ce = Cs * 0.144	12.6	1.88	301	1.33	304	28.8	**11**
Cadmium	2.985	6.0	17.9	ln(Ce) = 0.795*ln(Cs)+2.114	19.8	0.0639	1.81	2.07	3.94	0.290	**14**

[1] Note that this value was derived differently from, and is considerably greater than, the Total Dietary Intake of 0.138 kg diet dw/kg bw-d that was used in the BERA. The FIR given here, when divided by the robin's body weight, gives a dietary intake of 0.206 kg diet dw/kg bw-d).

[2] Literature-derived soil-to-plant BCFs were used for SWMU 14/15 in the BERA, but we used site-specific BCFs here to determine the impacts of this possible change on hazard quotients.

[3] BCFs from EPA's Eco-SSL guidance (Attachment 4-1) were used in preference to other literature-derived BCFs. For chemicals lacking Eco-SSL BCFs (i.e., boron, molybdenum), the values from BERA Table 6-3 were used, adjusted to dry weight basis (i.e., dry wt BCF = wet wt BCF / proportion solids = 0.023/0.16). In the revised BERA, site-specific measured earthworm concentrations should be used for molybdenum and boron, or a literature search should be conducted for earthworm BCFs for these metals.

ATTACHMENT 3

Central Blag Slough: Comparison of Soil-to-Plant Bioconcentration Factors (BCFs) and Plant Concentrations Determined Via Varying Methods

Table 1. Comparison of Soil-to-Plant BCFs (all units in [mg/kg plant dw] / [mg/kg soil])

Analyte	Eco-SSL BCF Equations[1]	Calculated Eco-SSL BCFs[2]	Literature-Derived BCFs Used by NIPSCO (from BERA Table 6-3)	Site-Specific BCFs (from BERA Table 6-3)
Aluminum	NA	NA	0.0040	0.036
Arsenic	$Cp = 0.03752 * Cs$	0.03752	0.038	0.056
Barium	$Cp = 0.156 * Cs$	0.156	0.16	0.79
Boron	NA	NA	4.0	34
Cadmium	$\ln(Cp) = 0.546 * \ln(Cs) - 0.475$	0.286	0.59	6.0
Chromium	$Cp = 0.041 * Cs$	0.041	0.041	0.048
Copper	$\ln(Cp) = 0.394 * \ln(Cs) + 0.668$	0.274	0.12	0.36
Lead	$\ln(Cp) = 0.561 * \ln(Cs) - 1.328$	0.0411	0.039	0.018
Manganese	$Cp = 0.079 * Cs$	0.079	0.079	0.96
Mercury	NA	NA	0.90	0.43
Molybdenum	NA	NA	0.25	0.094
Selenium	$\ln(Cp) = 1.104 * \ln(Cs) - 0.677$	0.532	0.67	NA

[1] From USEPA. 2007. Guidance for Developing Ecological Soil Screening Levels. Attachment 4-1: Exposure Factors and Bioaccumulation Models for Derivation of Wildlife Eco-SSLs. OSWER Directive 9285.7-55. Office of Solid Waste and Emergency Response, Washington, D.C. Revised April 2007.

[2] For BCF values that are dependent on soil concentrations, plant concentrations (Cp) were calculated first as described in the footnotes to Table 2 below. The BCFs were then calculated as $BCF = Cp/Cs$ based on the soil concentrations (Cs) and plant concentrations (Cp) listed in Table 2 below.

ATTACHMENT 3

Central Blag Slough: Comparison of Soil-to-Plant Bioconcentration Factors (BCFs) and Plant Concentrations Determined Via Varying Methods

Table 2. Comparison of Plant Concentrations[1] (all units in mg/kg dw)

Analyte	Soil Concentration[2]	Estimated Plant Concentrations Using Site-Specific BCFs	Estimated Plant Concentrations Using Eco-SSL BCFs[3]	Estimated Plant Concentrations Using NIPSCO's Literature-Derived BCFs	Estimated Plant Concentrations[4] (from BERA Table L-32)
Aluminum	3652	131	NA	14.6	18.42
Arsenic	9.897	0.554	0.371	0.376	0.097
Barium	NA	NA	NA	NA	NA
Boron	4.333	147	NA	17.3	9.85
Cadmium	5.534	33.2	1.58	3.27	2.34
Chromium	24.89	1.19	1.02	1.02	0.25
Copper	25.44	9.16	6.98	3.05	1.26
Lead	69.62	1.25	2.86	2.72	0.23
Manganese	286.4	275	22.6	22.6	54.13
Mercury	0.0659	0.0283	NA	0.05931	0.0043
Molybdenum	145.2	13.6	NA	36.3	1.70
Selenium	1.551	NA	0.825	1.04	0.11

[1] Except where oterwise noted, plant concentrations are calculated as Cp = Cs * BCF (using the applicable BCF from Table 1 above), where Cs = soil concentrations listed in this table.

[2] Soil concentrations listed here are the exposure point concentrations for Central Blag Slough, from Table 6-2 of the BERA.

[3] For cadmium, copper, lead and selenium, plant concentrations (Cp) were calculated according to the logarithmic equations given in Table 1 and using the soil concentrations (Cs) listed in Table 2.

[4] These concentrations were copied directly from Table L-32 of the BERA; it is unclear how these concentrations were calculated.

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March 15, 2013

Attached to EPA Area C BERA Comments

SUBJECT: United States Environmental Protection Agency (EPA) review of the August 2011 Report: Potential Impact of Fly-ash Groundwater Contamination on Vegetation of Cowles Bog, Indiana Dunes National Lakeshore (Report), prepared by Taylor University.

This Report documents the results of a preliminary two-fold research study conducted during the 2010-growing season on the effects of fly ash on the vegetation in the Cowles Bog area of the Cowles Bog Wetland Community Complex. Over the growing season, 34 observation sites were each visited three times to look for visible symptoms of heavy metal and nutrient toxicity in the wetland vegetation of Cowles Bog. Concurrently, a greenhouse experiment was conducted to determine the effects of varying concentrations of aluminum (Al), boron, (B), and molybdenum (Mo) on three wetland plant species. These three elements are commonly found in fly ash in elevated concentrations and have been found in elevated concentrations in the soils and groundwater of the study area.

The Report details symptoms of heavy metal and nutrient toxicity as including necrosis and marginal chlorosis in leaves from elevated Al, leaf tip and edge burn, necrotic spots in the leaf blade, and premature leaf drop and death from elevated B, and leaf malformations, golden-yellow discoloration of shoot tissue and inhibition of root and shoot growth from elevated Mo. Over the course of the study, the most frequently observed symptom in the plume area was leaf blade necrosis. However, symptoms of incomplete flowering, leaf tip burn and necrosis, necrotic spotting, chlorosis of the leaf blade and veins, marginal leaf curl, and purpling of the stem were observed in both the field observations and greenhouse experiments. In addition, qualitative inhibition of root growth was observed in all three plant species under all three nutrients.

The 2011 BERA, which was previously reviewed by EPA, had multiple lines of evidence pointing to uncertainties associated with the potential adverse risks to plants in the same study areas; Area C. In particular, the presence of barren soil was linked to low pH and elevated metals concentrations. For example, Mo concentrations in the barren soils were as much as 50 times greater than concentrations in the reference soils. In addition, important differences were apparent between the assemblages of plants in the impacted areas versus the reference areas. For example, the Mean C values for the Central Blag Slough and Eastern Wetland areas were lower than those in the reference areas. More specifically, more invasive species were found in the BERA survey plots than in the reference areas. Similarly, this Report documents a virtual *Typha latifolia* (cattail) monoculture in some areas of Cowles Bog. This fact coupled with the knowledge that the invasive cattail is inherently tolerant to elevated levels of heavy metals, such as B and Mo, points to this Report as yet another line of evidence suggesting that risks to plants in these areas are unacceptable and that negative impacts may be occurring. More specifically, it suggests that the elevated metal concentrations are impacting the plant community composition, leading to more invasive, pollution tolerant species at the site-related areas, as compared to reference areas.

In addition, EPA had several concerns with the plant toxicity study submitted as part of the BERA. One issue surrounded the lack of a wetland plant being included in the study and the possible implications that had on the non–wetland plants ability to perform in the study; i.e. non-wetland plants ability to grow in wetland soils. In addition, it was unclear whether the tested locations adequately spanned the range of concentrations observed at the site. In fact, it appeared that none of the samples used in the BERA toxicity tests had contaminant concentrations that were similar to the maximum concentrations or exposure point concentrations found in the study areas. In contrast, the Report subjected wetland species of plants to varying concentrations of contaminants. The maximum concentrations of B, 79 mg/L and Mo, 7.5 mg/L, applied in the Report study are substantially lower than the maximum concentrations of B, 253 mg/L and Mo, 804 mg/L, found in the Eastern Wetland as part of the BERA. Even with these lower contaminant concentrations, the Report found that B toxicity was uniformly expressed both in qualitative as well as quantitative measures of plant response across the range of concentrations. Mo and Al also exhibited toxicity qualitatively, but were less uniform across the range of concentrations and quantitative measures. Given these substantial negative effects were observed on plants more representative of those found at the site and given those plants were exposed to contaminant concentrations much lower than those observed at the site, this Report again suggests more negative effects are occurring at the site than are proposed in the BERA study.

Overall, this Report and its conclusions add to the already abundance of uncertainty associated with the potential ecological risks in Area C. Furthermore, it adds to the already numerous lines of evidence suggesting that risks that are unacceptable and negative impacts to ecological receptors may be occurring.

REPORT: Potential Impact of Fly-ash Groundwater Contamination on Vegetation of Cowles Bog, Indiana Dunes National Lakeshore.

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August 2011

ON THE COVER

Clockwise from top left: *Iris virginica* var. *shrevei* Cowles Bog site 5 (7/26/2010) with necrotic spotting, margin and tip burn on the leaves; *Asclepias incarnata* Cowles Bog site 5 (8/22/2010) with severe purpling of the leaf, necrotic spotting and margin burn; *Cephalanthus occidentalis* Blag Slough site 34 (8/22/2010) with pronounced chlorotic splotching; *Carex sp.* Cowles Bog site 3 (8/22/2010) with yellowing and necrotic spotting in all areas of the leaves.

CONTENTS:

INTRODUCTION:

Fly ash is a specific concern in the Cowles Bog Wetland Community Complex (CBWC) due to its composition, which includes silica oxides, aluminum, iron, and calcium along with trace elements such as boron and molybdenum (Wilcox and Hardy, 1988; Theis et al. 1978). The research in this report focuses on the potential effects that fly ash waste discharges from the Bailly Electrical Generating Station coal-fired power plant are having on the wetland vegetation of the CWBC. The Bailly power plant came online in 1963 and deposited its fly ash waste into drying ponds, which are separated from Blag Slough in the southwest of the CBWC by a sand dike. The drying ponds were left unsealed until 1980, at which time the direct flow of fly ash into the CBWC was halted (Pavlovic, 2009).

The CBWC is a mixture of various wetland and peatland communities, which occupy approximately 80-ha of the basin between the Calumet and Tolleston dunes on the southern shore of Lake Michigan in Porter County, Indiana (Reshkin, 1981). Eight vegetative communities have been identified within the CBWC, which are: a black oak (*Quercus velutina*) woodland; red maple (*Acer rubrum*) swamp; cattail (*Typha*) marsh; *Carex/Calamagrostis* marsh, a *Thuja occidentalis* swamp; (Tamarack) *Larix laricina* swamp; *Phragmities/Typha* marsh, and a shrub swamp (Wilcox et al. 1986).

Cowles Bog, the area of primary concern, is an approximately 22-ha fen located within the CWBC and has its water source of highly mineralized, artesian flow of ground water (Wilcox et al. 1986). According to recent testing, the southwest corner, due to its proximity to the Bailly Electrical Generating Station coal-fired power plant and the sand dike that separates the fly ash drying ponds from Cowles Bog, is considered a plume area where elevated levels of aluminum, boron, and molybdenum have been detected.

Preliminary two-fold research was undertaken to determine whether there is sufficient evidence to warrant further investigation of the effects of fly ash on the vegetation in the CBWC.

The first part of the study was conducted during the 2010-growing season. Over the growing season 34 observation sites were each visited three times to look for visible symptoms of heavy metal and nutrient toxicity in the wetland vegetation of Cowles Bog. Concurrently, a greenhouse experiment was conducted to determine the effects of varying concentrations of aluminum, boron, and molybdenum, which are elements commonly present in fly ash waste in elevated concentrations, on three native wetland species *Asclepias incarnata*, *Carex aquatilis*, and *Iris virginica*.

SITE HISTORY:

In 1963, Northern Indiana Public Service Company (NIPSCO) brought online a coal-fired power plant southwest of Cowles Bog to provide electricity to a steel mill being constructed by Bethlehem Steel Corporation (Pavlovic et al. 2009). Electrostatic precipitators, scrubbers, are routinely placed in smokestacks to collect fly ash from the gas stream to prevent much of the fly ash from entering the atmosphere (Wilcox and Hardy, 1988; Theis et al. 1978). The resulting fly ash waste, however, is mixed with water to form slurry that is then piped into settling ponds to dry out before being hauled away (Wilcox and Hardy, 1988).

From 1963 to 1978, the fly ash ponds were left unsealed and leachate from these ponds seeped into Blag Slough, a wet meadow immediately west of Cowles Bog and closest to the Bailly Electrical Generating Station fly ash ponds, through the sand dike at a rate of about 7.5 million liters per day (1.97 million gallons/day for ~ 17 years) until the ponds were completely sealed in 1980 (Pavlovic et al. 2009). Throughout the mid-70s studies were conducted on the hydrology, topography, stratigraphy, and water chemistry of CBWC. A hydrologic study by Meyer and Tucci (1978) provided evidence that ground water seepage from the fly ash pond was responsible for the regular flooding of Blag Slough. This seepage increased levels of calcium, potassium, sulfate, aluminum, boron, iron, magnesium, molybdenum, nickel, strontium, and zinc in ground- and surface water down gradient from the settling ponds (reviewed by Wilcox and Hardy, 1984).

A 1986 study examined the implications of seepage from fly ash settling ponds. This study concluded the seepage raised the water levels in the wetlands of the CBWC and posed a threat of contamination from chemical constituents that leached from the fly ash (Wilcox et al. 1986). A 2009 study examined the water and soil chemistry of Blag Slough for locations of toxicities, the implications these toxicities have had on the vegetative community development over time, and concluded that natural revegetation has taken place in the 23 year period of the investigation as pH levels have increased. However, areas with elevated heavy metal concentrations remain unvegetated and areas with elevated Al and B concentrations in the soil have vegetation suggesting phytotoxicity with symptoms of vein clearing and chlorosis (Pavlovic et al. 2009).

PART 1 – FIELD OBSERVATIONS:

2010 Field Observation Methods

Prior to beginning field observations, a literature search was conducted to determine commonly reported symptoms of aluminum, boron, and molybdenum. One prevalent symptom of heavy metal toxicity is the inhibition of root growth (Wong and Bradshaw, 1982), which can damage the root system and limit nutrient and water uptake into the plant (Gregory, 2009; Poozesh et al. 2007; Zhang et al. 2007). Observing this symptom was not practical for this field study; however, it was a focus of the greenhouse experiment (part 2). Aluminum toxicity symptoms include necrosis and marginal chlorosis in leaves (Roy et al. 1988), boron toxicity symptoms include leaf tip and edge burn (Brown and Hu, 1998), necrotic spots in the leaf blade (Sotiropoulos et al. 2002), and premature leaf drop and death (Goldberg, 1993), and molybdenum toxicity symptoms include leaf burning, and yellowing of the leaves (Gupta and Gupta, 1998) and an inhibition of root/shoot growth (Kevresan et al. 2001).

ARC View/GIS version 9.3 (ESRI) was used to apply a grid of 30-meter squares over a 2005 aerial image (Indiana Spatial Data Portal) of each wetland to be visited. In Cowles Bog, the area of interest was limited to the southwestern margin, extending from the upland transition to a distance of 60 m into the wetland. Each intersection on the grid was numbered and 30 observation sites, all of which were randomly chosen with a random number generator (random.org). Four targeted sites were chosen in addition to the 30 random observation sites.

In Cowles Bog there were a total of 19 observation sites, including all four targeted sites. Two targeted sites were in the southwest corner of Cowles Bog in the plume area of concern. An additional two targeted sites were in the northeast corner of Cowles Bog, distant from potential contamination but of similar habitat. The 15 observation sites that remained were located outside of Cowles Bog. Three observation sites were in Blag Slough, seven observation sites were in the wetland between Cowles Bog and Blag Slough, one observation site was in the small wetland west of Cowles Bog, one observation site was in the small wetland to the north of Cowles Bog, and the final three observation sites were in the larger wetland, still further north. These final four observation sites along with the targeted sites from the northeast corner of Cowles Bog were used as control sites because of their distance and disconnectedness from the plume area (Figure1) (Appendix A).

ARC/GIS was used to determine the approximate latitude and longitude for the 34 observation sites. The first of three visits was made on June 16, 2010 and a GPS unit was used to locate each proposed observation site. When a site was located it was flagged for precise relocation. The lat/long location was used as the center of the site and dominant vegetation was noted. Depending on the position of an individual observation site, a radius of approximately five meters was surveyed for visible symptoms of toxicity and documented photographically, if recognized. All attempts were made to locate each randomly chosen observation site. However, a site was discarded if the observation site was located entirely in open water or in an upland position, in these instances the next randomly generated site was used.

Field Results and Discussion

Symptoms of aluminum toxicity include necrosis and marginal chlorosis in leaves (Roy, 1988); boron toxicity symptoms include leaf tip and edge burn (Brown and Hu, 1998), necrotic spots in the leaf blade (Sotiropoulos et al. 2002), and premature leaf drop

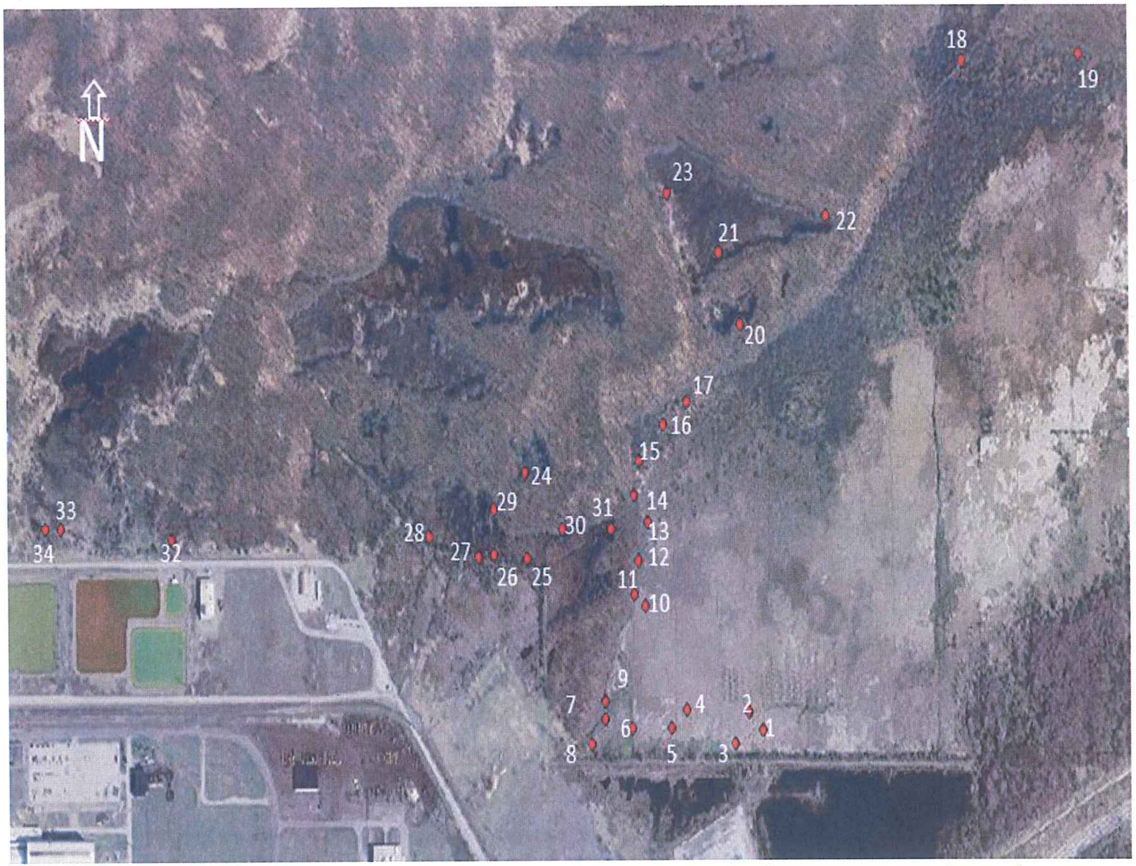

Figure 1. Observation Site Map in the Cowles Bog Wetland Community Complex

and death (Goldberg, 1993); and molybdenum toxicity symptoms include leaf malformation, golden-yellow discoloration of shoot tissue, and inhibition root and shoot growth (Hamlin, 2007; Marschner, 1995). However, there are two potential problems with regard to recognizing symptoms of toxicity *in situ*. The first problem is that any natural environment, but arguably wetland ones in particular, will exert stresses on resident plant species. As a result, even vegetation in sites with maximum biotic integrity can often exhibit at least limited leaf necrosis, chlorosis, or misshapen structures. Additionally, root inhibition is a symptom that is impractical to observe in the field. The second problem is that many plant species exhibit similar visible symptoms to multiple problems and determining if the symptom being seen is, for example, a symptom of aluminum toxicity or a symptom of calcium, phosphorous, or iron deficiency, becomes less clear. The symptoms being witnessed may be the result of a nutrient deficiency, a nutrient toxicity, or the result of other naturally occurring stressors.

With the above limitations in mind, some observed symptoms could readily be eliminated by noting that they occurred in the same species in sites both near to and far from the plume area. For example, leaf burn and necrosis in *Symplocarpus foetidus*, was seen at site 14 (near to plume area) and site 18(far from plume area) (Figures 2 & 3), *Ilex verticillata* at site 14 and site 18 (Figures 4 & 5), and *Cephalanthus occidentalis* at site 16 (near) and site 19 (far)(Figures 6 & 7). These symptoms obviously were equivocal and were discarded. However, if a symptom was observed in the plume area, without being observed in the same plant species at one of the six control sites (sites 18-23), it was assumed to be a potential symptom of toxicity.

The most frequently observed symptom in the plume area was leaf blade necrosis. At observation sites 3, 5, 6, 7, 8, and 9, which were in the plume area of Cowles Bog, necrosis was present in a variety of species. At site 5 *Scirpus pungens* (Figure 8), *Iris virginica* (Figure 9), *Epilobium coloratum* (Figure 10), *Asclepias incarnata* (Figures 11 & 12), and *Verbena hastata* (Figures 13 & 14) were recognized as exhibiting necrotic spotting, chlorosis, and leaf burn. At site 3 *Schoenoplectus tabernaemontani* (Figure 15), *Sagittaria latifolia* (Figure 16), *Alisma subcordatum* (Figure 17), *A. incarnata* (Figure 18), and *Pontederia cordata* (Figure 19), at site 6 *Rumex* sp. (Figure 20) and *Persicaria* sp. (Figure 21), at site 7 *Scirpus cyperinus* (Figure 22) and *Eupatorium perfoliatum* (Figure 23), at site 8 *Sparganium eurycarpum* (Figure 24) and at site 9 *S. tabernaemontani* (Figure 25) were observed as having symptoms of toxicity. Over the course of the three visits necrosis was persistent but did not appear, in any individual plant, to worsen over time. Outside of Cowles Bog, sites 32-34 in Blag Slough displayed a splotchy leaf chlorosis on *Cephalanthus occidentalis* (see the cover of this Report) and to a more limited extent *Lycopus sp.* and *Pilea pumila.* Although sites 25-28 are proximal to the plume area, apparent toxicity symptoms were not observed. These sites are dominated by *Phragmites australis,* a clonal invasive species. This species, as well as another clonal invasive species, *Typha latifolia*, exhibits a remarkable capacity to tolerate heavy metal contamination (Ye et al. 1997a, 1997b). This capacity may explain the lack of visible symptoms at sites 25-28.

In summary, over the three visits made during the 2010-growing season to the CBWC evidence of potential heavy metal contamination in the vegetation was observed, especially in the southwest corner of Cowles Bog. The greenhouse experiment (part 2 of this report) showed that elevated levels of aluminum, boron, and molybdenum, similar to those observed at CBWC, have significant, deleterious effects on the growth of three native wetland species *A. incarnata, C. aquatilis,* and *I. virginica*. Furthermore, the symptoms witnessed in the greenhouse were frequently witnessed in the plume area vegetation. Additional study of the vegetation of the CWBC, including whether plant tissues are accumulating elevated levels of aluminum, boron, and/or molybdenum, is warranted.

Figure 2.—*S. foetidus* (Site 13, near plume)

07/25/2010 13:10

Figure 3.—*S. foetidus* (Site 18, far from plume)

07/25/2010 10:49

Figure 4.—*I. verticillata* (Site 14, near plume)

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Figure 5.—*I. verticillata* (Site 18, far from plume)

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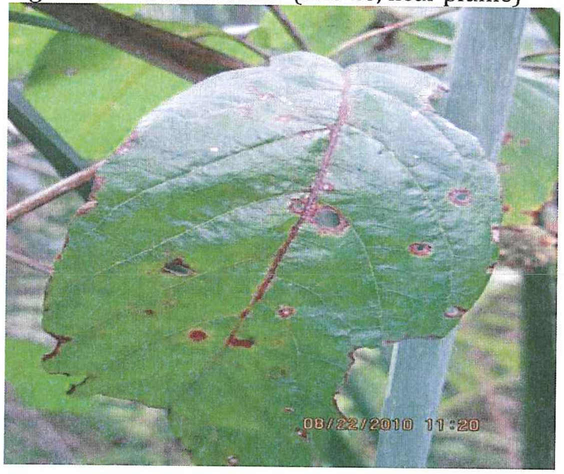
Figure 6.—*C. occidentalis* (Site 16, near plume)



08/22/2010 11:20

Figure 7.—*C. occidentalis* (Site 19, far from plume)

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Figure 8.—*S. pungens* (Site 5)

Figure 9.—*I. virginica* (Site 5)

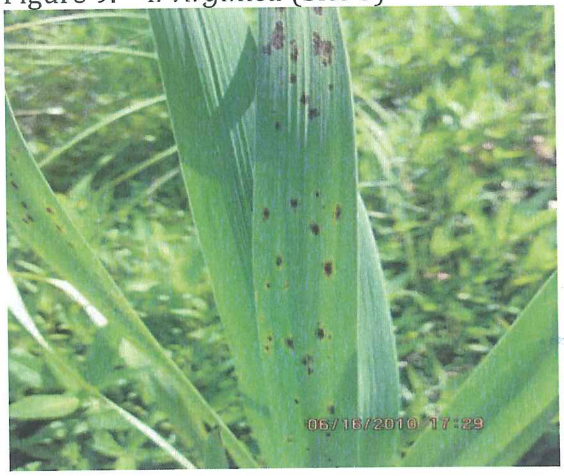


Figure 10.—*E. coloratum* (Site 5)

Figure 11.—*A. incarnata* (Site 5)

Figure 12.—*A. incarnata* (Site 5)

Figure 13.—*V. hastata* (Site 5)

Figure 14.—*V. hastata* (Site 5)

Figure 15.—*S. tabernaemontani* (Site 3)

Figure 16.—*S. latifolia* (Site 3)

Figure 17.—*A. subcordatum* (Site 3)

Figure 18.—*A. incarnata* (Site 3)

Figure 19.—*P. virginica* (Site 3)

Figure 20.—*Rumex sp.* (Site 6)

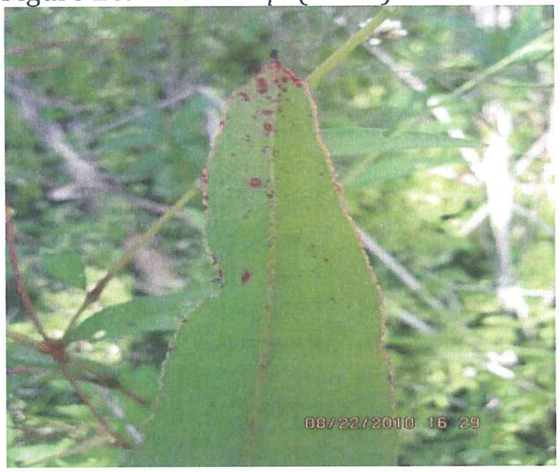


Figure 21.—*Persicaria sp.* (Site 6)

Figure 22.—*S. cyperinus* (Site 7)

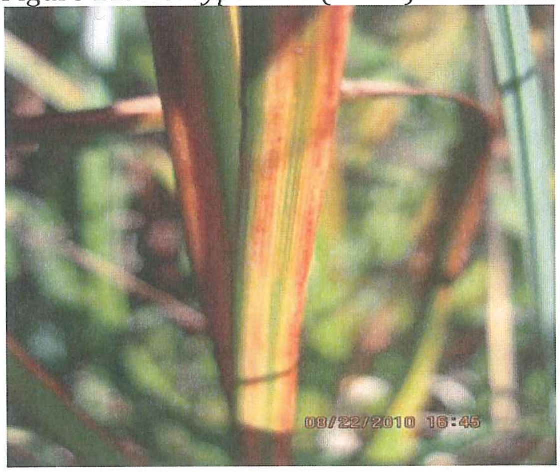


Figure 23.—*E. perfoliatum* (Site 7)

Figure 24.—*S. eurycarpum* (Site 8)

Figure 25.—*S. tabernaemontani* (Site 9)

PART 2 – GREENHOUSE EXPERIMENT AND EFFECTS OF Al, B, AND Mo:

Experiment Summary

Aluminum (Al), Boron (B), and Molybdenum (Mo) have been found in potentially toxic levels in the fly ash produced by coal-fired power plants. Varying concentrations of Al, B, and Mo were applied to three wetland plant species, *Asclepias incarnata, Carex aquatilis*, and *Iris virginica*. Plants were grown in a washed sand medium and received a modified Hoagland's solution every other day. Three concentration levels of Al (9 mg, 18 mg, and 27 mg/L), four concentration levels of B (14 mg, 26 mg, 47 mg, and 79 mg/L), and three concentration levels of Mo (2.5 mg, 5.0 mg, and 7.5 mg/L) were added as treatments. All three plant species showed visible symptoms of toxicity such as leaf tip necrosis and marginal leaf curl; the most severe and widespread occurring with the B treatments. Visual observations in the greenhouse revealed necrotic spotting in the leaf blade in most B treatments and highest Al concentration as early as day 15. Inductive Coupled Plasma Mass Spectrometry (ICP-MS), performed on the aboveground plant material of *A. incarnata* and *I. virginica*, indicates increasing boron uptake with concentration. While quantitative measures showed inhibition for all three species and nutrients, *Asclepias incarnata* was especially sensitive to B applications.

Literature Background

Minimal research has been conducted to determine at what concentrations constituents of fly ash may become toxic to and how they affect native wetland vegetation. Coal mines, whether active or abandoned, are significant sources of metal contamination and discharges (Batty et al. 2002). In addition, the burning of coal in electrical generation power plants can be a major source of heavy metal contamination, in particular aluminum, boron, and molybdenum (Wilcox and Hardy, 1998).

Vegetation can respond in one of three ways to increasing concentrations of heavy metals in the soil. Some are considered accumulators, which are species that accumulate and concentrate metals in the aboveground tissues. Others are called indicators, where internal concentrations reflect the external environment, a third group are excluders, which are plants that have shoot concentrations low in heavy metals and remain constant over many soil concentrations up to a critical soil level above which unrestricted transport, the point at which the plant can no longer prevent metals from entering, takes place (Baker, 1981).

Elemental uptake by wetland plants varies among species and is related to rooting depth and plant life form (Weis and Weis, 2004). In general, the inhibition of root growth is one of the most rapid responses to toxic concentrations of a heavy metal (Wong and Bradshaw, 1982). Trace elements often show an order of magnitude greater concentration in roots than in shoots. Boron is one exception. Boron is a passive mover throughout the transpiration stream and accumulates in the aboveground tissue, especially the leaves (Supanjani, 2006).

Aluminum. Soils contain, on average, 7 – 8% Aluminum (Al) and under acidic conditions Al becomes solubilized, increasing its mobility (Batty et al. 2002) and availability to plants (Miyasaka et al. 2007; Delhaize and Ryan, 1995; Rout et al. 2001; Abdalla, 2008). Runoff from coal stockpiles and coal-fired power plants are acidic and contain high levels of Al (Collins et al. 2004). High levels of Al in the soil can become a major limiting factor for plant production (Delhaize and Ryan, 1995).

Attempts have been made to establish critical Al concentrations for toxicity in plants (Foy, 1998). However, plant species respond in different ways to Al toxicity. Some plants have the ability to accumulate large amounts of Al in their foliage without any visible evidence of injury (Rout et al. 2001). However, Al toxicity also can induce deficiencies of other nutrients. Al toxicity can reduce the accumulation of calcium (Ca) in plant tissue to a level that Al toxicity resembles Ca deficiency (Rengel, 1992). Reduced Ca transport is expressed as curling of young leaves and collapse of petioles (Rout et al. 2001; Foy, 1984).

Al toxicity also can induce an iron (Fe) deficiency, which is expressed as chlorosis, and phosphorous (P) deficiency, which produces overall stunting, production of small dark green leaves and late maturity, purpling of the stem, leaf vein, and yellowing of leaf tips (Rout et al. 2001; Foy, 1998).

Al commonly accumulates in the roots in greater concentrations than in the shoots (Collins et al. 2004). The first, observable symptom of Al toxicity is the inhibition of root elongation (Miyasaka et al. 2007; Rengle, 1992; Roy et al. 1988; Delhaize and Ryan, 1995; Rout et al. 2001; Mossor-Pietraszewska, 2001). This inhibition damages the root system, limiting both nutrient and water uptake to the plant (Gregory, 2009; Poozesh et al. 2007; Zhang et al. 2007). Symptoms of Al toxicity can occur within hours of exposure (Miyasaka et al. 2007) and symptoms include stunted root growth, reduction in root hair development, and, swollen root apices (Matsumoto, 2002); in some cases, roots can become thickened and brown (Rout et al. 2001).

At the cellular level Al interferes with cytoskeleton structure and function, disrupts calcium homeostasis, phosphorous metabolism, and can cause oxidative stress (Miyasaka et al. 2007). Aluminum toxicity in leaves results in increased diffusion resistance, reduction of stomatal aperture, decreased photosynthetic activity, total decrease of leaf number and size, and a decrease of shoot biomass (Mossor-Pietraszewska, 2001). As a result, young leaves become small, curved along the margin and chlorotic and older leaves have marginal chlorosis (Roy, 1988).

Boron. Boron (B), an essential micronutrient (Gupta, 2007), is required for plant growth (Goldberg, 1993; Supanjani, 2006; Hu and Brown, 1997). Therefore, B is necessary in a continuous supply throughout the life of the plant and uptake is primarily through the roots. The species of B absorbed from the soil solution by the roots is often boric acid $B(OH)_3$ (Hu and Brown, 1997). Boric acid is a weak monobasic acid that acts as an electron acceptor (Gupta, 2007) in aqueous solution (Hu and Brown, 1997; Nable et al. 1997). Boron can become toxic in elevated concentrations (Miwa et al. 2007) and inhibit plant growth and development (Redington and Peterson, 1983).

Boron toxicity can occur when soils: 1) are naturally high in B, 2) are over-fertilized with minerals high in B, 3) receive fossil fuel combustion residues, which are produced from the burning of coal for electricity, or are used as disposal sites for waste materials containing B, such as fly ash and industrial chemicals (Nable et al. 1997) and 4) when irrigated with water high in B (Leyshon and James, 1993). Fly ash is of particular concern because of the high concentrations of B in fly ash may be readily available to plants and can prevent the establishment of vegetation on contaminated areas (Nable et al. 1997, Piha et al. 1995), especially during the first growing season (Wong and Bradshaw, 1982).

Plants vary in their B requirement, but the range of essential and toxic levels is smaller than for any other nutrient element (Goldberg, 1993; Reid et al. 2004). Research by Gupta et al. (1985) showed that boron is required in low concentrations for plant growth and becomes phytotoxic at concentrations only slightly higher than the optimal range (Sartaj and Fernandes, 2005). Boron is known to be a passive mover in plants (Supanjani, 2006). The amount of B taken up by the roots and transported to the shoots is related to the rate of transpiration (Sotiropoulos et al. 2002; Raven et al. 1980).

Studies have demonstrated that the mobility of B can vary dramatically between species (Brown and Hu, 1988). Boron enters the transpiration stream via the roots and tends to accumulate at the sites of termination in leaves (Brown and Hu, 1998; Nable et al. 1997; Reid et al. 2004; Sotiropoulos et al. 2002; Raven, 1980). In species where B is immobile toxicity symptoms always are exhibited as leaf tip and edge burn (Brown and Hu, 1998).

However, in species where B is mobile toxicity is exhibited as die back in young shoots rather than marginal leaf burn (Brown and Hu, 1998). Boron immobility is evidenced by elevated B concentrations in older leaves. Elevated B concentrations in younger leaves are an indication of B mobility because they have transpired less water than older leaves young leaves (Brown and Hu, 1998).

Boron does not accumulate evenly in leaves and typically concentrates in leaf tips of monocots and leaf margins of dicots. This is where toxicity symptoms typically first appear (Gupta, 2007; Kohl Jr. and Oertili, 1961). In general, B concentrations are lower in plant stems (Gupta, 2007). Soil pH influences the availability of B to plants and becomes less available as pH increases (Gupta, 2007; Hu and Brown, 1997). Furthermore, B toxicity can produce necrotic spots in the leaf blade (Sotiropoulos et al. 2002), marginal and tip chlorosis (Gupta, 2007), leaf burn (Nable et al. 1997), interveinal chlorosis, premature leaf drop, and plant death (Goldberg, 1993).

Molybdenum. Molybdenum (Mo) is an abundant essential micronutrient found in most plant tissues. Gupta and Lipsett (1981) concluded that the allocation of Mo throughout plant organs varies with the plant species, but generally the concentration is highest in the seeds. The concentration level considered toxic differs from plant to plant but dicots are typically more sensitive than monocots (Hamlin, 2007). However, Mo can reach toxic levels in the soil with applications of municipal sewage sludge or in soils near mining and smelting activities (Gupta, 1998).

The availability of Mo is tied to soil pH; therefore, Mo is more available at higher pH and less available at lower pH (Kaiser et al. 2005; Gupta, 1997). Under acidic soil conditions the molybdate anion is strongly adsorbed to the surface of Fe and Al oxides (Smith et al. 1997) and this adsorption is greatest at pH 4.0 (Keddy et al. 1997). Another factor in Mo availability is soil moisture. Poorly drained soils can accumulate high quantities of available MoO_4^{2-} (Gupta, 1998). However, the majority of plants tested are not particularly sensitive to excessive levels of Mo in the soil medium (Hamlin, 2007). Symptoms of Mo toxicity in plants include: burning, chlorosis and yellowing of leaves (Gupta, 1998) and an inhibition of root/shoot growth (Kevresan et al. 2001).

Greenhouse Experimental Methods

A total of 468 plants of three native species, *A. incarnata*, *C. aquatilis*, and *I. virginica*, were grown in approximately 38 cubic inch pots. Plants were organized into 13 groups, which were randomly organized on two greenhouse benches, and 12 of each species were organized randomly within each group. Washed sand was used as the growing medium. Immediately after transplanting was complete a modified Hoagland's solution was applied. The modified Hoagland's solution consisted of 940 ml of distilled water, 10 ml magnesium sulfate ($MgSO_4$) 0.14 M, 10 ml potassium nitrate (KNO_3) 0.17 M, 10 ml potassium hydrous phosphate (KH_2PO_4) 0.12 M, 10 ml iron ethylenediaminetetraacetic acid (Fe EDTA), and 10 ml calcium nitrate ($Ca(NO_3)_2 \cdot 4H_2O$) 0.10 M (Hoagland and Aron, 1950). The typical trace elements were omitted from the Hoagland's solution. The trace element solution was omitted because varying concentrations of boric acid, molybdic acid disodium salt dihydrate were applied as treatments. Aluminum chloride ($AlCl_3$) also was applied to the plants in this experiment but is not part of the Hoagland's solution.

Prior to the start of the experiment plants were treated with 50 ml of modified Hoagland's solution every other day for five weeks, daily if plants looked stressed, to ensure that the plants recovered from transplant shock and to allow time for the plants to begin regular production of new vegetative and root growth.

Plants were sorted into ten groups of 36, 12 plants of each of species. Treatment levels of Al, B, and Mo were applied every other day for 60 days. The concentrations were: Al = 9, 18, 27 mg/L; B = 14, 26, 47, 79 mg/L; Mo = 2.5, 5.0, 7.5 mg/L. There were 108 plants, (36 of each species), set aside as controls. Among the control plants, 36 (12 of each species) received Hoagland's solution and distilled water with pH reduced to 4.8. This was to provide a control group for the Al treatments where natural acidity ranged was approximately 4.8. Concentrations of Al, B, and Mo were gradually elevated to the treatment levels over a 13-day period. Due to apparently random plant loss during the course of the experimental period, final sample sizes ranged from 10-12. In addition, two individuals of *A. incarnata* were deleted from Mo concentration 2 since they were notably more robust before first measurements on day 28.

First growth measurements were taken on day 28 of the experiment. Stem height, number of leaves and branches, and total combined length of all branches were the measurements taken for *A. incarnata*. The number of shoots, number of leaves with a sheath greater than 2 cm, and length of longest leaf were measured for *C. aquatilis*. The number of leaves greater than 2 cm, length of longest leaf, number of dead leaves, and length of shortest leaf were recorded for *I. virginica*. The measurements were again recorded on day 42, and for the final time on day 58. On day 61 all of the plants were removed from their pots and root lengths, length of longest root, and photographs were taken.

After roots were measured and the plants photographed, the plants were dried at 120° F in a heated drying closet for four days and dry weights of roots and shoots, including leaves, were recorded. Data was analyzed with ANOVA for its ability to show if there are significant differences between pairs of groups. However, ANOVA cannot show which pairs are significantly different. Therefore, Tukey's Post Hoc tests were performed on measured variables against concentrations of an individual treatment to determine which groupings, if any, had significant differences. The critical p-value, or alpha, used was 0.05.

Normalization, by using the natural log, of the data was necessary on root weight, stem weight, and total weight for *C. aquatilis* and *I. virginica* with Al and Mo treatments, all three plant species for B, and stem weight only for *A. incarnata* with Mo treatments. As well, root length and length of the longest root for *C. aquatilis* with B treatments and *I. virginica* with B and Mo treatments required normalization.

Columbia Analytical Services in Seattle, WA, performed Inductive Cold Plasma Mass Spectrometry (ICP-MS) on aboveground tissue samples. ICP-MS was used to analyze boron content of 24 plant samples. Three samples were taken from the *A. incarnata* control group and three samples also were taken from each of the four boron treatment levels of *A. incarnata*. Three samples were taken from the *I. virginica* control group as well as from the B treatment levels 2 and 4 of *I. virginica*. Sample sizes of 0.5 - 1.3 grams were required from the plants above ground tissue for each sample. Tissue samples from as many as five plants were bulked within treatment type in order to obtain these sample amounts. Boron was the focus of this test because it was the nutrient whose specimens were exhibiting the majority of and most severe symptoms of toxicity and this test would provide further evidence for whether or not these symptoms could be attributed to the addition of the boron treatments.

Results from Greenhouse Experiment

Qualitative Observations: Qualitative inhibition of root growth was observed in all three plant species under all three nutrients (Figures 26-30; 38-55). The roots of *I. virginica* were particularly thickened and turned brown (Figure 31) at the lowest Al concentration. Leaf tip and edge burn were produced in *A. incarnata* and *I. virginica* (Figures 32 & 33) at the lowest concentration of B. Other symptoms of B treatment included necrotic spots on the leaf blade (Figures 34 & 35) and premature leaf drop (Figures 36 & 37).

Figure 26.—*A. incarnata* roots (Control)

Figure 27. —*A. incarnata* roots (Control pH)

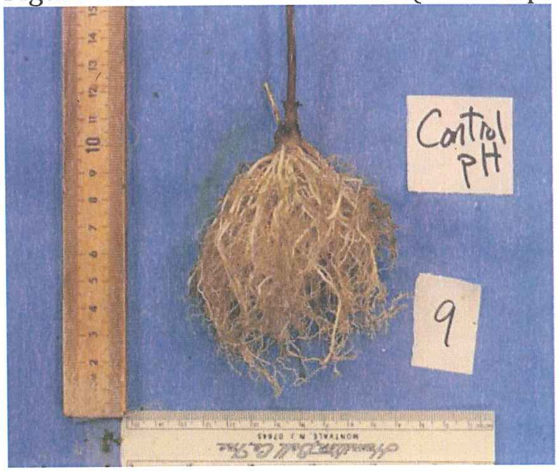


Figure 28. —*A. incarnata* roots (B1)

Figure 29. —*A. incarnata* roots (Mo1)

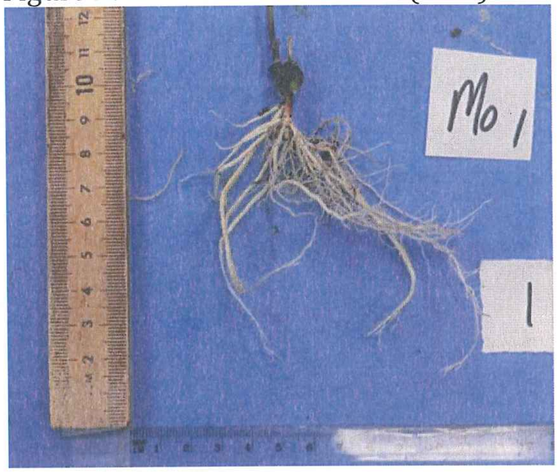


Figure 30. —*A. incarnata* roots (Al1)

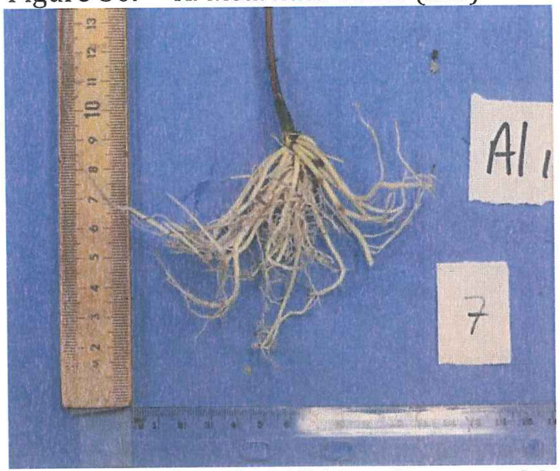
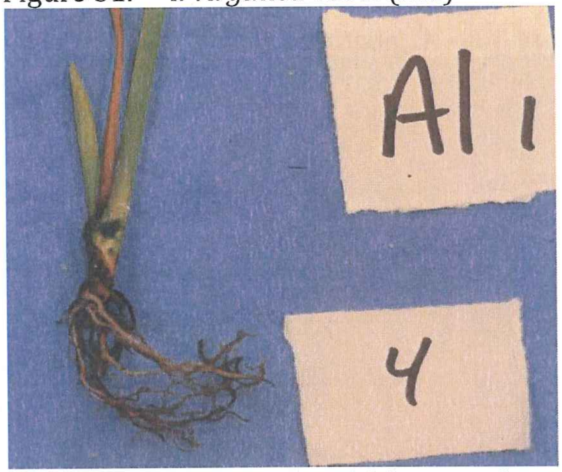


Figure 31. —*I. virginica* roots (Al1)



Figures 26-30 show the inhibition of root growth between the control and boron, molybdenum, and aluminum 1 treatments of *A. incarnata*. Figure 31 shows inhibited root growth and roots that are brittle, thickened, and brown following aluminum 1 treatment.

Figure 32. —*A. incarnata* (B1 Day 42)

Figure 33. —*I. virginica* (B1 Day 56)

Figures 32 & 33 show leaf tip and edge burn from B toxicity in *A. incarnata* and *I. virginica*.

Figure 34. —*A. incarnata* (B3 Day 33)

Figure 35. —*C. aquatilis* (B1 Day 47)

Figures 34 & 35 show boron induced necrotic spots on the leaf blades of *A. incarnata* and *C. aquatilis*.

Figure 36.—*A. incarnata* (Control)

Figure 37. —*A. incarnata* (B1)

Figure 36 shows normal leaf retention; Figure 37 shows premature leaf drop.

Figure 38. —*A. incarnata* (Al Control)

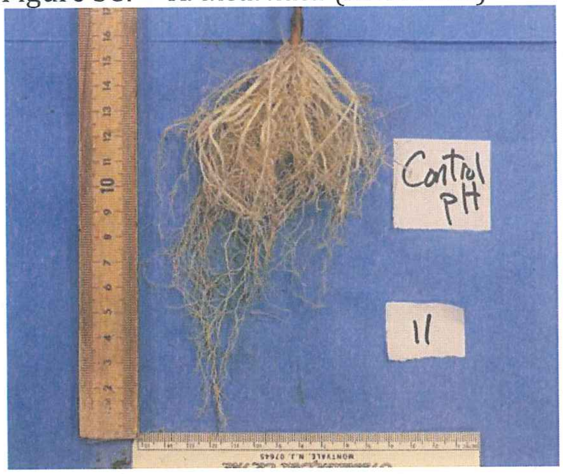


Figure 39. —*A. incarnata* (Al1)

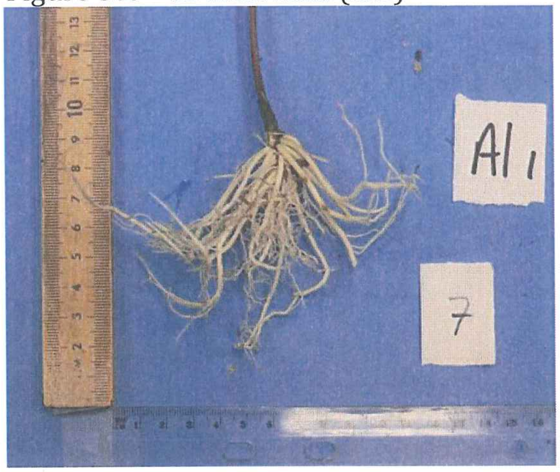


Figure 40. —*C. aquatilis* (Al Control)

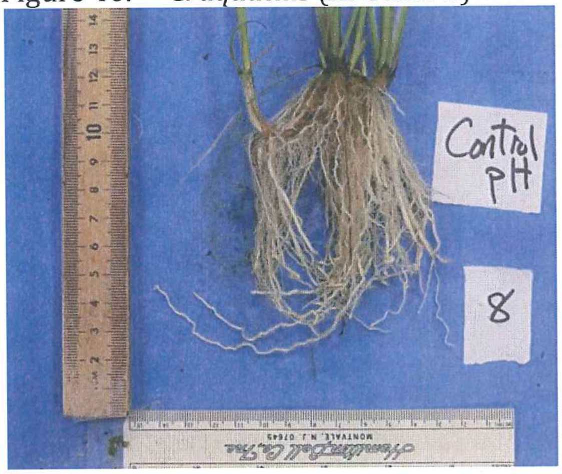


Figure 41. —*C. aquatilis* (Al1)

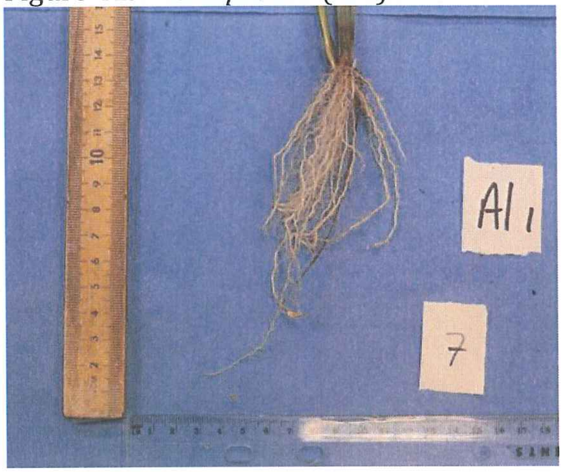
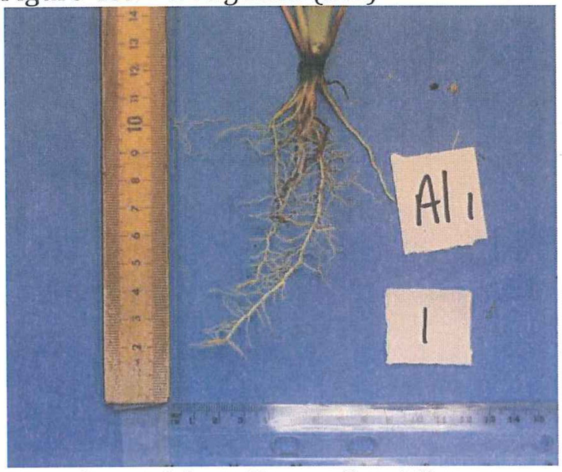


Figure 42. —*I. virginica* (Al Control)

Figure 43. —*I. virginica* (Al1)



Figures 38-43 show the inhibition of root growth between Al control (low pH control) and Al treatments in all 3 plant species.

Figure 44.—*A. incarnata* (Control)

Figure 45.—*A. incarnata* (B1)

Figure 46.—*C. aquatilis* (Control)

Figure 47.—*C. aquatilis* (B1)

Figure 48.—*I. virginica* (Control)

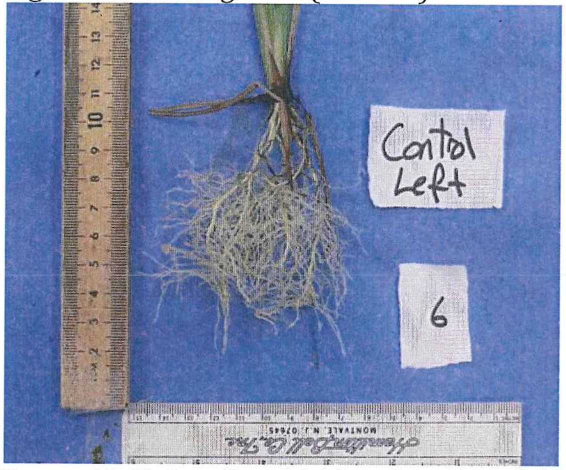
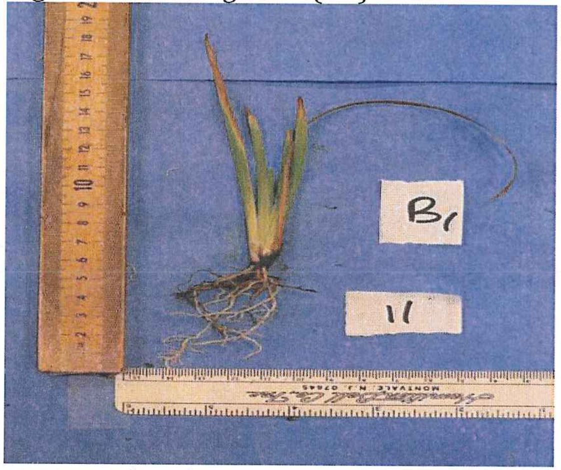


Figure 49.—*I. virginica* (B1)



Figures 44-49 show the inhibition of root growth between controls and B treatments in all 3 plant species.

Figure 50.—*A. incarnata* (Control)

Figure 51.—*A. incarnata* (Mo1)

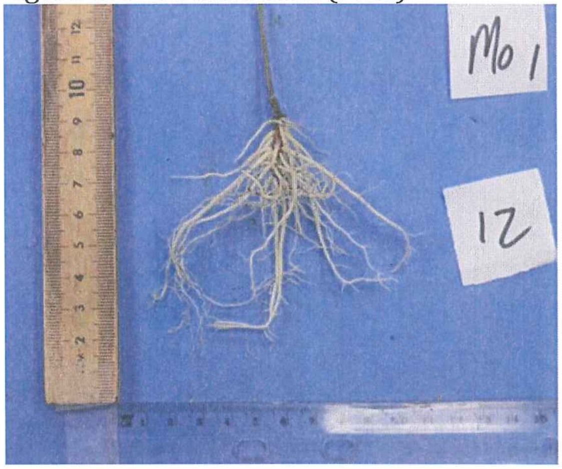


Figure 52.—*C. aquatilis* (Control)

Figure 53.—*C. aquatilis* (Mo1)

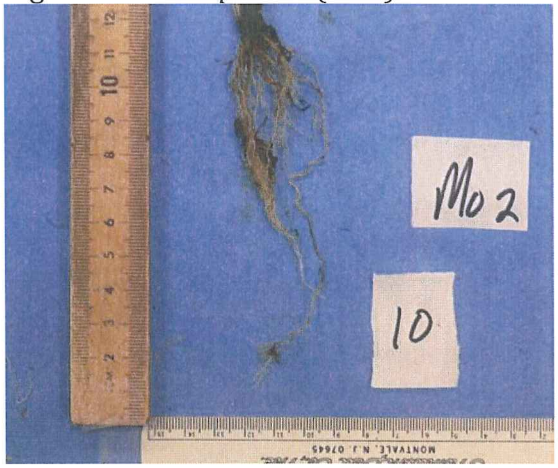


Figure 54.—*I. virginica* (Control)

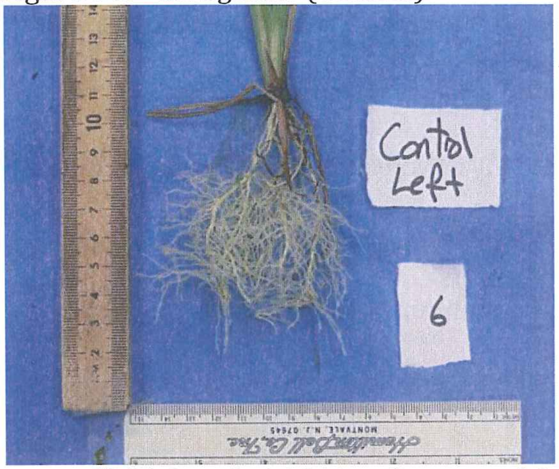
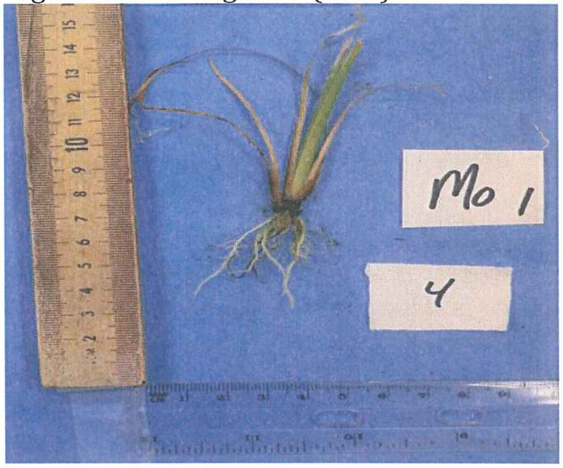


Figure 55.—*I. virginica* (Mo1)



Figures 50-55 show the inhibition of root growth between controls and Mo treatments in all 3 plant species.

Figure 56. —*A. incarnata* (Mo2 Day 56)

Necrotic spots in the leaf blade and along the margin as well as purpling of the leaf blade were witnessed by day 15 in *A. incarnata* for all nutrient treatment levels of Al, B, and Mo, except for the lowest concentration of boron. The most severe symptoms expressed were at higher concentrations of Al and B. By day 20 these symptoms became apparent in the B treatments in *C. aquatilis*. Necrosis became increasingly severe throughout all three plant species in all three nutrient concentration levels (4 in the case of boron) and by day 56 the majority of plants were expressing moderate to severe toxicity symptoms. *Asclepias incarnata* in molybdenum treatment level 2 attempted to produce an inflorescence. The inflorescence was small, dull colored, dry, and failed to open normally (Figure 53).

ANOVA Analyses. Aluminum had a statistically significant relationship on root, stem and total weight ($p \leq 0.004$), root length ($p = 0.029$), and stem length ($p = 0.040$) of *A. incarnata* and length of the longest root ($p = 0.001$), number of sheaths over 2 cm long ($p = 0.042$), and length of the longest leaf ($p = 0.024$) when applied to *C. aquatilis* (Figures 57-62; Appendix B).

Results of the Post Hoc test showed that when aluminum was applied to *A. incarnata* the root length mean of the control group was significantly less than that of Al treatment 2 (Figure 58). Likewise stem length at the lowest Al concentration was less than the mean of the next higher treatment (Figure 59). On the other hand, the various weight parameters for Al treatment 2 were not significantly different from the control (Figure 57; Appendix B). When Al was applied to *C. aquatilis* several measurements of growth, namely longest root length, number of sheaths over 2 cm, and longest leaf length, may have been enhanced at the lowest concentration (Figures 60-62) but potentially inhibited at higher concentrations.

Boron had a statistically significant relationship when applied to *A. incarnata* on root, stem, and total weight ($p = 0.001$), length of the longest root ($p = 0.001$), and the number of leaves ($p = 0.002$) (Figures 57, 63-65; Appendix C). The Post Hoc test showed that all concentrations of B had a significant difference in root weight, stem weight, and total weight compared with the control (Figure 57). Other indicators of growth such as length of longest root (Figure 63), number of leaves (Figure 64), and root length (Figure 65) were significantly reduced at least at the highest B concentration. While the two monocot species, *C. aquatilis* and *I. virginica*, had obvious qualitative symptoms, the quantitative measures, including total weight (Table 1), were not significantly inhibited over the course of this experiment.

Molybdenum had a statistically significant relationship on stem weight ($p = 0.003$), stem length ($p = 0.005$), and number of leaves ($p = 0.001$) of *A. incarnata* and on length of the longest leaf ($p = 0.013$) of *C. aquatilis* (Figures 57, 66-70; Appendix D). The Post Hoc test revealed that when Mo was applied to *A. incarnata* there was a significant reduction of

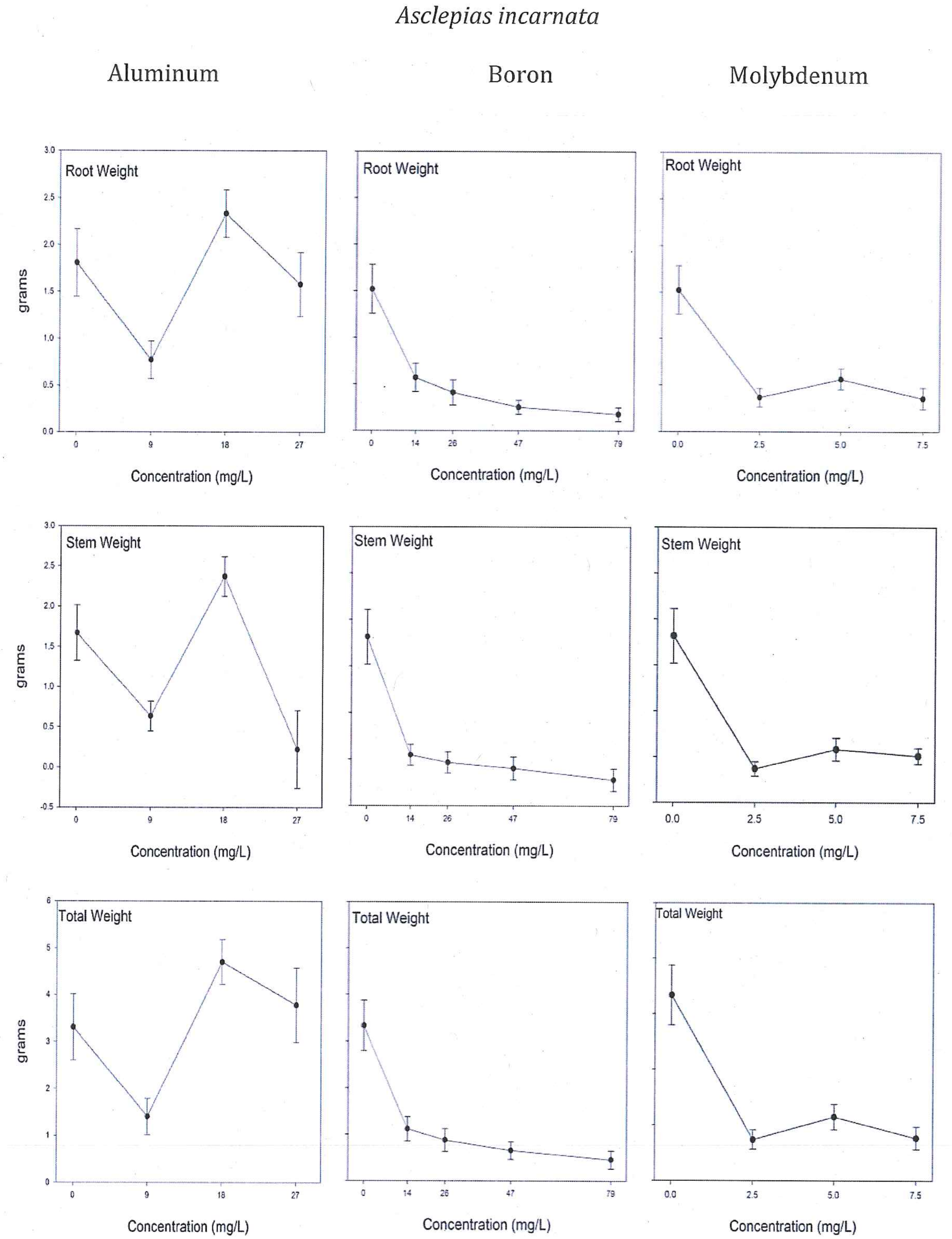


Figure 57. Response of *A. incarnata* to applications of aluminum, boron, and molybdenum. Al, B, and Mo concentrations are in mg/L; root, stem, and total weights are in grams.

Figure 58. Al: Root Length

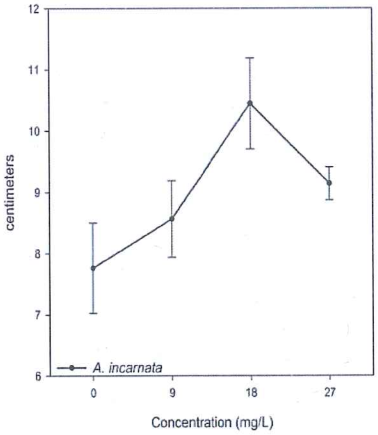


Figure 59. Al: Stem Length

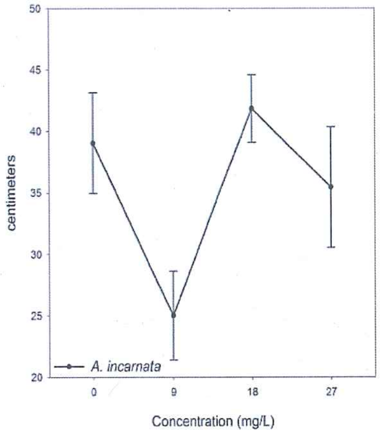


Figure 60. Al: Longest Root

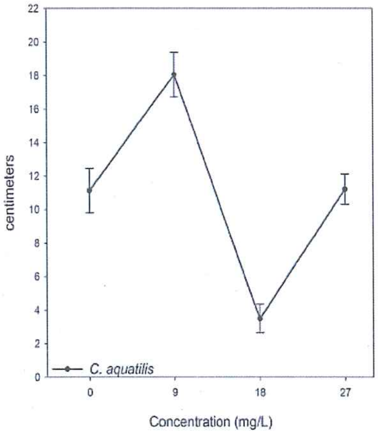


Figure 61. Al: # Sheaths > 2cm

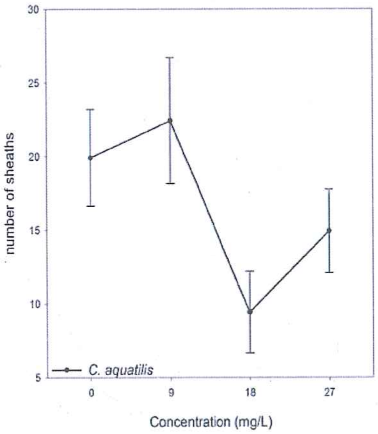


Figure 62. Al: Longest Leaf

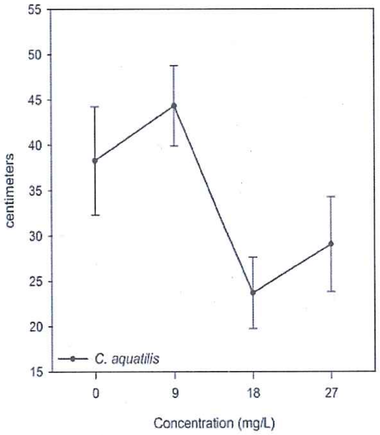


Figure 63. B: Longest Root

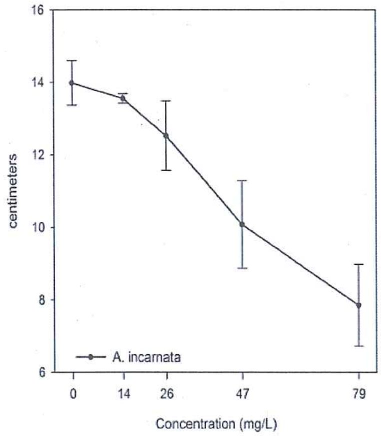


Figure 64. B: Number of Leaves

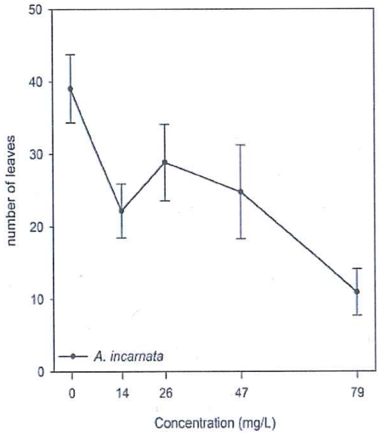


Figure 65. B: Root Length

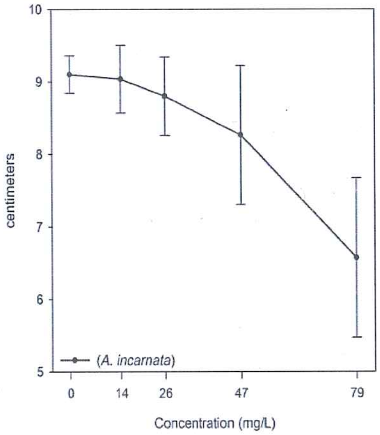


Figure 66. Mo: Number of Leaves

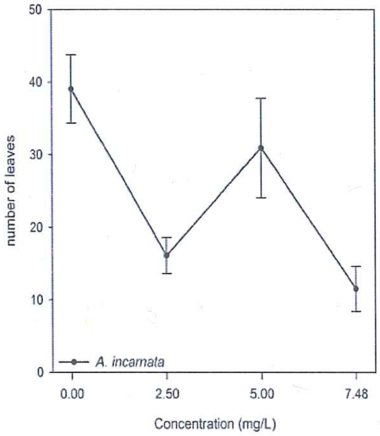


Figure 67. Mo: Stem Length

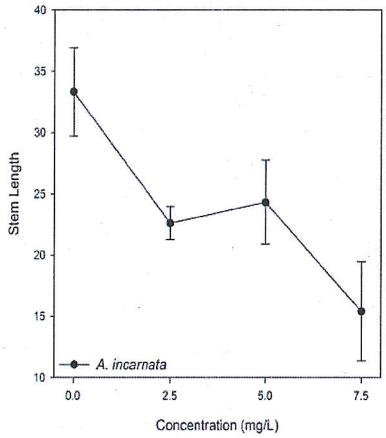


Figure 68: Mo: # Sheaths > 2cm

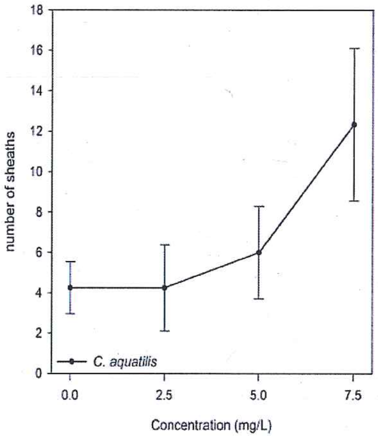


Figure 69. Mo: Longest Leaf

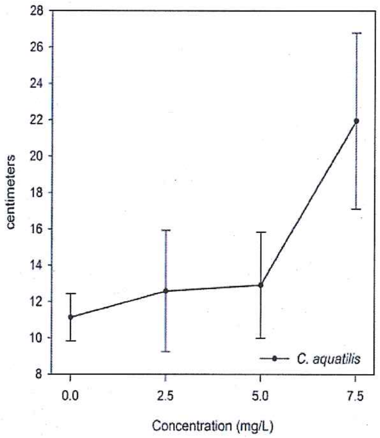
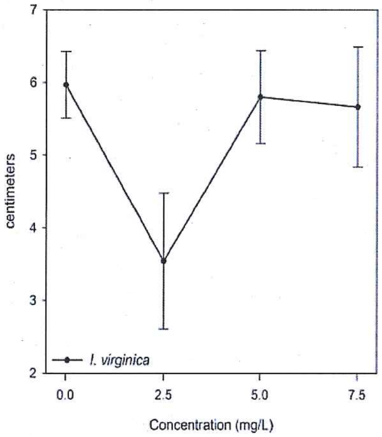


Figure 70. Mo: Root Length



stem weight between the control group and treatment levels 1 and 3, on stem length between the control group and treatment level 3, and number of leaves between the controls and treatment levels 1 and 3. A significant difference could not be demonstrated between the control and Mo treatment 2, a group with a high degree of variability among test plants (Figure 57). Not surprisingly, this same response was exhibited in another growth response, the number of leaves (Figure 66). Across the entire experiment, *A.*

incarnata at the highest Mo concentration suffered the most mortality. As a result, only ten plants had measurable root systems and eight plants with aboveground parts.

When Mo was applied to *C. aquatilis* a significant difference was found in the number of sheaths longer than 2 cm (Figure 68) and in the length of the longest leaf (Figure 69). In both instances these parameters increased with concentration of Mo, reaching a statistically significant threshold at the highest Mo concentration used in the experiment. On the other hand, root length of *I. virginica* was inhibited with low levels of Mo but no significance difference was observed at other Mo concentrations (Figure 70).

Inductive Coupled Plasma Mass Spectrometry. ICP-MS was used for this study to measure B uptake in samples of *A. incarnata* and *I. virginica*. In both *A. incarnata* and *I. virginica*, accumulation of B was evident. *Asclepias incarnata* control had a boron mean uptake of 62 ppm compared to 179 ppm, 446 ppm, 553 ppm, 427 ppm at the progressively higher concentrations of B. *Iris virginica* control treatment had a boron mean uptake of 107 ppm, while B treatment level 2 and 3 were 419 ppm and 797 ppm. The Post Hoc test revealed for *A. incarnata* that the mean of the control samples was less than the means of treatment levels 2, 3, and 4 and for *I. virginica* the mean of the control samples was lower than the mean of treatment level 4 (Appendix E).

Discussion

Visually the three native wetland plant species responded similarly to varying concentrations of Al, B, and Mo. Aluminum and B, at elevated concentrations, produced leaf purpling, necrotic spotting, and tip death in *A. incarnata* by day 15 of the experiment. By day 20 the two lowest B concentrations and the lowest Mo concentration in *A. incarnata* were affected and the necrosis expanded to include *C. aquatilis*. And by day 56 all three plant species, all treatment concentration levels of the three nutrients, had expressed pervasive necrosis and yellowing of leaves and in one specimen of *A. incarnata* incomplete flowering was expressed. Qualitatively root inhibition was apparent in *A. incarnata* in all three nutrients and concentration levels (Figures 26-30, 38-39, 44-45, 50-51). The controls of all three plant species did express some leaf wilting, leaf tip death, and purpling of the leaf margin. However, these symptoms were neither as severe nor widespread as in the plants receiving Al, B, and Mo. And plant mortalities, of which there were 52, during the experiment, appeared to be random, with the possible exception of the highest concentration of Mo, and not the result of treatments.

The symptoms observed in the greenhouse experiment are commonly noted in the literature (e.g., Miyasaka et al. 2007; Gupta, 2007; Sotiropoulos wt al. 2002; Kevresan et al. 2001). However, the prior and current literature was limited to research in vegetables and woody species, primarily. There has been little, if any, research on the responses of elevated levels of Al, B, and Mo, or other constituents of fly ash leachate, to native wetland plant species.

It was particularly instructive that the three species used in this study had some noteworthy differences in their response to elevated levels of Al, B, and Mo. The dicot *A. incarnata* seemed the most sensitive of the three species, especially to increasing concentrations of B. The applications of B to *A. incarnata* had a dramatic effect on root, stem, and total weight (Figure 57) as well as length of the longest root, number of leaves, and root length (Figures 63-65). These results were further reinforced with the ICP-MS tests. The ICP-MS tests revealed that *A. incarnata* and *I. virginica* are accumulator species, which are species that accumulate and concentrate metals in the aboveground tissues.

Although increasing concentrations of B produced progressively greater inhibitions of growth, Al treatments had unexpected variation in response (e.g., Figure 57) in the form of an unexpectedly pronounced inhibition of growth at the lowest Al concentration. Several explanations may be posited including a natural variability in plant response to elevated levels of nutrients and heavy metals in the soil medium. The fact that elemental uptake by wetland plants varies among species and is related to rooting depth and plant life form (Weis and Weis, 2004) could explain why some plants are bigger, more resilient, and appear more tolerant to varying concentration levels. This may suggest that small differences in the condition of the plants at the on-set of the treatment may lead to large differences in their ability to acclimatize over the course of the experiment.

Alternatively, because the inhibition of root growth is one of the most rapid responses to toxic concentrations of a heavy metal (Wong and Bradshaw, 1982), even a low but toxic Al concentration could have broad consequences on plant growth. One might wonder whether more extensive root damage leads to elevation of pH levels within the rhizosphere with subsequent effect on the absorption of Al (Taylor and Foy, 1985). Experimental results suggest that there are various mechanisms involving extracellular and intracellular carboxylate ion production that assist in the sequestering and detoxification of Al in plants (Panda and Matsumoto, 2007). These may act differentially over a range of concentrations.

The resilience of plant growth in response to Al and Mo was evident in several growth responses. In this experiment, toxic effects on root growth of *A. incarnata* only became apparent at and above 18 mg/ml concentration (Figure 58) and in *C. aquatilis* the number of sheaths and length of the longest leaf only decreased at Al concentrations above 9 mg/ml (Figures 61-62). And perhaps the most interesting result was the increase in the number of sheaths greater than 2 cm and leaf length of *C. aquatilis* with increased concentrations of Mo (Figures 68-69).

In summary, the above results suggest that B toxicity is uniformly expressed both in qualitative as well as quantitative measures of plant response across a range of concentrations. In contrast, the responses to Mo and especially Al, while evident and no less severe in foliage symptoms, were less uniform across the range of concentrations and quantitative measures. The latter may indicate some potential for these three plant species to acclimatize to these two fly ash constituents.

This greenhouse experiment has applications that can be translated into the field. The findings for these three common native wetland species aided in the recognition of symptoms in the field sites and corroborate observations from CBWC, especially the SW corner of Cowles Bog. The greenhouse experiment produced symptoms of incomplete flowering, leaf tip and leaf margin burn and necrosis, necrotic spotting, chlorosis of the leaf blade and veins, marginal leaf curl, and purpling of the stem and these symptoms also were observed in Cowles Bog in many species.

The long-term implications of these findings suggest that the vegetative quality of affected areas of Cowles Bog will remain low until the effects of the fly ash leachate are eliminated from the site. High levels of B, which have an especially negative impact on vegetation during the first growing season (Wong and Bradshaw, 1982), make the establishment of new native vegetation difficult. At the same time, Ye et al. (1998)

concluded that the invasive non-native *Typha latifolia* (cattail) is inherently tolerant to elevated levels of heavy metals commonly found in the leachate of fly ash. A virtual cattail monoculture is currently present in some portions of Cowles Bog and, with its sequestered B, presents a continuing risk to the establishment of more conservative, native plant species.

Further study is necessary to determine the specific levels of the constituents of fly ash, including Al, B, and Mo in Cowles Bog. The continuation of groundwater and vegetation monitoring is necessary and the testing of plant samples *in situ* by ICP-MS could be a valuable tool in determining the uptake concentrations of specific, individual fly ash constituents in the vegetation in the CBWC.

LITERATURE CITED:

Abdalla, M. M. 2008. Physiological aspects of aluminum toxicity on some metabolic and hormonal contents of *Hordeum vulgare* seedlings. Australian Journal of basic and Applied Sciences 2:549-560.

Baker, A.J.M. 1981. Accumulators and excluders-strategies in response of plants to heavy metals. Journal of Plant Nutrition 3:643-654.

Batty, L. C., A.J.M. Baker, and B.D. Wheeler. 2002. Aluminum and phosphate uptake by *Phragmities australis*: the role of Fe, Mn, and Al root plaques. Annals of Botany 89:443-449.

Brown, P. H., and H. Hu. 1998. Boron mobility and consequent management in different crops. Better Crops 82:28-31.

Collins, B. S., Rebecca R. Sharitz, and Daniel P. Coughlin. 2004. Elemental composition of native wetland plants in constructed mesocosm treatment wetlands. Bioresource Technology 96:937-948.

Delhaize, E. and P.R. Ryan. 1995. Aluminum toxicity and tolerance in plants. Plant Physiology 107:315-321.

ESRI (Environmental Systems Resource Institute). 2010. ArcMap 9.3. ESRI, Redlands, California.

Foy, C.D. 1984. Physiological effects of hydrogen, aluminum, and manganese toxicities in acid soils. Agronomy Monograph 12:57-97.

Foy, C.D. 1998. Plant adoption to acid aluminum – toxic soils. Communications in Soil Science and Plant Analysis 19:959-987.

Goldberg, S. 1993. Chemistry and mineralogy of boron in soils. Pp. 3-44, *In Boron and its Role in Crop Production*. (Umesh C. Gupta ed.) CRC Press, Boca Raton, Florida.

Gregory, S.J. 2009. Investigation into the relationship between aluminum treatment and the Superoxide dismutase (SOD) enzyme system in *Lolium perenne* (*L. perenne* cv.Nui). Masters Thesis.

Gupta, U.C. and S. Gupta. 1998. Trace element toxicity relationships to crop production and livestock and human health: implications for management. Communications in Soil Science and Plant Analysis 29:1491-1522.

Gupta, U.C. 2007. Boron. Pp. 242-268, *In Handbook of Plant Nutrition*. (Allen V. Baker and David J. Pilbeam eds.) Taylor & Francis, New York, New York.

Hamlin, R.L. 2007. Molybdenum. Pp. 375-389, *In Handbook of Plant Nutrition*. (Allen V. Baker and David J. Pilbeam eds.) Taylor & Francis, New York, New York.

Hoagland, D.R. and D.I. Aron. 1950. A water culture Method for growing plants without soil. California Agriculture Experimental Statistics Circular 347.

Hu, H. and P.H. Brown. 1997. Absorption of boron by plant roots. Plant and Soil 193:49-58.

Indiana Spatial Data Portal. www.indiana.edu/~gisdata/

Kaiser, B.N., K.L. Gridley, J.N. Brady, T. Phillips, and S.D. Tyerman. 2005. The role of molybdenum in agriculture plant production. Annals of Botany 96:745-754.

Keddy, K.J., L.C. Munn, and L. Wang. 1997. Chemistry and mineralogy of molybdenum in soils. Pp. 4-22, *In Molybdenum In Agriculture*. (Umesh C. Gupta, ed.) Boca Raton, Florida.

Kevresan, S. N. Petrovic, M. Popovic, and J. Kendrac. 2001. Nitrogen and protein metabolism in young pea plants as affected by different concentrations of nickel, cadmium, lead, and molybdenum. Journal of Plant Nutrition 24:1633-1644.

Kohl, H.C. and J.J. Oertli. 1960. Distribution of boron in leaves. Plant Physiology 4:420-424.

Leyshon, J.A. and W.Y. James. 1993. Boron toxicity and irrigation management. Pp. 207-226, *In Boron And Its Role* In *Crop Production*, (Umesh C. Gupta, ed.) CRC Press, Inc.; Boca Raton, FL.

Matsumoto, H. 2002. Metabolism of organic acids and metal tolerance in plants exposed to aluminum. Pp. 95-110, *In Physiology And Biochemistry Of Metal Toxicity And Tolerance In Plants.* (M.N.V.Prasad and K. Strzalka eds.) Kluwer Academic Publishers: The Netherlands.

Minitab 16 Statistical Software (2010). (Computer Software) State College, PA: Minitab, Inc. (www.minitab.com)

Miwa, K., J. Takano, H. Omori, M. Seki, K. Shinozaki, and T.Fujiwara. 2007. Plants tolerant of high boron levels. Science 318:1417.

Miyasaka, S.C., N.V. Hue, and M.A. Dunn. 2007. Aluminum. Pp. 441-481, In: Handbook of Plant Nutrition. (Allen V. Baker and David J. Pilbeam eds.) Taylor & Francis, New York, New York.

Mossor-Pietraszewska, T. 2001. Effect of aluminum on plant growth and metabolism. Acta Biochimica Polonica 48:673-686.

Nable, R.O., G.S. Bañuelos, and J.G. Paull. 1997. Boron Toxicity. Plant and Soil 193:181-198.

Panda, S.K. and Hideaki Matsumoto. 2007. Molecular physiology of aluminum toxicity and tolerance in plants. The Botanical Review 73:326-346.

Pavlovic, N.B., S.A. Leicht-Young, D. Wilcox, R. Hieber, D. Mason, and K. Frohnapple. 2009. Twenty-three years of vegetation change in a fly-ash leachate impacted meadow. Great Lakes Network Report GLKN/2009/05. Great Lakes Inventory & Monitoring Network, Ashland, Wisconsin.

Piha, M.J., H.W. Vallack, N. Micheal, and B.M. Reeler. 1995. A low impact approach to vegetation establishment on mine and coal ash wastes in semi-arid regions. II. Lagooned pulverized fuel ash in Zimbabwe. Journal of Applied Ecology 32:382-390.

Poozesh, M., P. Cruz, P. Choler, and G. Bertoni. 2007. Relationship between the Al resistance of grasses and their adaptation to an infertile habitat. Annals of Botany 99:947-954.

Raven, J.A. 1980. Short and long distance transport of boric acid in plants. New Phytologist 84:231-249.

Reddington, C.B. and J.L. Peterson. 1983. Influence of boron on but blasting and plant growth in *Zinnia elegans*. Bulletin of the Torrey Botanical Club 110:77-79.

Reid, R.J., J.E. Hayes, A. Post, J.C.R. Stragnoulis, and R.D. Graham. 2004. A critical analysis of the causes of boron toxicity in plants. Plant, Cell and Environment 25:1405-1414.

Rengel, Z. 1992. Role of calcium in aluminum toxicity. New Phytologist 121:499-513.

Rout, G.R., S. Samantaray, and P. Das. 2001. Aluminum toxicity in plants: a review. Agronomie 21:3-21.

Roy, A.K., A. Sharma, and G. Talukder. 1988. Some Aspects of aluminum toxicity in plants. The Botanical Review 45:145-178.

Sartaj, M. and L. Fernandes. 2005. Adsorption of boron from landfill leachate by peat and the effect of environmental factors. Journal of Environmental Engineering and Science 4:19-28.

Smith, K.S., L.S. Balisrieri, S.M. Smith, and R.C. Severson. 1997. Distribution and mobility of molybdenum in the terrestrial environment. *In Molybdenum In Agriculture.* (Umesh C. Gupta, ed.). Cambridge University Press, New York, New York.

Sotiropoulos, T.E., Ioannis N. Therios, Kortessa N.Dimassi, A. Bosabalidis, and G. Kofidis. 2002. Nutritional status, growth, CO_2 assimilation, and leaf anatomical responses in two kiwifruit species under boron toxicity. Journal of Plant Nutrition 25:1249-1261.

Supanjani, K.D. Lee. 2006. Hot pepper response to interactive effects of salinity and boron. Plant Soil Environment 52:227-233.

Taylor, G.S. and C.D. Foy. 1985. Mechanisms of aluminum tolerance in *Triticum aestivum* L. (Wheat). I. Differential pH induced by winter cultivars in nutrient solutions. American Journal of Botany 72:695-701.

Theis, T.L., J.D. Westrick, C.L. Hsu, and J.J. Marley. 1978. Field investigations of trace metals in groundwater from fly ash disposal. Water Pollution Control Federation 50:2457-2469

Weis, J.S. and P. Weis. 2004. Metal uptake, transport and release by wetland plants: implications for phytoremediation and restoration. Environmental International 30:685- 700.

Wilcox, D.A., R.J. Shedlock, and W.H. Hendrickson. 1986. Hydrology, Water Chemistry, and Ecological Relations in the Raised Mound of Cowles Bog. Journal of Ecology 4:1103-1117.

Wilcox, D.A. and M.A. Hardy. 1988. Effects of Coal Fly-Ash Disposal on Water Chemistry in an Intradunal Wetland at Indiana Dunes. Pp. 57- 67 *In Interdisciplinary Approaches To Freshwater Wetlands Research.* (Wilcox, D.A. ed.). Michigan State University Press, East Lansing, Michigan.

Wilcox, D.A. 1988. The Necessity of Interdisciplinary Research in Wetland Ecology: The Cowles Bog Example. Pp. 1-9. *In Interdisciplinary Approaches To Freshwater Wetlands Research.* (Wilcox, D.A. ed.). Michigan State University Press, East Lansing, Michigan.

Wong, M.H. and A.D. Bradshaw. 1982. A comparison of the toxicity of heavy metals, using root elongation of Rye grass, *Lolium perenne.* New Phytologist 91:255-261.

Ye, Z.H., A.J.M. Baker, M.H. Wong, and A.J. Willis. 1997. Zinc, lead, and cadmium tolerance, uptake and accumulation by *Typha latifolia.* New Phytologist 136:469-480.

Ye, Z.H., A.J.M. Baker, M.H. Wong, and A.J. Willis. 1997. Zinc, lead and cadmium tolerance, uptake and accumulation by the common Reed, *Phragmites australis* (Cav.) Trin. ex Steudel Annals of Botany 80:363-370.

Zhang, J., Z. He, H. Tian, G. Zhu, and X. Peng. 2007. Identification of aluminum-responsive genes in rice cultivars with different aluminum sensitivities. Journal of Experimental Botany 58:2269-2278.

Appendix A.

Latitude/Longitude of sites in study

Site #	Latitude	Longitude	Location
1	41° 38.229’	87° 05.816’	Cowles Bog (CB)
2	41° 38.241’	87° 05.837’	Cowles Bog
3	41° 38.219’	87° 05.858’	Cowles Bog
4	41° 38.243’	87° 05.929’	Cowles Bog
5	41° 38.231’	87° 05.953’	Cowles Bog
6	41° 38.230’	87° 06.011’	Cowles Bog
7	41° 38.236’	87° 06.052’	SW Corner Cowles Bog
8	41° 38.219’	87° 06.072’	SW Corner Cowles Bog
9	41° 38.249’	87° 06.052’	Cowles Bog
10	41° 38.314’	87° 05.990’	Cowles Bog
11	41° 38.321’	87° 06.007’	Cowles Bog
12	41° 38.345’	87° 06.000’	Cowles Bog
13	41° 38.371’	87° 05.986’	Cowles Bog
14	41° 38.390’	87° 06.006’	Cowles Bog
15	41° 38.413’	87° 05.998’	Cowles Bog
16	41° 38.438’	87° 05.964’	Cowles Bog
17	41° 38.454’	87° 05.928’	Cowles Bog
18	41° 38.685’	87° 05.514’	Cowles Bog Boardwalk
19	41° 38.691’	87° 05.340’	North Side Cowles Bog
20	41° 38.506’	87° 05.848’	Sm Wetland North of CB
21	41° 38.556’	87° 05.878’	Lrg Wetland North of CB
22	41° 38.581’	87° 05.719’	Lrg Wetland North of CB
23	41° 38.596’	87° 05.955’	Lrg Wetland North of CB
24	41° 38.405’	87° 06.170’	Sm Wetland West of CB
25	41° 38.346’	87° 06.168’	Lrg Wetland West of CB
26	41° 38.350 ‘	87° 06.217’	Lrg Wetland West of CB
27	41° 38.348’	87° 06.240’	Lrg Wetland West of CB
28	41° 38.361 ‘	87° 06.314’	Lrg Wetland West of CB
29	41° 38.380’	87° 06.216’	Lrg Wetland West of CB
30	41° 38.367’	87° 06.113’	Lrg Wetland West of CB
31	41° 38.366’	87° 06.041’	Lrg Wetland West of CB
32	41° 38.359’	87° 06.697’	Blag Slough
33	41° 38.367’	87° 06.862’	Blag Slough
34	41° 38.367’	87° 06.886’	Blag Slough

Appendix B.

ANOVA:

Mean weights in grams, lengths in centimeters, and number of sheaths ± standard error of control and three aluminum treatments (Al applied as $AlCl_3$) and representative p-values for *A. incarnata* and *C. aquatilis*.

Nutrient	Plant Species	Measurement	Control	Treatment 1 Al = 9 mg/L	Treatment 2 18 mg/L	Treatment 3 27 mg/L	P-Value
Aluminum	A. incarnata	Root Weight	1.81 ± 0.36 ab	0.77 ± 0.20 b	2.33 ± 0.25 a	1.58 ± 0.34 ab	0.006
Aluminum	A. incarnata	Stem Weight	1.67 ± 0.34 ab	0.64 ± 0.19 b	2.37 ± 0.25 a	2.20 ± 0.48 a	0.004
Aluminum	A. incarnata	Total Weight	3.31 ± 0.70 ab	1.41 ± 0.38 b	4.70 ± 0.48 a	3.78 ± 0.80 a	0.005
Aluminum	A. incarnata	Root Length	7.76 ± 0.74 b	8.56 ± 0.63 ab	10.45 ± 0.74 a	9.14 ± 0.27 ab	0.029
Aluminum	A. incarnata	Stem Length	32.54 ± 5.53 ab	18.76 ± 4.22 b	38.35 ± 4.30 a	35.44 ± 4.91 ab	0.04
Aluminum	C. aquatilis	Longest Root	11.13 ± 1.33 b	18.05 ± 1.33 a	9.49 ± 0.85 b	11.22 ± 0.91 b	0.001
Aluminum	C. aquatilis	Number of Sheaths	19.92 ± 3.27 ab	22.42 ± 4.27 a	9.42 ± 2.77 b	14.92 ± 2.83 ab	0.042
Aluminum	C. aquatilis	Length of Longest Leaf	38.28 ± 5.97 ab	44.33 ± 4.45 a	23.68 ± 3.94 b	29.04 ± 5.25 ab	0.24

Means that do not share a letter are significantly different.

APPENDIX C.

ANOVA:

Mean weights in grams, lengths in centimeters, and numbers of leaves ± standard error of control and four boron treatments (B applied as $B(OH)_3$) and representative p-values for *A. incarnata*.

Nutrient	Plant Species	Measurement	Control	Treatment 1 B = 14 mg/L	Treatment 2 26 mg/L	Treatment 3 47 mg/L	Treatment 4 79 mg/L	P-Value
Boron	A. incarnata	Root Weight	1.52 ± 0.26 a	0.57 ± 0.15 ab	0.41 ± 0.14 bc	0.25 ± .07 bc	0.18 ± .08 c	0.001
Boron	A. incarnata	Stem Weight	1.82 ± 0.30 a	0.55 ± 0.11 ab	0.47 ± 0.11 bc	0.40 ± 0.12 bc	0.28 ± 0.12 c	0.001
Boron	A. incarnata	Total Weight	3.35 ± 0.54 a	1.11 ± 0.26 ab	0.87 ± 0.25 bc	0.65 ± 0.19 bc	0.45 ± 0.20 c	0.001
Boron	A. incarnata	Root Length	9.10 ± 0.26 a	9.04 ± 0.47 ab	8.80 ± 0.54 ab	8.27 ± 0.96 ab	6.57 ±1.10 b	0.053
Boron	A. incarnata	Longest Root	13.98 ± 0.625 a	13.55 ± 1.32 ab	12.53± 0.96 ab	10.08 ± 1.21 bc	7.85 ± 1.13 c	0.001
Boron	A. incarnata	Number of Leaves	39.04 ± 4.70 a	22.17 ± 3.71 ab	28.83 ± 5.30 ab	24.75 ± 6.48 ab	10.92 ± 3.20 b	0.002

Means that do not share a letter are significantly different.

APPENDIX D.

ANOVA:

Mean weights in grams, length in centimeters, and number of leaves and sheaths ± standard error of control and three molybdenum treatments (Mo applied as molybdic acid disodium salt dihydrate) for *A. incarnata* and *C. aquatilis*.

Nutrient	Plant Species	Measurement	Control	Treatment 1 Mo = 2.5 mg/L	Treatment 2 5 mg/L	Treatment 3 7.5 mg/L	P-Value
Molybdenum	A. incarnata	Root Weight	1.53 ± 0.26 a	0.37 ± .97 bc	0.56 ± 0.11 ab	0.36 ± 0.12 c	0.001
Molybdenum	A. incarnata	Stem Weight	1.82 ± 0.30 a	0.37 ± .08 b	0.58 ± 0.12 ab	0.51 ± .09 b	0.001
Molybdenum	A. incarnata	Total Weight	3.34 ± 0.54 a	0.74 ± 0.17 b	1.15 ± 0.23 ab	0.76 ± 0.20 b	0.001
Molybdenum	A. incarnata	Stem Length	33.33±3.61 a	22.62±1.34 ab	24.32±3.43 ab	15.42±4.07 b	0.005
Molybdenum	A. incarnata	Number of Leaves	39.04 ± 4.70 a	16.08 ± 2.48 b	30.90 ± 6.84 a	11.50 ± 3.12 b	0.001
Molybdenum	C. aquatilis	Number of Sheaths	4.25 ± 1.29 b	4.25 ± 2.13 ab	6.00 ± 2.29 ab	12.33 ± 3.78 a	0.056
Molybdenum	C. aquatilis	Longest Leaf	11.13 ± 1.30 b	12.58 ± 3.34 ab	12.91 ± 2.92 ab	21.95 ± 4.85 a	0.013

Means that do not share a letter are significantly different.

Appendix E.

Mean mg/kg (ppm) of boron uptake for samples of *A. incarnata* and *I. virginica*

Sample	Asc inc Control	Asc inc B1	Asc inc B2	Asc inc B3	Asc inc B4
1	65	211	359	732	444
2	56	98	376	405	418
3	64	229	602	523	420
Mean	61.7^{c}	179.3^{bc}	445.7^{ab}	533.3^{a}	427.3^{ab}

Sample	Iris Control	Iris B2	Iris B4
1	101	430	690
2	119	408	590
3	101	na	1110
Mean	107^{b}	419^{ab}	796.7^{c}

Means that do not share a letter are significantly different.

Attachment D

Remedial Alternatives: EPA Threshold and Balancing Criteria

Area	Corrective Measure Alternative		Alternative Score by Criterion							Total Score	Cost
			Long-term Effectiveness	Toxicity, Mobility, and Volume Reduction	Short-term Effectiveness	Implementability	Green Remediation	Community Acceptance	State Acceptance		
SWMU-15	1	Full Excavation and Off-site Disposal	6	6	3	6	3	6	6	36	$40,700,000
	2	Full Excavation and On-site Consolidation	4	2	1	3.5	1	1	1	13.5	$38,300,000
	3	Full Excavation, 1/2 Off-site Disposal, 1/2 On-site Consolidation	5	4	2	3.5	2	4	4	24.5	$42,500,000
	4	Partial Excavation, Off-site Disposal and Solidification	3	5	5	5	5	5	5	33	$20,500,000
	5	Partial Excavation, On-site Consolidation and Solidification	2	3	4	1.5	4	3	3	20.5	$25,000,000
	6	Encapsulation	1	1	6	1.5	6	2	2	19.5	$28,900,000
	Total Score by Criterion		21	21	21	21	21	21	21	N/A	N/A
Greenbelt & Eastern	1	Full Excavation and Off-site Disposal	Excavation & Off-Site Disposal is required by NPS and is the only alternative evaluated for the Greenbelt & Eastern Wetland area.							N/A	$276,000
Ground water	1	In-Situ Remediation by Permeable Reactive Barrier	1	2	1.5	2	2	1	1	10.5	$890,000

	2	Groundwater Pump & Treat	3	3	1.5	1	1	2	2	13.5	$7,500,000
	3	Monitored Natural Attenuation	2	1	3	3	3	3	3	18	$880,000
	Total Score by Criterion		6	6	6	6	6	6	6	N/A	N/A
Previously Barren Soil Areas	1	Excavation & Off-site Disposal with Soil Replacement	1	3	2	1	1	1	1.5	10.5	$133,000
	2	Soil Flushing / pH Adjustment	2	2	2	2	2	2	1.5	13.5	$104,000
	3	Monitored Natural Attenuation	3	1	2	3	3	3	3	18	$84,000
	Total Score by Criterion		6	6	6	6	6	6	6	N/A	N/A

The scoring of alternatives is based on a ranking performed in descending order, with the highest ranking alternative for each criterion receiving a score of 6 and the lowest ranking alternative receiving a score of 1 for SWMU 15. For “Groundwater Beneath the IDNL” and “Previously Barren Soil Areas”, the highest ranking alternative receives a score of 3, and the lowest ranking alternative receives a score of 1. Scores are relative and apply only within a specified area. Ties are assigned a score based on the average method of determining ties – all alternatives that rank the same for a specific criterion are assigned a score based on the average value of their sorted position between 1 and 3 (or their sorted position between 1 and 6 for SWMU 15 alternatives). For example, Alternatives 1 and 2 for “Groundwater Beneath the IDNL” are determined to be equal and rank the lowest for short-term effectiveness. The assigned score of 1.5 for each is the average of their sorted position within the ranking of that criterion: (2+1)/2 = 1.5.

Remedial Alternatives: Costs

Area	**Corrective Measure Alternative**	**Total Score**	**Capital Cost**	**O&M Cost**	**Project Management, Engineering, & Contingency Cost**	**Total Cost**
SWMU-15	Full Excavation and Off-site Disposal	36	$31,600,000	$100,000	$9,000,000	**$40,700,000**
	Full Excavation and On-site Consolidation	13.5	$26,200,000	$3,100,000	$9,000,000	**$38,300,000**
	Full Excavation, 1/2 Off-site Disposal, 1/2 On-site Consolidation	24.5	$30,800,000	$1,700,000	$10,000,000	**$42,500,000**
	Partial Excavation, Off-site Disposal and Solidification	33	$15,700,000	$100,000	$4,700,000	**$20,500,000**
	Partial Excavation, On-site Consolidation and Solidification	20.5	$17,200,000	$1,700,000	$6,100,000	**$25,000,000**
	Encapsulation	19.5	$15,000,000	$7,100,000	$6,800,000	**$28,900,000**
Greenbelt & Eastern Wetland	Full Excavation and Off-site Disposal	N/A (See Table above)	$166,000	$18,000	$92,000	**$276,000**
Groundwater Beneath IDNL	In-Situ Remediation by Permeable Reactive Barrier	10.5	$430,000	$270,000	$190,000	**$890,000**

	Groundwater Pump & Treat	13.5	$3,000,000	$2,500,000	$2,000,000	**$7,500,000**
	Monitored Natural Attenuation	18	$60,000	$550,000	$270,000	**$880,000**
Previously Barren Soil Areas	Excavation & Off-site Disposal with Soil Replacement	10.5	$84,000	$11,000	$38,000	**$133,000**
	Soil Flushing / pH Adjustment	13.5	$32,000	$44,000	$28,000	**$104,000**
	Monitored Natural Attenuation	18	$61,000	$0	$23,000	**$84,000**

A Citizen's Guide to Solidification and Stabilization

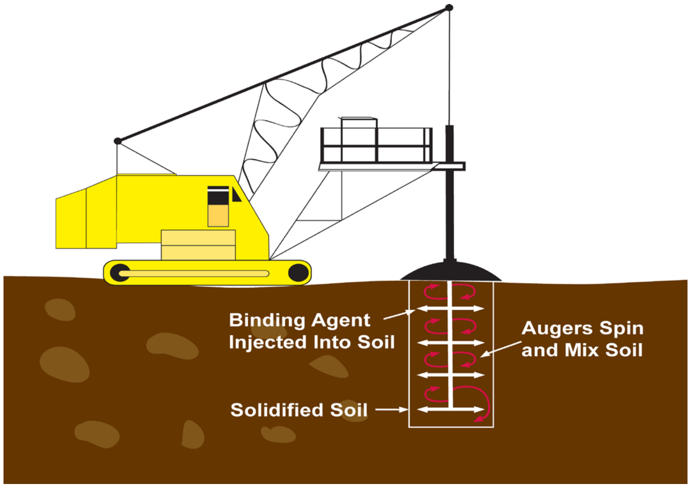
What Are Solidification And Stabilization?

Solidification and stabilization refer to a group of cleanup methods that prevent or slow the release of harmful chemicals from wastes, such as contaminated soil, sediment, and sludge. These methods usually do not destroy the contaminants. Instead, they keep them from "leaching" above safe levels into the surrounding environment. Leaching occurs when water from rain or other sources dissolves contaminants and carries them downward into groundwater or over land into lakes and streams.

Solidification binds the waste in a solid block of material and traps it in place. This block is also less permeable to water than the waste. Stabilization causes a chemical reaction that makes contaminants less likely to be leached into the environment. They are often used together to prevent people and wildlife from being exposed to contaminants, particularly metals and radioactive contaminants. However, certain types of organic contaminants, such as PCBs and pesticides, can also be solidified.

How Does It Work?

Solidification involves mixing a waste with a binding agent, which is a substance that makes loose materials stick together. Common binding agents include cement, asphalt, fly ash, and clay. Water must be added to most mixtures for binding to occur; then the mixture is allowed to dry and harden to form a solid block.



Binding agents can be injected into soil and mixed using augers.

Similar to solidification, stabilization also involves mixing wastes with binding agents. However, the binding agents also cause a chemical reaction with contaminants to make them less likely to be released into the environment. For example, when soil contaminated with metals is mixed with water and lime — a white powder produced from limestone — a reaction changes the metals into a form that will not dissolve in water.

Additives can be mixed into the waste while still in the ground (often referred to as "in situ"). This usually involves drilling holes using cranes with large mixers or augers, which both inject the additives underground and mix them with the waste. The number of holes needed depends on the size of the augers and the contaminated area. Dozens of holes may need to be drilled. When the waste is shallow enough, the contaminated soil or waste is excavated and additives are mixed with it above ground (often referred to as "ex situ"). The waste is either mixed using backhoes and front end loaders or placed in machines called "pug mills." Pug mills can grind and mix materials at the same time.

Solidified or stabilized waste mixed above ground is either used to fill in the excavation or transported to a landfill for disposal. Waste mixed in situ is usually covered with a "cap" to prevent water from contacting treated waste (See *A Citizen's Guide to Capping* [EPA 542-12-004].)

How Long Will It Take?

Solidification and stabilization may take weeks or months to complete. The actual time it takes will depend on several factors. For example, they may take longer where:

- The contaminated area is large or deep.
- The soil is dense or rocky, making it harder to mix with the binding agent.
- Mixing occurs above ground, which requires excavation.
- Extreme cold or rainfall delays treatment.

Are Solidification And Stabilization Safe?

The additives used in solidification and stabilization often are materials used in construction and other activities. When properly handled, these materials do not pose a threat to workers or the community. Water or foam can be sprayed on the ground to make sure that dust and contaminants are not released to the air during mixing. If necessary, the waste can be mixed inside tanks, or the mixing area can be covered to minimize dust and vapors. The final solidified or stabilized product is tested to ensure that contaminants do not leach. The strength and durability of the solidified materials are also tested.

Large augers inject and mix binding agent with contaminated soil.

How Might It Affect Me?

Nearby residents or businesses may notice increased truck traffic as equipment and additives are brought to the site or as treated waste is transported to a landfill. They also may hear earth-moving equipment as waste is excavated or mixed. When cleanup is complete, the land often can be redeveloped.

Why Use Solidification Or Stabilization?

Solidification and stabilization provide a relatively quick and lower-cost way to prevent exposure to contaminants, particularly metals and radioactive contaminants. Solidification and stabilization have been selected or are being used in cleanups at over 250 Superfund sites across the country.

Contaminated soil mixed with cement in a pug mill is spread on the ground as pavement.

Example

Solidification and stabilization were used to clean up contaminated sludge and soil at the South 8th Street Landfill Superfund site in Arkansas. From the 1960s to 1970s, municipal and industrial wastes were disposed at the site, including a 2.5-acre pit of waste-oil sludge. In the 1980s, that area was found to be contaminated with oily wastes, PCBs, pesticides, and lead.

In 1999, cranes with augers were used to inject and mix limestone, fly ash, and Portland cement with 40,000 cubic yards of sludge and soil in the pit. These additives helped solidify the mixture as well as stabilize the lead and other metals. The hardened material was left in place and covered with a soil cap. Evaluations in 2004 and 2009 indicated that the cleanup approach is still protecting human health and the environment. The site has been deleted from the National Priorities List, the list of the nations most serious hazardous waste sites.

For More Information

For more information about this and other technologies in the Citizen's Guide Series, visit:

www.cluin.org/remediation
www.cluin.org/products/citguide

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