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Mr. Ross del Rosario
USEPA Region 5 – SR-6J
77 W. Jackson Boulevard
Chicago, Illinois 60604-3590

March 30, 2015
(1983)

RE: **Response to USEPA Comments (dated 02/26/15) on Focus FS Report – Revision 1 and Submittal of Focused Feasibility Study Report – Revision 2**
Waukegan South Plant Manufactured Gas Plant (MGP) facility in Waukegan, Illinois
North Shore Gas Company

CERCLA Docket No. V-W-'07-C-877
CERCLIS ID – ILD984809228

Dear Mr. del Rosario:

This letter provides responses to United States Environmental Protection Agency (USEPA) and Illinois Environmental Protection Agency (IEPA) comments issued February 26, 2015 on the Focused Feasibility Study (FS) Report– Revision 1 for the North Shore Gas Former Waukegan South Plant MGP Site. The attached Focused FS Report – Revision 2, addresses these comments based on clarification and consensus obtained during the March 11, 2015 Agency Conference Call.

For ease of review, USEPA comments are listed (in italics) and followed by the response to comment.

USEPA Comments

1. ***In Reference to Previous USEPA FFS General Comment #4 and IBS's Response:*** *The IBS response is acceptable. However, it is noted for future design reference that the cited concentration value for the design is more than 25,000 times greater than the reported solubility of BaP in water. In light of this response and the unlikely scenario that extracted groundwater would contain BaP at this concentration during implementation of remedies D5, D6 or D7, it may be more realistic to base the influent concentration used for alternative design on the solubility of the compounds detected.*

IBS Response: Noted. IBS will evaluate additional methods to estimate the influent concentration to a groundwater treatment plant during the remedial design phase; however, no changes have been made in the Focused FS Report.

2. ***In Reference to Previous USEPA FFS General Comments #7 and #8 and IBS's Response:*** *The reference at the top of page 4 should be 6.1, instead of 6.2.2. In addition, the reference in the middle of page 4 should be 6.1, instead of 6.3. Please check the rest of the document for correct references to section 6.1 and 6.3 as it appears changes in section numbering within Section 6 led to incorrect references.*

IBS Response: The comment refers to an error in the section numbers included on page 4 of the response to comments letter. The references within the report are accurate and no modification to the FS Report is necessary to address this comment.

3. ***In Reference to Previous USEPA FFS General Comment #8 and IBS's Response:*** *The current approach is acceptable for FFS purposes. However, it is noted for future design consideration that the proposed design concept may result in the truncation of DNAPL flow paths to the recovery line. If the DNAPL level in the collection sump is maintained below the drain line invert, water will be preferentially*

recovered due to viscosity differences between the two fluids. To maximize DNAPL recovery with the passive system, DNAPL sump level should be maintained at the highest elevation possible with small, and more frequent extraction cycles. The ideal situation is where DNAPL is removed from the line as fast as it accumulates. This will impart a slow (but continuous) depletion of the DNAPL pool. Batch pumping, as proposed, may fracture DNAPL flow paths and result in the immobilization of DNAPL in the areas around the recovery well.

IBS Response: Noted. IBS will evaluate approaches for removal of accumulated DNAPL from sumps during the remedial design phase; however, no changes have been made in the Focused FS Report.

4. ***In Reference to Previous USEPA FFS General Comment #10 and IBS's Response:*** *IBS comments noted. The issue of evaluating and monitoring the potential spread of NAPL during the stepped remedial approach should be addressed in the RD.*

IBS Response: Noted.

5. ***In Reference to Previous USEPA FFS Specific Comment #1 and IBS's Response:*** *As is specified in the revised FFS Section 4.5.2, it 'is requested that the DNAPL pre-design investigation take place before implementation of Option D4. Figure 16 should be modified accordingly to show the pre-design DNAPL investigation occurring before implementation of option D4, and language in Sections 6.3 and related Section 6.2 should be clarified to reflect the pre-design investigation. Pre-design investigations should be done as soon as possible to provide an updated baseline of DNAPL presence, mobility, thickness, and volume which will assist in not only locating horizontal wells, but also in providing information that will allow better assessment of DNAPL presence across the site. The details of the pre-design investigation can be provided in the planning phase, however, Integrys should plan to integrate analytical approaches to measure pore fluid saturation, interfacial tension, and mobility thresholds in the subsurface that could provide important information for system design. These approaches, if applied before and after remediation phases, could be very useful in demonstrating how the system was performing (along with operational data observations).*

IBS Response: A pre-design investigation box has been added to Figure 16 in advance of Option D4. As discussed with USEPA, the exact details of this investigation will be tailored to the selected remedial option and will be developed in a remedial design work plan. IBS will consider the value of the referenced analytical approaches during the Proposed Remedial Action Plan and Record of Decision Process. As such, no changes have been made in the Focused FS Report.

6. ***Figure 16 Additional Comments:*** *See attached recommended changes to Figure 16.*

   STEP 1. Draft versions of this figure presented on January 8 indicated that field monitoring (i.e., a measureable decrease as illustrated by monitoring) would serve as the decision metric. However, the revised Figure 16 includes a metric which is undefined and appears insufficient for decision making purposes (See proposed modifications to Figure 16).

   STEPS 1-3. The current decision flow did not appear to allow the process to continue to the next step after 2 years (See proposed modifications to Figure 16).

IBS Response: Figure 16 has been updated based on the discussions during the March 11, 2015 conference call and the modified figure provide by USEPA in an email sent on March 12, 2015.

7. ***In Reference to Previous USEPA FFS Specific Comment #3 and IBS's Response:** IBS comments noted. The issue of evaluating potential reactive gate approaches can be considered as part of a future site-wide FS.*

IBS Response: Noted.

8. ***In Reference to Previous USEPA FFS Specific Comment #5 and IBS's Response:** Implementation of a containment only option (D3) does not meet the NCP expectation for addressing principal threat wastes, and therefore cannot fully meet ARARs as currently noted in Table 5. Section 4.4.4 and Table 5 should be revised to indicate that ARARs are only partially met under Option D3. EPA recognizes that engineering controls, which a vertical engineered barrier is, for the containment of principal threat waste may be used when treatment is considered impractical. However, NAPL treatment at this site is not considered impractical at this time, so removal/treatment options are prioritized for this interim DNAPL remedy.*

IBS Response: IBS agrees that under existing site conditions, DNAPL removal/treatment is practical at the site. The practicality of removal/treatment is currently demonstrated by the periodic removal of accumulated DNAPL from vertical wells. Based on the demonstrated practicality of DNAPL removal, IBS has updated the Section 4.4.4 and Table 5 to state that Option D3 partially meets the ARARs. In the future, if DNAPL recovery is demonstrated to be impractical, engineering controls coupled with necessary administrative controls may be considered. Sections 4.2.2, 4.3.2, 4.4.4, 5.2, and Table 5 have been updated, accordingly.

9. ***In Reference to Previous USEPA FFS Specific Comment #7 and #8 of IBS's Response:** While it would be helpful to see estimated volumes of DNAPL removed by each approach under the assumed implementation efficiencies to better evaluate the benefits and shortfalls of each alternative, the revisions to Section 4.5.2 and 4.6.2 and the qualitative discussions in Sections 4.5.6, 4.6.6., and 4.7.6 are acceptable at this time. However, as noted in item #5 (Response to Specific Comment #1), implementation of the DNAPL pre-design investigation is recommended as soon as possible in the pre-design phase before implementation of Option D4 (if it is selected) in order to provide an updated baseline of DNAPL presence, mobility, thickness and overall volume.*

IBS Response: Noted. IBS agrees that the pre-design investigation discussed in Section 4.5.2 can be used to help refine the pre-remedy DNAPL conditions at the site. As mentioned in response to Comment 5, the exact details of this investigation will be tailored to the selected remedial option and will be developed in a remedial design work plan.

10. ***In Reference to Previous USEPA FFS Specific Comment #9 and IBS's Response:** The response and FFS language revisions regarding horizontal well spacing is acceptable, as noted above. However, for future remedial design consideration, CH2M HILL suggests that Integrys consider modifying the well installation approach as presented on the conceptual cross section on Figure 13. Specifically, it is recommended that Integrys consider the use of repeating well pairs that are installed at each location just like the center well set shown in the conceptual cross section on Figure 13. Installation of separate lines will allow seamless conversion from Option D4 to Option D5. Each well pair would be considered as injection/extraction well pairs, rather than the more limiting single injection wells. By using dual lines, the upper and lower lines can be used for any purposes (injection or extraction) and add more flexibility to operation of the system. Injecting water into the DNAPL zone may not be preferable, but injecting groundwater in the upper line above the DNAPL results in a mound which may be more efficient at displacing DNAPL to the recovery point than simply trying to flush it there. Conversely, in the surfactant*

NATURAL RESOURCE TECHNOLOGY

remedial case, you would want it to be injected in the DNAPL zone. Therefore, the paired well approach allows provisions to inject and extract, as necessary.

IBS Response: Noted. IBS will evaluate horizontal well placement and configurations during the remedial design phase; however, no changes have been made in the Focused FS Report.

11. ***In Reference to Previous USEPA FFS Specific Comment #15 (Section 6.2 Performance Standard)*** *and IBS's Response: Revised language in Section 6.2 retains thickness measurement as the overall metric for remedy success and extraction operation completion (1 inch or less). The decline curve serves as the basis for when a DNAPL recovery effort is exhausted. We suggest that both requirements must be achieved before the remedy is considered complete, with the decline curve taking precedent, because the measurements are more repeatable. In the interest of streamlining this comment and expediting completion of the FFS document, revised text (in track changes mode) has been prepared for EPA consideration. Please see attached document entitled "Recommended Revisions to FFS Section 6.2 Performance Standard"*

IBS Response: Section 6.2 has been updated based on the discussions on the March 11, 2015 conference call and the modified text provided USEPA in an email sent on March 12, 2015.

12. ***In Reference to Previous USEPA FFS Specific Comment #18 (Appendix B Remedial Option Cost Estimates) and IBS's Response:*** *The following items are noted predominantly for future remedial design considerations. No changes are necessary to finalize the FFS, unless the comment significantly modifies the cost of one option against the other options.*

    a) *D3. Package GW treatment plant installation startup and testing costs seem low. No costs are shown for conveyance piping of treated water to local POTW despite a subtitle indicating as such.*

    b) *D4. Horizontal drain lines are to be installed through DNAPL impacted areas. The assumption for IDW disposal (T&D) as non-hazardous may not be realistic. A provision for a percentage of hazardous waste disposal costs would seem appropriate, especially since it appears that current DNAPL is managed as RCRA hazardous waste.*

    c) *D4. Drain line maintenance (jetting) may be highly disruptive to DNAPL recovery efforts (flow path truncation). Consider removal of this line item. D4. The estimate structure makes it very difficult to see what components of the remedy are needed for the alternative and what components are needed for expansion after year 2. Consider presenting details as part of extraction or injection system components if feasible.*

    d) *D5. Costs for GW treatment plant installation and startup testing appear to be low. The system is described as a complex series of process units. Significant interconnections piping, electrical and process controls are also likely. Consider increasing this value to reflect time requirements of installing and starting a complicated treatment process.*

    e) *D5. Typically about 20% of extracted GW in a flooding system is treated and disposed rather than re-injected. This approach helps to impart an inward gradient towards the treatment area. Consider integrating capital costs for conveyance and operations costs for discharge of treated groundwater to the local POTW.*

    f) *D6. Integrate comments above for D5 groundwater treatment to D6.*

IBS Response:

a) The scoped groundwater treatment plant is a pre-fabricated water treatment system housed within modified shipping containers. The operation of the system is fully tested in the factory prior to being shipped to site. Once units arrive onsite, assembly is limited to connection of piping, electrical, and controls between the shipping containers. The line item of startup and testing assumes a general testing for leaks and functionality. There is a one year system startup period included in the O&M costs to account for the ongoing modifications to improve the efficiency of groundwater treatment plant performance. Costs for conveyance piping have been added to Option D3, as requested.

b) Per 40 CFR § 261.24, MGP-derived waste is exempt from being defined as characteristically hazardous via TCLP. The DNAPL that is currently recovered from site wells exceeds ignitability (flash point <140 °F) criteria, and thereby is managed as characteristically hazardous waste due to ignitability.

   Soil impacted by site DNAPL was generated during previous removal action. This excavated soil was below flash point criteria and managed as nonhazardous special waste at the Subtitle D Waste at Countryside Landfill in Grayslake, Illinois. It is anticipated that soil removed during installation of horizontal wells will have similar properties to the soil removed during the previous removal action. Therefore, no modification has been made in the Focused FS Report. The actual disposal method will be further evaluated during the remedial design phase of the project.

c) The jetting line item was intended to account for cost associated with regular maintain of the wells to prevent iron and biofouling. The word “jetting” has been replaced by “maintenance”.

d) The scoped groundwater treatment plant is a pre-fabricated water treatment system housed within modified shipping containers. The operation of the system is fully tested in the factory prior to being shipped to site. Once the unit arrive onsite, assembly is limited to connection of piping, electrical, and controls between the shipping containers. The line item of startup and testing assumes a general testing for leaks and functionality. As discussed in the Section 4.6.2, there is a one year system startup period included in the O&M costs to account for the ongoing modifications to improve the efficiency of groundwater treatment plant performance.

e) An evaluation of discharging a portion of the extracted groundwater to NSSD for Options D5 and D6 will completed in the remedial design phase of the project. For purposes of this Focused FS Report, Options D5 and D6 have been updated assuming 20% of the extracted groundwater will be discharged to the sanitary district.

f) Noted.

13. Tables

Table 1: Remove the NCP as an ARAR. EPA generally doesn't include it in the ARAR tables. As the implementing regulation for the Superfund program, it cannot be waived.

Table 2. We note that all of the enhanced recovery options are a form of in-situ treatment using physical or chemical modifications. It may be more appropriate to group these remedial technologies under the In-situ treatment General response action rather than Ex-situ where currently presented.

IBS Response: NCP has been removed from Table 1, as requested.

In Response to Table 2, IBS has adjusted the classification of enhanced recovery techniques from ex-situ to in-situ, as requested. IBS originally considered any DNAPL remediation approach that involved extraction of DNAPL so that it can be managed on the ground-surface as an ex-situ approach. The categorization of DNAPL recovery approaches as in-situ or ex-situ has no effect on the FS-level analysis, therefore the requested modification has been made to the Focused FS Report.

14. ***New Comment:*** *Expand the discussion on Section 1.2.8.2 on what happens to the recovered DNAPL when it is received by the off-site facility (SET). Specifically, what characteristics justify the use of DNAPL as a fuel (e.g., energy content) and what process (es) does the TSD facility perform on the DNAPL leading to it being blended as fuel and used by local cement kilns. Lastly, please indicate in this section that the DNAPL is being categorized as a RCRA hazardous waste.*

IBS Response: Section 1.2.8.2 has been updated with additional information about the DNAPL disposal process.

<u>IEPA Comments</u>

1. *Section 4.3, D2 - Institutional Controls, pages 26-27: Sufficient description is provided for institutional controls to prevent the use of groundwater as a drinking water source. However, more detail is indicated to describe how worker caution controls for the protection of future construction workers will be implemented and enforced, especially for impacted areas located on adjacent properties.*

IBS Response: Worker caution controls for future construction workers will be controlled through development and implementation of land use controls and an intrusive activities management plan. Text describing these controls has been included in Section 4.3.

2. *Section 4.5.2, D4-Horizontal Well DNAPL Recovery: No discussion could be found in this section explaining how recovery system effluent (DNAPL and water) will be stored, treated and/or disposed. Please revise this section to describe the fate of effluent recovered from the horizontal well system. It is noted that the Alternative D4 cost estimate found in Appendix B assumes drumming the DNAPL/water and transport of these drums to facility (SET) in Houston, Texas.*

IBS Response: Sections 4.5.2, 4.6.2, 4.7.2, and 4.8.2 have been updated with the presumed approach for disposal/recycling of recovered DNAPL based on existing disposal activities.

3. *Section 4.6.4, D5 - Compliance with ARARs, page 45: Regarding the conditions Illinois EPA has for potential re-injection of treated DNAPL/water as part of this interim action, please add the following as the final bullet on page 45, "The interim action will not be inconsistent with the final remedial action goal of remediating contaminated groundwater to Illinois' Class 1 Groundwater Quality Standards."*

IBS Response: The text has been added as a bullet in Section 4.6.4, as requested.

4. *Section 4.8.2, D7 - Remedial Option Description, page 56: The text discusses the increased risk of vapor intrusion associated with the Thermally Enhanced Recovery options. At a minimum, increased soil vapor and potentially indoor air monitoring are indicated to ensure the protection of users of the Akzo facility buildings and the WPD Maintenance Building during implementation of this alternative. Accordingly, please revise this section and Section 4.8.7 (Short-Term Effectiveness) to include adequate soil vapor and/or indoor air monitoring for the protection of indoor workers as part of this remedial alternative.*

IBS Response: Section 4.8.7 has been updated to state that monitoring will be performed to ensure the health of construction workers as well as workers in adjacent commercial/industrial facilities if thermally enhanced recovery options are implemented.

5. *Section 6, General: The stepped approach for South Plant is laid out in this section. Up to three of the remedial alternatives could be implemented. The first step would involve Horizontal Well DNAPL Recovery (D4), which is a passive technique. If recovery rates for D4 indicate enhanced recovery techniques should be implemented, then the recovery system would be upgraded to Physically Enhanced DNAPL Recovery (D5) or water flushing. If deemed necessary, the infrastructure for DS could be re-purposed to accommodate Chemically Enhanced DNAPL Recovery (D6). Implementation ofD4 alone is estimated to achieve 95% total DNAPL recovery in approximately 31 years. The enhanced alternatives are expected to take considerably less time, 5 to 8 years, to achieve the same 95% reduction. As long as IBS demonstrates that it can meet the re-injection conditions identified by IEPA, selection of Alternative D5 is the preferred first step alternative for the State.*

IBS Response: Noted.

6. *Table 1: IEPA is cognizant that the alternatives in this FFS only address the mass and mobility of principle threat MGP waste at the site, which is dense non-aqueous liquids (DNAPL). As such, no attempt at meeting Illinois' Groundwater Quality Standards (35 IAC 620) is contemplated for this interim action. Rather, restoring groundwater to beneficial use levels will occur as part of follow-on work once the principle threat waste has been addressed to the extent practicable. However, since the long-term goal is to meet the 35 IAC 620 standards, they should be listed as applicable chemical-specific applicable or relevant and appropriate requirements (ARARs), not "relevant and appropriate."*

IBS Response: Illinois' Groundwater Quality Standards have been modified to chemical-specific, applicable requirements, as requested.

USEPA Voicemail Comment on March 27, 2015

1. *Based on USEPA management review, modify reference to the titles of each of the evaluated remedies from remedial options to remedial alternatives.*

IBS Response: References to remedial option throughout the report text, tables, figures, and appendices, have been updated to remedial alternative, as requested. The only exception is in Section 3, where the report refers to screening of process options, consistent with the alternative development process outlined in the USEPA Remedial Investigation and Feasibility Study (RI/FS) guidance (USEPA, 1988).

Please contact Mr. Naren Prasad of IBS at 312.240.4569 if you should have any questions regarding the content of this letter.

Sincerely,

NATURAL RESOURCE TECHNOLOGY, INC.

Marcus D. Byker, PE	Jennifer M. Hagen, PE
Environmental Engineer	Senior Engineer

Enc: Focused FS Report Revision 2

cc: Mr. Paul Lake, IEPA (via FedEx and email)
Mr. Naren Prasad, IBS (via email)
Mr. David Klatt, CH2MHill (via email)

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Focused Feasibility Study Report

North Shore Gas Company
Former Waukegan South Plant MGP Site
Waukegan, Illinois

Project No: 1983

Revision 2

March 30, 2015

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FOCUSED FEASIBILITY STUDY REPORT

NORTH SHORE GAS COMPANY
FORMER WAUKEGAN SOUTH PLANT MGP SITE
WAUKEGAN, ILLINOIS

Project No. 1983

Prepared For:

North Shore Gas Company
130 East Randolph Street
Chicago, Illinois 60601

Prepared By:

Natural Resource Technology, Inc.
234 W. Florida Street, Fifth Floor
Milwaukee, Wisconsin 53204

Revision 2
March 30, 2015

Marcus Byker

Marcus D. Byker, PE
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TABLE OF CONTENTS

FIGURES

IMBEDDED WITHIN TEXT

INCLUDED AS ATTACHMENT

TABLES

IMBEDDED WITHIN TEXT

INCLUDED AS ATTACHMENT

APPENDICES

ACRONYMS AND ABBREVIATIONS

µg/L	Micrograms Per Liter
Akzo	Akzo Nobel Aerospace Coatings, Inc.
AOC	Administrative Order on Consent
ARARs	Applicable or Relevant and Appropriate Requirements
Barr	Barr Engineering Company
bgs	Below Ground Surface
BLRA	Baseline Risk Assessment
BMc	Burns & McDonnell
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
CERCLA (“Superfund")	Comprehensive Environmental Response, Compensation, and Liability Act
COPCs	Contaminants of Potential Concern
CWG	Carbureted Water Gas
DNAPL	Dense Non-Aqueous Phase Liquid
COW	City of Waukegan
EJ&E	Elgin, Joliet and Eastern Railroad
ERH	Electric Resistance Heating
FS	Feasibility Study
GRA	General Response Action
HDPE	High-density polyethylene
HDD	Horizontal Directional Drilling
IBS	Integrys Business Support, LLC
IEPA	Illinois Environmental Protection Agency
mg/kg	Milligrams Per Kilogram
MGP	Manufactured Gas Plant
msl	Mean Sea Level
NCP	National Contingency Plan
NRT	Natural Resource Technology, Inc.
NSSD	North Shore Sanitary District
NSG	North Shore Gas Company
PAHs	Polynuclear Aromatic Hydrocarbons
PRAP	Preliminary Remediation Action Plan
PRG	Preliminary Remediation Goal
RAO	Remedial Action Objective
RI	Remedial Investigation
RI/FS	Remedial Investigation and Feasibility Study
ROD	Record of Decision
ROW	Right-Of-Way
SOW	Statement of Work
SSWP	Site-specific Work Plan

SVOCs	Semi-Volatile Organic Compounds
TACO	Tiered Approach to Corrective Action Objectives
TBC	To Be Considered
TCL	Target Compound List
UIC	Underground Injection Control
USACOE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Society
VOCs	Volatile Organic Compounds
WPD	Waukegan Port District

1 INTRODUCTION

This Focused Feasibility Study (FS) evaluates interim dense non-aqueous phase liquid (DNAPL) remedial alternatives for the North Shore Gas Company (NSG), former South Plant Manufactured Gas Plant (MGP) Site located in Waukegan, Illinois. NSG is a subsidiary of Integrys Energy Group, and Integrys Business Support, LLC (IBS), currently manages the Site for NSG. This Focused FS was developed in accordance with the Administrative Order on Consent (AOC) and Statement of Work (SOW) between the United States Environmental Protection Agency (USEPA) and NSG, identified as Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or "Superfund") Docket No. V-W-07-C-877, dated July 23, 2007. The AOC/SOW addresses two former NSG MGPs: the Waukegan North Plant MGP and the Waukegan South Plant MGP; however, this report focuses exclusively on the Waukegan South Plant MGP. The extent of the former Waukegan South Plant MGP property is referred to herein as the “South Plant MGP” or “MGP” while the larger area where contamination has been detected is referred to herein as the “Site”. Under the AOC/SOW, a generic approach to address all former NSG MGP sites has been developed (the Multi-Site approach), which may be modified to account for site-specific differences that may exist at a particular MGP site.

Substantial investigation and remedial actions were previously completed at the Site as documented in the *Remedial Action Completion Report for Soil Above the Water Table, Former South Plant* (referred to as the Completion Report) (Burns & McDonnell (BMc), March 2005), Site-Specific Work Plan (SSWP) (BMc, September 2008), and the Remedial Investigation (RI) Report Revision 1 (Natural Resource Technology (NRT), January 2014).

A FS Revision 0 that addressed soil, groundwater, DNAPL, and soil vapor was submitted for USEPA review on May 9, 2014. During a progress meeting conducted on August 12, 2014, USEPA requested IBS to develop a Focused FS, which will be followed by an Interim Record of Decision (ROD) addressing DNAPL remediation. This approach will allow for implementation of a DNAPL remedy, allowing IBS and the USEPA to make informed decisions about how to address any potential remaining site risks following DNAPL remediation. A Focused FS Revision 0 was submitted to USEPA on September 26, 2014, and USEPA provided comments to this document on December 16, 2014. Based on clarification and consensus obtained during a January 8, 2015 Agency Meeting, a Focused FS Revision 1 was submitted to USEPA on February 9, 2015. The USEPA provided written comments on the Focused FS Revision 1 on February 26, 2015. This Focused FS Revision 2 addresses comments provided by USEPA in the

February 26, 2015 comment letter and March 11, 2015 conference call and subsequent comments provided by USEPA in an email sent on March 12, 2015.

This Focused FS is based on data and conclusions presented in the RI Report (NRT, January 2014). Further, this Focused FS was completed in accordance with applicable federal regulations, including CERCLA as amended by the Superfund Amendments and Reauthorization Act and the National Contingency Plan (NCP). Relevant guidance documents are referenced in Section 7.

1.1 Purpose and Organization of Report

The purpose of this Focused FS is to develop, screen, and evaluate remedial alternatives that address subsurface DNAPL present at the site resulting from former MGP operations. The evaluation of remedial alternatives includes comparison against the following criteria:

- Overall protection of human health and the environment
- Compliance with Applicable or Relevant and Appropriate Requirements
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost
- State Acceptance
- Community Acceptance

To achieve this objective, this Focused FS Report is organized into the following sections:

- Section 1 – Introduction and Site Background Information
- Section 2 – Development of Remedial Action Objectives
- Section 3 – Development and Screening of Technologies
- Section 4 – Detailed Analysis of Remedial Alternatives
- Section 5 – Comparative Analysis of Remedial Alternatives
- Section 6 – Additional Considerations for Remedy Selection and Implementation
- Section 7 – References

1.2 Background Information

This section summarized background information presented in the USEPA approved Completion Report (BMc, March 2005), SSWP (BMc, September 2008), and the RI Report – Revision 1 (NRT, January 2014).

Owner/Operator:	North Shore Gas Company Contact: Mr. Naren Prasad (IBS Project Manager) 200 E. Randolph St., 24th Floor Chicago, IL 60601 312.240.4569
Site Location:	T45N, R12E, Section 22 2 North Pershing Road and 1 South Pershing Road City of Waukegan, Lake County, Illinois
USEPA ID Illinois EPA #	ILD984809228 0971900058

1.2.1 Site Description and Surrounding Land Use

The former South Plant MGP property is located at 2 North Pershing Road and 1 South Pershing Road in City of Waukegan, Illinois. The location of the Site is presented on Figure 1. The former MGP is located in an industrial/commercial area and it is currently vacant and covered with grass. The former MGP is approximately 1.9 acres in area and generally rectangular, though it tapers to the south. North and South Pershing Road is an asphalt-paved road maintained by the City of Waukegan that was constructed through the former MGP property in 1970. The portion of the former MGP currently owned by the Waukegan Port District is landscaped with a sign welcoming visitors to the Waukegan South Harbor Marina.

The Site includes the former MGP and adjacent properties where MGP residuals have been identified through site investigation activities. These properties and their associated zoning designations are shown on Figure 2 and include:

- **Waukegan Port District (WPD)** – located east of the former MGP. Includes a marina, a visitor center/administration building, a maintenance building, and asphalt-paved parking lots (used for boat storage in the winter). This property is approximately 13.1 acres and is adjacent to marina and Lake Michigan.

- **Akzo Nobel Aerospace Coatings, Inc. (Akzo)** – located east/southeast of the former MGP and adjacent to Lake Michigan. The property is approximately 6.2 acres and consists of asphalt-paved parking lots and buildings used for manufacturing paints and coatings.

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- **Elgin, Joliet and Eastern (EJ&E)** – refers to the railroad tracks and right-of-way (ROW) located east and at the south end of the former MGP. This parcel is approximately 0.7 acres and the tracks diagonally across the south end of the former MGP property.
- **City of Waukegan (COW)** – located southeast of the former MGP between the EJ&E, Akzo, and WPD properties. This property is a vegetated and vacated former city street ROW. This parcel abuts a ComEd substation (not included in the investigation) and together these parcels are approximately 0.5 acre. Other COW property investigated includes nearby roads and associated ROWs.

The former MGP property is also bounded to the north by a City-owned Metra train parking lot and to the west by a Union Pacific railroad yard. There are no known MGP-residuals on these properties and both are up gradient of the former MGP based on local groundwater flow.

Waukegan Harbor and Lake Michigan are located approximately 600 feet east of the former MGP. A break wall extending east-northeast into Lake Michigan separates North Waukegan Harbor from South Waukegan Harbor. North Waukegan Harbor was constructed in the 1890s and contains a United States Army Corps of Engineers (USACOE) navigation channel that exits east to Lake Michigan; South Waukegan Harbor was constructed in the mid-1980s as a marina for recreational boats and has a southern exit to Lake Michigan. The Waukegan River is located approximately 1,000 feet south of the former MGP and flows east into Lake Michigan.

1.2.2 Site History

The Waukegan Pipeline Service Company constructed the original MGP in 1897 and the Waukegan Gas, Light, and Fuel Company purchased the MGP property in 1898. NSG purchased the MGP property in 1900 and leased the southern 0.37 acres from the EJ&E Railroad. The South Plant MGP operated on a full time basis from 1898 to 1927. Historic records indicate the coal carbonization process was likely used during the MGP's early operational period and that it was converted to a carbureted water gas (CWG) plant in 1917. The MGP was shut down in 1927 but was operated as a peak production unit during high demand periods between 1935 and 1946. The MGP was closed in 1946 and demolished in 1951. The locations of former MGP structures are shown on Figure 3.

CWG MGPs typically generated and discharged wastewater as part of normal plant operations, and the wastewater would have discharged from a "tar-water-separator" or a similar settling apparatus. There is no visible overland release or discharge associated with the MGP on historic aerial photographs. Historic information from the City of Waukegan and North Shore Sanitary District (NSSD) suggests wastewater will most likely have been discharged to the Dugan Street sewer, which flowed south along the west side of the MGP and connected to the Water Street sewer (SSWP Appendices A4 and A5). Prior to 1935, the

Water Street sewer flowed east and discharged into Lake Michigan at an outfall on the Akzo property, as shown on Figure 4. In 1935, the Water Street sewer was connected to another sewer that ran north through the Akzo property to the NSSD wastewater treatment plant. Thus, prior to 1935, MGP wastewater may have potentially discharged to Lake Michigan via the Water Street outfall, but after 1935, this water would have been treated at the NSSD plant. Based on historic data, neither the Dugan or Water Street sewers ever discharged to the Waukegan River. Historic information indicates the sewers were installed about six feet below ground surface (bgs), which is shallow enough to place them above the water table in areas of concern. A summary of significant observations obtained from the aerial photographs are below.

Year(s)	**Observations**
1937	Former MGP structures, EJ&E Railroad tracks and roundhouse, the Public Service Company of Northern Illinois coal-fired electric power plant (on Akzo property), and the Union Pacific Railroad yard and roundhouse are present. Undeveloped land and beaches to the east. The power plant water intake was present where the present-day harbor break wall is located. A vertical wall is present at the power plant lakefront and the Water Street outfall is present.
1953 &1959	Above ground MGP structures were removed and the area to the east between the EJ&E Railroad and Lake Michigan was undeveloped.
1964	Three Midland-Dexter Company (now Akzo) buildings are present (the current office and buildings to the south). Water Street no longer extends to the lakefront. The power plant and its intakes/outfalls are gone. Fill material and rip rap are present on the beach adjacent to Lake Michigan and the break wall south of the present-day South Waukegan Harbor was being extended into the lake.
1970, 1972, 1975, & 1981	Four buildings and a parking lot are on the Akzo property (current production facility) and the break wall along South Waukegan Harbor was almost complete. By 1975 a line of riprap was located along the east boundary of the Akzo parking lot adjacent to the beach (the 1981 aerial is similar to 1975).
1985,1988,1994, & 2001	The South Waukegan Harbor marina was constructed and dredged Lake Michigan sediments were used as fill to construct the WPD parking lot. An anchored sheet pile wall and rip rap are adjacent to the marina and a parking lot and roadway are on the south break wall. The lakefront beach southeast of Akzo was extended about 150 feet into Lake Michigan compared to 1937 (when the Water Street outfall was present). The later aerials look much like 1985 aerial and current conditions in the area.

1.2.2.1 Lake Front Development History

Historic WPD drawings and figures show the design and construction of the South Waukegan Harbor Marina and parking lot since the early 1980s. The drawings show the existing WPD parking lot and Administration Building were extended into the former waters of Lake Michigan. A summary of the 1980s harbor development is below.

- **1982:** an anchored steel sheet pile wall (bulkhead) was driven into the underlying clay unit about 180 feet east of the Akzo eastern property line into Lake Michigan. Two breakwaters were constructed to form the east and south boundaries of the marina.
- **1983:** between one to eight feet of sediment was dredged from inside the breakwaters to create the bottom of the South Waukegan Harbor Marina. The dredged material was placed behind the sheet pile wall to create the land for the WPD visitor parking lot.
- **1984:** the storm water sewers and associated oil/water separators and outfalls were installed about five to six feet bgs under the WPD visitor parking lots, as well as the parking lot pavement, structures and landscaping.
- **2007/2008:** WPD dredged an additional one to three feet of sediment from the southern portion of the marina and disposed of the dredge material off-site at the Waukegan airport. Analytical results indicated there were no impacts in the top 12 inches of the dredged sediment material (SSWP Appendix A7 – T.J. Thomas Associates, Inc., October 2007).

Construction records indicate the bulkhead extends at least 18.5 feet below the Lake Michigan Low Water Datum of 577.5 feet, and this is approximately 559 feet elevation North American Vertical Datum 1988. This elevation is at least 2.5 to 7 feet below the silt/clay surface.

1.2.3 Site Utilities

No subsurface utilities have been installed within the former MGP; however, multiple sanitary sewer, storm sewer, gas lines, water lines, electric lines, and telephone lines bisect the surrounding properties, as shown on Figure 4. The majority of these utilities are located on the WPD property. Additional descriptions of surface water drainage and storm sewers utilities are included in the Section 1.2.4.

1.2.4 Topography and Drainage

The Site is generally flat and near an elevation of approximately 597 feet above mean sea level (MSL) according to the United States Geological Survey (USGS) 7.5-Minute Waukegan Quadrangle (USGS, 1993). Regional surface water generally flows east and southeast into Lake Michigan. Lake Michigan water levels have been recorded by the USACOE since 1918. Historic water levels have fluctuated over time with a record low of 576.0 feet MSL in March 1964 and a record high of 582.5 feet MSL in October 1986 (USACOE, 2012).

Local and Site surface water flow is predominately controlled by urban infrastructure, including paved sidewalks, streets, parking lots, building structures and sewer systems. The ground surface in the Site vicinity consists of grass vegetation, buildings, and asphalt-paved parking lots and roads. According to the Federal Emergency Management Agency, the Site is not located within the 100-year floodplain. [1]

Lake Michigan is the closest surface water body and is located approximately 600 feet east of the former MGP. Multiple storm sewer inlets are located on or near the WPD and Akzo properties and these inlets direct surface water into the COW combined sewer system for treatment at the NSSD plant. According to the SSWP (BMc, September 2008) these inlets were installed at elevations too high for potential MGP residuals to enter and the fill in which they were placed was installed after MGP operations had ceased, suggesting they are not a conduit for MGP residual migration. In addition, the sand soil and fill, which are of an alluvial beach origin and have relatively high permeability, reduce the potential that preferential flow paths for contaminant migration develop along utility corridors or other subsurface features in the area.

Much of the surface water on the former MGP infiltrates into the ground because most of this area is vegetated. Other surface water discharges into the sewers along South Pershing Road. Storm sewers installed in the 1980s as part of the harbor development discharge to Lake Michigan after the storm water is passed through oil/water separators on the WPD property. The Waukegan River, which flows east into Lake Michigan, is located approximately 1,000 feet south of the former MGP and adjacent to Akzo. No wetland areas are present within the Site boundaries based on the United States Fish and Wildlife Service National Wetland Inventory maps.[2]

1.2.5 Site Geology/Hydrology

Site geology generally consists of fill, underlain by an alluvial sand layer, which is underlain by a low-plasticity clay layer. Additional information about these generalized stratigraphy are included in the below bullets.

[1] Lake County, Illinois . 2014. FEMA Floodplain Map Viewer. http://maps.lakecountyil.gov/mapsonline/
[2] U.S. Fish and Wildlife Service. 2014. National Wetland Inventory. http://www.fws.gov/wetlands/Data/Mapper.html

- **Fill –** Primarily sand with lesser amounts of gravel, slag, and wood fragments. Thickness ranges from two feet on the west side of the Site to 20 feet adjacent to Waukegan Harbor. In paved areas, the fill includes approximately three inches of asphalt and up to eight inches of sub-base.

- **Sand Unit –** Primarily natural fine-grained silty sand of alluvial origin. The top of the sand unit was encountered from one to four feet bgs, with an average thickness of approximately 14 feet.

- **Clay Unit –** Primarily very stiff to hard, low plasticity silty clay. Top of clay was encountered at depths ranging from 14 to 18 feet bgs across the majority of the Site but was present as shallow as 4.5 to 6 feet bgs near the Waukegan River. Figure 5 shows the top of the clay-confining unit beneath the Site.

The alluvial sand unit is the primary water-bearing unit at the Site and has an estimated conductivity of 1×10^{-3} centimeters per second (NRT, January 2014). Shallow groundwater is encountered within the alluvial sand unit about seven feet bgs and groundwater contours indicate flow is east toward Lake Michigan. Localized radial groundwater flow is evident near the sheet pile wall along the harbor. Groundwater water elevations for the March 2013 sampling event are presented in Figure 6.

1.2.6 Surface Water Flow

Waukegan Harbor and Lake Michigan are located approximately 600 feet east of the MGP. The predominant currents in Lake Michigan are north to south. Schwab and Beletsky (February 2003) chronicled Lake Michigan to be predominantly a counter-clockwise gyre, indicating the flow in the vicinity of Waukegan and surrounding communities to be north to south.

The Waukegan River is located approximately 1,000 feet south of the MGP and flows east into Lake Michigan. According to the Great Lakes Commission, the Waukegan River drains a 12 square mile watershed area. The watershed is highly urbanized, containing only 13 percent undisturbed land, and lack of a natural floodplain area has limited expansion of flow in the Waukegan River, causing erosion to occur in the channel itself. Currently, few storm water detention basins exist and bank erosion in the area is a direct cause of sedimentation into Lake Michigan.[3] Erosion in the channel releases urban contaminants that affect the water and sediment quality in the river and at its mouth. However, it is unlikely the river influences Lake Michigan currents for any more than brief periods during large storm events.

[3] Great Lakes Commission. 2012. http://www.glc.org/tributary/models/waukegan.html

1.2.7 Previous Investigations Performed

Site investigation activities have been performed since the early 1990s. Most site investigation and interim remedial activities on the MGP and WPD properties were conducted in accordance with Illinois EPA (IEPA) Site Remediation Program, as defined in Chapter 35 of the Illinois Administrative Code (IAC), Part 740 (35 IAC, Part 740). Investigations completed prior to the interim soil remediation activities on the MGP focused on identifying locations of MGP-residuals and evaluating soil and groundwater conditions. Investigation activities included test pits, soil borings, soil probes, and groundwater wells. Soil and groundwater samples were collected and analyzed for a variety of constituents of potential concern (COPC). Investigations completed after the soil remediation activities on the MGP primarily focused on delineating the extent of impacts to groundwater on the WPD property as well as the delineation and recovery of DNAPL from the NSG and WPD properties.

Entities investigating the site, and the order in which they completed their investigations, include the IEPA, Barr Engineering Company (Barr), BMc, and NRT. Brief descriptions of the previous investigations completed by each are presented below and the referenced reports were previously submitted to USEPA.

1.2.7.1 Illinois Environmental Protection Agency Investigations

A preliminary site inspection was conducted on September 17, 1991 and in November 1991. The IEPA collected 11 surface soil samples on the former MGP property as part of a screening site inspection. Based on the inspection and the analytical result, IEPA recommended the former MGP be placed on the Comprehensive Environmental Response, Compensation, and Liability Information System and be assigned a medium priority status.

1.2.7.2 Barr Engineering Company Investigations

Following the work by IEPA, Barr conducted a preliminary site investigation in the early 1990s to determine if there was a potential for environmental impact at the former MGP. The preliminary site investigation concluded constituents associated with past MGP activities might be present in subsurface soil. The findings of this investigation were summarized in a Preliminary Site Investigation Report (Barr, 1993).

Barr conducted a site investigation in 1999 to compile and evaluate previously collected data, evaluate the nature and extent of impacts, and obtain additional data to assess risks present at the former MGP. The majority of the 1.9 acres of the former MGP property were addressed, excluding the paved portions of South Pershing Road and South Harbor Place. Eight trenches and four soil borings (which were converted into temporary piezometers) were completed. Soil samples were collected and analyzed for volatile organic compounds (VOCs), polynuclear aromatic hydrocarbons (PAHs) and total organic carbon. Water samples collected from the piezometers were analyzed for VOCs, PAHs, various metals, and cyanide species. The majority of the soil samples exceeding Tiered Approach to Corrective Action Objectives (TACO) Tier 1 levels (as defined in 35 IAC, Part 742) were collected in the upper three feet of soil. Impacts identified in samples collected three feet bgs or deeper were related to suspected petroleum-like material near the water table. Impacts from both tar and petroleum compounds were suspected to be present in soil and groundwater at the former MGP. The Site Investigation Report (Barr, June 2002) was submitted to IEPA, which determined additional work was necessary.

1.2.7.3 Burns & McDonnell Investigations

Between 2002 and 2006, BMc conducted a number of investigations on the MGP and adjacent properties. Investigations were completed for specific objectives, and those completed prior to submittal of the SSWP are summarized below along with the reference for each report submitted to IEPA.

June – Sept. 2002	Supplemental site investigation activities. The objective was to address data gaps in the Barr site investigation and further delineate the lateral and vertical extent of source material through 21 soil probes and 22 soil borings advanced on the former MGP property. Three soil borings were advanced in the WPD property parking lot and maintenance yard east of the former MGP. Select soil samples were collected and analyzed for target compound list (TCL) VOCs, TCL semi-volatile organic compounds (SVOCs), priority pollutant metals, and total cyanide. Four soil borings, including three on the WPD property, were converted to groundwater monitoring wells. Groundwater samples were collected from the wells and analyzed for TCL VOCs, TCL SVOCs, priority pollutant metals, and total cyanide. Test pits were excavated on the former MGP to further define known and suspected source material areas based on visual observations. Both soil and groundwater samples exceeded TACO Tier 1 Screening Levels for various PAHs and the VOCs benzene, toluene, ethylbenzene and xylene (BTEX). Source material was observed and characterized as tar saturated soil and DNAPL. The work was summarized in the February 2003 *Supplemental Site Investigation Report (BMc, February 2003)* and approved by IEPA in an April 7, 2003 letter.
July 2003	Additional investigation activities to establish remediation objectives. Further definition of the extent of suspected source material (based on visual characterization) was intended with 18 soil borings advanced on the former MGP and select soil samples collected and analyzed for TCL VOCs, TCL SVOCs, priority pollutant metals and total cyanide. Three areas containing potential source material above the water table (based on visual identification and/or laboratory analysis) were identified. COPCs in soil above the water table included BTEX, PAHs, arsenic and lead. The *Remediation Objectives Report and Remedial Action Plan for Soil Above the Water Table* was submitted to IEPA (BMc, November 2003) and proposed removal of the top 3.5 feet of soil across the entire MGP and remove source material in locations to the water table (approximately 7 feet bgs).

June –Aug. 2003	Offsite investigation activities to delineate the extent of groundwater impacts associated with the former MGP on the WPD property. Twenty-three (23) soil borings were advanced on WPD property and six were converted to monitoring wells. Groundwater samples collected from the wells on the former MGP and WPD properties were analyzed for TCL VOCs, TCL SVOCs, priority pollutant metals, total and amenable cyanide, and pH. Three areas on WPD property were identified on the southwest corner of the boat parking lot, the northwest corner of the maintenance yard, and the south property boundary of the maintenance yard (areas directly east of the former MGP).that exhibited tar-like DNAPL or tar-saturated soil. These impacts were observed between 6 and 16 feet bgs within the fluctuation zone of the water table and/or on top of the clay unit. The *Offsite Investigation Report of the Adjacent Waukegan Port Authority Property* (BMc, December 2003) was submitted to IEPA in December 2003 and approved June 2004.
Feb. - March 2004	Four soil borings and 24 soil probes were advanced on the Akzo property to characterize soils deeper than 10 feet bgs. The upper 10 feet of each location was blind drilled and not characterized in accordance with the Akzo access agreement. Visual observations of soil type and conditions at depths from 10 to 24 feet bgs were recorded on drilling logs. MGP and petroleum-like odors were identified in most locations, but no samples were collected because of the access agreement. The *Offsite Investigation of the Adjacent Akzo Nobel Property* (BMc, March 2004) report was submitted to IEPA in March 2004.
May 2004	Supplemental offsite investigation to further delineate the extent of groundwater impacts on the WPD property. Thirty-eight borings were advanced and 17 were converted to groundwater monitoring wells. Groundwater samples from these and prior wells were analyzed for TCL VOCs, TCL SVOCs, priority pollutant metals, total and amenable cyanide. Two additional areas characterized as tar-like DNAPL or tar-saturated soil were identified on the southeast corner of the boat parking lot and northwest corner of the visitor parking lot. These impacts were observed between 6 and 22 feet bgs (within the water table fluctuation zone or on top of the clay unit). The *Supplemental Offsite Investigation Report of the Adjacent Waukegan Port Authority Property* (BMc, July 2005) was submitted to IEPA in July 2005.
May 2005	MFG, Inc. performed a ground-penetrating radar survey at the South Plant MGP to determine the presence and location of former structures beneath South Pershing Road, and potential subsurface features and anomalies were identified. These data were included in the BMc July 2005 *Summary Letter Report–Ground Penetrating Radar Survey* as well as the SSWP.
May – Aug. 2005	Groundwater investigation activities were completed on the MGP and WPD properties. Work included installing and developing groundwater monitoring and DNAPL recovery wells; and collecting groundwater samples from newly installed and previously existing wells. The objective was to obtain groundwater data for both properties during a single sampling event. Sixty 2-inch diameter groundwater monitoring wells were installed in areas identified during this and previous investigation activities (42 and 18 on the MGP and WPD properties, respectively). Nine 6-inch diameter DNAPL recovery wells were also installed on the former MGP and WPD property to the east. Wells installed to the east are located in the boat parking lot, the maintenance building parking area, and the Administration building parking lot.

NATURAL RESOURCE TECHNOLOGY

	Groundwater levels and samples were collected from 67 of the 87 monitoring wells; 20 wells were not measured or sampled due to the presence of DNAPL. The 67 groundwater samples were submitted for laboratory analysis for TCL VOCs and TCL SVOCs. The *NSG – South Plant and Waukegan Port District 2005 Groundwater Investigation Activities* report was submitted to IEPA in August 2007.
Aug. 2005	A DNAPL investigation on the NSG and WPD properties included installation of additional monitoring wells and soil sampling for forensic analysis. Soil samples were generally collected near the water table and/or the clay/sand interface, and 88 samples were submitted for laboratory analysis. Samples were selected based on Photoionization Detector readings, odors, or visual evidence of impacts. Separate reports were prepared for the NSG and WPD properties and these reports, the *NSG – South Plant 2005 DNAPL Investigation* and the *NSG – Waukegan Port District 2005 DNAPL Investigation* (BMc, August 2007a, August 2007b, and August 2007c), were submitted to USEPA in August 2007. The results indicate that while petroleum hydrocarbons are present across the former MGP property, the majority of impacts on the WPD property are MGP related.
Dec. 2005	Five soil gas samples from a depth of approximately 4.7 to 5 feet bgs were collected near the WPD maintenance building. Evaluation of the soil gas results using the Johnson and Ettinger Model (USEPA 1991) indicated a low risk potential for vapor intrusion to indoor air within the WPD maintenance building. The *NSG – Waukegan Port District Soil Gas Investigation Report* (BMc, June 2006) was submitted to IEPA in June 2006.
Sept. 2006	A second round of groundwater sampling was completed to obtain water quality data for MGP and WPD properties during a single sampling event. Samples were collected from 67 of the 87 wells (two were damaged and 18 could not be sampled because they were dry, obstructed, or contained DNAPL). Groundwater samples were analyzed for TCL VOCs and TCL SVOCs. The *NSG – South Plant and Waukegan Port District 2006 Groundwater Sampling Activities* (BMc, September 2007) report was submitted to IEPA in September 2007.

1.2.7.4 Previous Harbor Sediment Sampling and Maintenance Dredging

In October 2007, the WPD collected sediment samples from the south half of the marina prior to dredging to maintain navigation depths. Samples were collected from six locations to a depth of two feet below top of sediment, and results indicated the material was dominated by fine sand and silt. Analytical results indicate the following:

- Petroleum volatile organic compounds concentrations were below detection levels.
- Benzo(a)pyrene was the only PAH to exceed the Taco Tier 1 residential ingestion objective value of 0.09 milligrams per kilogram (mg/kg) in three sediment samples (results range from 0.24 to 0.33 mg/kg), but residential ingestion is not an applicable exposure pathway given Site conditions as discussed in Section 5 of the RI Report (NRT, January 2014). In addition, benzo(a)pyrene concentrations were below the background value of 2.1 mg/kg for a metropolitan area.
- Total PAH concentrations are below the Probable Effects Concentration of 22.8 mg/kg.
- All other analytical results were below applicable Taco Tier I and state of Illinois groundwater standards.

1.2.8 Previous Remedial Actions

Completed response actions include removal of impacted soil above the water table on the former MGP property and the DNAPL recovery from recovery wells on the MGP and WPD properties. Brief descriptions of these response actions are below.

1.2.8.1 Remedial Action for Soil above the Water Table

Between December 2003 and February 2004, all soil above the water table on the former MGP property was excavated and disposed off-site as part of a focused remediation effort. Excavation of the top 3.5 feet of soil across the entire property was completed along with deeper excavation up to depth of nine feet in suspected source material areas as identified in Figure 7. Material removed from excavated areas consisted of fill, soil, suspected source material (characterized as tar-impacted fill/soil), piping, and debris. After successful removal of suspected source material, 36 soil confirmation samples indicated impacted material above the water table was removed except under the South Pershing Road right-of-way and along the west property boundary (which was later investigated as part of the RI Activities (NRT, January 2014).

Following excavation and confirmation sampling, a plastic liner was placed within the excavations to separate the clean imported backfill from the potentially impacted soil below. Plastic liners were also placed along the sidewalls of excavations located adjacent to the South Pershing Road right-of-way and along the western property line to prevent impacts within the right-of-way and from off-site from migrating into the clean imported backfill. Approximately 19,223 tons of excavated material was disposed as nonhazardous special waste at the Subtitle D Waste Management Countryside Landfill in Grayslake, Illinois. These remediation activities were summarized in the *Remedial Action Completion Report For Soil Above the Water Table* (BMc, March 2005), which was submitted to IEPA in March 2005.

1.2.8.2 DNAPL Recovery Activities

DNAPL recovery activities consist of removal of accumulated DNAPL within twelve 2-inch vertical monitoring wells and seven 6-inch diameter vertical recovery wells. DNAPL recovery activities commenced in April 2006 and are ongoing as of March 2015. Initially, recovery events occurred at approximate 3-week intervals; however, in beginning in May 2007 recovery activities transitioned to approximately 6-week intervals. DNAPL recovery was suspended during the sub-slab vapor investigation to avoid potential impact to vapor soil vapor sampling results.

DNAPL recovery events consist of measuring DNAPL thickness using a weighted string. The thickness of DNAPL in each well is recorded to track trends of DNAPL accumulation. Following thickness measurement, a peristaltic pump is used to extract DNAPL from wells with measurable DNAPL thickness. Volume estimates are recorded from each well as the DNAPL is pumped directly to Department of Transportation approved steel drums. DNAPL is manifested and transported offsite as D001 (Ignitable) RCRA hazardous waste. The manifest lists North Shore Gas as the generator, SET Environmental as the transporter, SET Environmental – Houston as the designated facility, and H141 (Transfer Offsite) as the management method code. Once the waste is received by SET Environmental – Houston, the generator status is transferred from North Shore Gas to SET Environmental. The DNAPL may be consolidated with like material and is shipped to a cement kiln using the Reclamation and Recovery Management Method Code H050 in accordance with RCRA hazardous waste recycling regulations. Recovery activities are ongoing and as of January 2015, DNAPL recovery activities have resulted in the removal approximately 1,370 gallons from the Site.

1.3 Nature and Extent of DNAPL Contamination

Since 2009, the groundwater sampling protocol includes documenting the presence and thickness of DNAPL in groundwater wells while performing groundwater sampling. Observations of DNAPL in Site wells are summarized in Appendix A. Figure 8 presents the extent of DNAPL contamination based on the March 2013 through March 2014 groundwater sampling events. The figure identifies two distinct zones of DNAPL impacts radiating from the former MGP. The first zone is a 150-ft wide DNAPL plume that radiates from the north side of the former MGP, following a localized depression in the confining clay layer and extending to the northeast, under South Harbor Place Drive, into the southwest corner of the WPD parking lot.

The second zone of DNAPL impacts radiates to the southeast of the former MGP where the plume is approximately 200 feet wide, underneath the WPD maintenance building/Akzo facility to a localized depression in the confining clay layer located west of the WPD Administration Building, where the plume is approximately 425 feet wide.

2 DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

2.1 Summary of Baseline Risk Assessment

A Baseline Risk Assessment (BLRA) was completed as part of the RI Report (NRT, January 2014) evaluated soil, groundwater, soil vapor, surface water, and sediment data against appropriate screening levels identified in the Multi-Site Risk Assessment Framework (Exponent, 2007). The BLRA evaluated DNAPL as a source of contamination of soil, groundwater, and soil gas, rather than a media itself. As a result, a comprehensive risk assessment specific to DNAPL was not completed. The BLRA did discuss exposure pathways to DNAPL as part of evaluation of soil, groundwater, soil vapor, surface water, and sediment. A summary of these exposure pathways is included below.

2.1.1 Human Health Receptors

The BLRA evaluated the current and potential future land uses at the Site. Under current and potential future land-use conditions at the Site, the potential human receptors and the associated exposure pathways are graphically presented in the conceptual site model in Figure 9 and summarized below:

- **Industrial/Commercial Land Use - Worker**: through incidental ingestion, dermal contact, vapor intrusion, and inhalation of DNAPL affected soil (as a result of soil disturbance). Dermal exposure and ingestion of DNAPL is not expected due to the depth to groundwater and DNAPL (ranging from six to 13 feet bgs – below depths encountered for landscaping activities) and public water supply.

- **Industrial/Commercial Land Use – Construction Worker:** through incidental ingestion, dermal contact, and inhalation of DNAPL affected soils (as a result of soil disturbance) and groundwater, surface water, and sediment via dermal contact and inhalation.

- **Recreational Land Use – Visitor:** through incidental ingestion and dermal contact with surface water and sediment potentially impacted by DNAPL.

- **Residential Land Use** (the residential land use is a hypothetical future land use scenario for informational purposes)**:** through incidental ingestion and dermal contact of DNAPL impacted soil (surface and subsurface) as a result of soil disturbance, inhalation of vapors and dust as a result of soil disturbance, and inhalation of vapors as a result of vapor intrusion from DNAPL impacted subsurface soil and groundwater.

As described in the BLRA, construction worker scenario was evaluated in a semi-quantitative manner and recreational use was evaluated using a site-specific quantitative approach.

2.1.2 Potential Human Health Risks

In some areas of the Site, DNAPL is present near or below the water table and so will also pose an exposure concern if intrusive activities occur associated with future construction projects. If construction activities in the area are expected to result in workers having direct contact with groundwater or DNAPL, this potential exposure should be evaluated before work proceeds. Concern with off-gassing of the DNAPL and associated potential vapor intrusion was evaluated through soil vapor sampling.

2.1.3 Ecological Receptors and Risk

The BLRA evaluated the ecological risks at the Site and concluded that the upland area of the Site does not support habitat for ecological receptors due to the developed nature of the properties, consistent with the commercial/industrial zoning of the land. The BLRA also concluded that the nature and concentration of the COPCs detected in surface water and sediment in the marina, Lake Beach, and open-water environment is not expected to pose an ecological concern. Potential risks associated with future DNAPL that could potentially discharge into the marina will be addressed through upland DNAPL management.

2.2 Applicable or Relevant and Appropriate Requirements

Section 121 of CERCLA requires, subject to specified exceptions, that remedial actions must be protective of human health and the environment. In addition, remedial actions performed under the Superfund program must be undertaken in compliance both state and federal Applicable or Relevant and Appropriate Requirements (ARAR). The NCP defines applicable requirements as:

> "…those clean-up standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable."

The NCP defines relevant and appropriate requirements as:

> "…those clean-up standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws, that, while not 'applicable' to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate."

In addition to ARARs, the USEPA may identify other relevant information, criteria, or guidance as to be considered (TBC). TBCs may not be legally binding or enforceable but may be useful for consideration when developing remedial alternatives. Both ARARs and TBCs may be chemical-specific, location-specific, or action-specific. Table 1 summarizes preliminary federal and state ARARs and TBCs. The ARARs and TBCs may be modified until a ROD is issued and may be reexamined during the five-year review process if a new or modified requirement calls into question the protectiveness of the selected remedy.

2.2.1 Chemical-specific ARARs

Chemical-specific ARARs are generally health or risk based standards that define concentration limits for environmental media or discharges. These requirements may be used to set cleanup levels for constituents of concern in environmental media.

2.2.2 Location-specific ARARs

Location-specific ARARs are based on the Site's characteristics or location including natural site features such as wetlands, floodplains, and endangered or threatened species and habitats. Location-specific ARARs may also apply to man-made features such as cultural resource areas.

2.2.3 Action-specific ARARs

Action-specific ARARs are technology-based or activity-based limits that guide how the remedial action will be implemented or how remedial waste may be handled.

2.3 Development of Preliminary Remediation Goals

For soil, soil vapor, and groundwater impacts, preliminary remediation goals (PRGs) are typically developed based on an acceptable cumulative risk threshold or acceptable chemical concentration values. The USEPA views free product (i.e. DNAPL) as a principal threat waste, and thus there is no acceptable risk threshold or chemical concentration value to present as a PRG. In the absence of numeric guidelines, the PRG for DNAPL will be defined as the Remedial Action Objective for DNAPL as presented in Section 2.4.

Although a PRG has not been developed for DNAPL as part of this Focused FS, PRGs for soil, soil vapor, and groundwater will be developed, where necessary, as part of the future FS addressing former MGP impacts that remain following the completion of the interim DNAPL remedy. Given that DNAPL acts as the primary source of contamination for the remaining media, development of PRGs for the remaining media will also address any potential residual DNAPL present at the conclusion of the interim DNAPL remedy.

2.4 Remedial Action Objectives

An RAO describes the goal(s) that the proposed remedial action is expected to accomplish. An RAO provides a basis to evaluate the process options discussed in Section 3 and the remedial alternatives evaluated in Section 4. Typically there are separate RAOs to address each impacted media or anticipated exposure route. Due to the focused nature of the Focused FS, the following RAO has been developed, in coordination with the USEPA, to address DNAPL:

- Reduce the mass and mobility of recoverable DNAPL to the extent practicable.

Additional RAOs for the remaining former MGP impacts will be developed as part of a future Site-wide FS, which will address the remaining impacted media. The future FS will be completed as a separate document from this Focused FS.

2.5 Areas and Volumes of DNAPL Contamination

An area of DNAPL contamination is typically determined by field observations of free product within soil boring logs and/or field observations of accumulated DNAPL within Site groundwater monitoring wells. Throughout Site investigations, over 100 monitoring wells and 100 soil borings were advance to delineate the extent of MGP-residuals. Based on the field data collected during these investigations, a model estimating the surface area, thickness, and volume of DNAPL was developed. Information from this model was used to evaluate conceptual remedial alternatives and develop associated costs. To complete this model, the below process was followed. A summary of the model parameters and results is included in Appendix C1.

- **Step 1** – Wells representative of the potential DNAPL bearing zone (i.e. bottom of screened interval near to, at, or slightly into the confining clay layer) were identified. The elevation of DNAPL as collected during recent groundwater sampling events was tabulated and imported into the Site GIS database.

- **Step 2** –ESRI ArcMap GIS Geostatistical Analyst Extension was used to develop a surface, modeling the thickness of DNAPL on top of the clay layer throughout the Site. The radial basis data interpolation function was selected because it honors the elevation and location of field results while performing interpolations. The Geostatistical Analyst Extension was used to optimize the interpolation by iteratively running multiple scenarios to determine the most accurate model scenario. This predicted DNAPL surface was compared against the confining clay surface to calculate the volume of media impacted by DNAPL. This volume represents the total volume of soil, groundwater, and DNAPL.

- **Step 3** – The total volume obtained in Step 2 was multiplied by a range of literature provided porosity values for sand. The resulting volume range represents the volume of fluid in soil pore spaces impacted by DNAPL (i.e. sum of groundwater and DNAPL volumes).

- **Step 4** – The volume range obtained in Step 3 was multiplied by a range of literature provided fractional DNAPL saturation values. The resulting volumes represent the range of potentially recoverable DNAPL.

Based on the above process, Table A presents the probably range of potentially recoverable DNAPL at the Site. For purpose of this Focused FS, the average volume estimate of 527,000 gallons will be used as the estimated volume of potentially recoverable DNAPL.

Table A – Summary of DNAPL Volume Estimate

Property	Low	Average	High
Volume From GIS Spatial Analysis (cubic yards)	15,205	15,205	15,205
Effective Porosity (volume/volume)[1]	0.28	0.31	0.33
Fractional DNAPL Saturation (volume/volume)[2]	0.40	0.55	0.70
Total Volume DNAPL (cubic yards)	1,703	2,608	3,512
Total Volume DNAPL (gallons)	**344,000**	**527,000**	**710,000**

1 - Based on Morris and Johnson, 1967
2 - Based on Pankow and Cherry, 1996

The areas and volumes of DNAPL presented in this subsection are based the thickness of DNAPL observed during groundwater sampling activities and should be considered sufficient for a comparative analysis of FS-level remedial alternatives. Depending on the selected remedy, pre-design investigations may be beneficial to further refine the areas and volumes of DNAPL prior to final design and subsequent implementation of remedial measures.

NATURAL RESOURCE TECHNOLOGY

3 DEVELOPMENT AND SCREENING OF TECHNOLOGIES

3.1 General Response Actions

General Response Actions (GRAs) are those actions that may satisfy the RAO. The GRAs for DNAPL at the Site are as follows:

- **No Action –** Provides a baseline for comparison with other alternatives and is required by the NCP.
- **Institutional Controls -** Prevents human exposure to DNAPL but does not address reducing toxicity, mobility, or volume of DNAPL.
- **Monitored Natural Recovery -** Use and monitoring of natural degradation processes to reduce toxicity, mobility, or volume of DNAPL.
- **Containment -** Limits or controls the migration/mobility of DNAPL beyond the present boundary into adjacent areas but does not contribute to reducing toxicity or volume.
- **In-Situ Treatment –** Use processes implemented while the contamination remains in place (in-situ) to reduce the toxicity, mobility, or volume.
- **Ex-Situ Treatment –** Use processes implemented while the contamination is removed (ex-situ) to reduce the toxicity, mobility, or volume.

Each of these response actions were compared with the RAO. Only GRAs applicable to the Site were included in Table 2, with subsequent screening of individual technologies and process options for these GRAs in Table 3.

3.2 Identification and Screening of Technology Types and Process Options

Each of the respective technology types and process options for each GRA were evaluated against following criteria (in order):

- **Implementability**: This criterion addresses the technical and administrative feasibility of implementing the technology as well as the availability of contractors and materials, the potential Site constraints (on- and off-site), the difficulties monitoring the effectiveness of the process option, and agency coordination or permits.

NATURAL RESOURCE TECHNOLOGY

- **Effectiveness**: This criterion evaluates the ability of a technology to achieve the RAO and to provide long-term protection of human health and the environment. Potential short-term impacts to human health and the environment, and the reliability of the technology are also evaluated.
- **Cost**: This criterion utilizes engineering judgment to develop relative estimated costs of each technology for a given RAO. The cost estimates are qualitative (low, moderate and high) at this technology screening stage of the FS.

With respect to these criteria, the foremost criterion was implementability. If a determination was made that the technology was not implementable, it was eliminated from further evaluation. At this stage of screening, cost alone was not necessarily considered a primary criterion for eliminating a technology type or process option. Cost considerations will be weighed more heavily as part of the Comparative Analysis included in Section 5.

3.3 Remedial Alternatives

At the conclusion of initial screening completed in Section 3.2, the following DNAPL remedial alternatives were retained for further considered in Section 4:

- D1 – No Action
- D2 – Institutional Controls
- D3 – Vertical Engineered Barrier
- D4 – Horizontal Well DNAPL Recovery
- D5 – Physically Enhanced DNAPL Recovery
- D6 – Chemically Enhanced DNAPL Recovery
- D7 – Thermally Enhanced DNAPL Recovery

4 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

This section presents detailed descriptions and evaluations of the DNAPL remedial alternatives retained for consideration as part of the preliminary analysis completed in Section 3. The objective of this section is to provide sufficient remedial alternative descriptions and evaluations to allow for adequate comparison and selection of the most appropriate remedy. In addition, the detailed descriptions discuss the assumptions made to prepare cost estimates for each alternative. The details of the selected remedy will be refined through the remedial design phase.

In accordance with CERCLA Section 121, the NCP, and USEPA Remedial Investigation and Feasibility Study (RI/FS) guidance (USEPA, 1988), the DNAPL remedial alternatives were evaluated against seven evaluation criteria. These criteria include the following two threshold criteria and five balancing criteria:

Threshold Criteria

- **Overall Protection of Human Health and the Environment –** This criterion assesses how well each alternative, as a whole, achieves and maintains protection of human health and the environment.

- **Compliance with ARARs –** This criterion assesses how the alternatives comply with location-, chemical-, and action-specific ARARs, and whether a waiver is required or justified. The ARAR assessment also addresses TBCs identified by USEPA.

Balancing Criteria

- **Long-Term Effectiveness and Permanence –** This criterion evaluates the long-term effectiveness of the alternative in maintaining protection of human health and the environment after the RAO identified in Section 2.4 has been met. This criterion includes consideration of the magnitude of residual risks and the adequacy and reliability of controls.

- **Reduction of Toxicity, Mobility, or Volume through Treatment –** This criterion evaluates the effectiveness of treatment processes used to reduce toxicity, mobility, or volume of DNAPL. It also considers the degree, to which treatment is irreversible, and the type and quantity of residuals remaining after treatment.

- **Short-Term Effectiveness –** This criterion examines the effectiveness of the alternatives in protecting human health and the environment during the construction and implementation of a remedy until the RAO identified in Section 2.4 has been met. It considers the protection of the community, workers, and the environment during implementation of remedial actions.

- **Implementability –** This criterion assesses the technical and administrative feasibility of an alternative and availability of required goods and services. Technical feasibility considers the ability to construct and operate a technology and its reliability, the ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of a remedy. Administrative feasibility considers the ability to obtain approvals from other parties or agencies and the extent of required coordination with other parties or agencies.

- **Cost –** This criterion evaluates the direct and indirect capital, and annual operation and maintenance costs of each alternative. Present worth costs are presented to properly compare the total costs for the various remedial alternatives. Cost estimates are intended to be within an accuracy range of plus 50 percent to minus 30 percent.

  Present worth costs for each remedial alternative are provided in Appendix B and include:

  - Consulting costs, including engineering design, plans and specifications, permitting, oversight, and documentation as a percentage of the construction capital costs.

  - Annual operation and maintenance costs, if applicable.

  - A 25% contingency on construction capital costs to account for unforeseen project complexities such as adverse weather, unexpected subsurface conditions, increased standby times, etc.

  At request of USEPA, present worth costs were calculated using a real discount rate of 7%. This discount rate is consistent with the static non-federally funded site discount rate included in USEPA's July 2000 *A Guide for Developing and Documenting Cost Estimates During the Feasibility Study* for sites. However, it should be noted that for federally funded sites, the July 2000 USEPA guidance document implements a dynamic approach by defaulting to real interest rates developed the Office of Management and Budget, which are updated annually to reflect current economic conditions. The real discount rate for federally funded sites in 2000, when the guidance document was published, was set at 4.2% for a 30-year analysis. Based on current (2015) economic conditions, the Office of Management and Budget suggests 1.4% is the appropriate real discount rate for 30-year present worth analysis on federally funded sites.

  Due to the fixed discount rate approach required for non-federally funded sites, the present worth estimates in this Focused FS Report underestimate the actual total O&M costs for the presented remedial alternatives. The magnitude of the underestimation in total O&M costs will vary based on the magnitude of annual O&M costs and projected duration of the remedial alternative.

Modifying Criteria

This Focused FS does not assess DNAPL remedial alternatives against modifying criteria. The modifying criteria will be addressed by USEPA based on IEPA and public comments following USEPA's selection of a proposed remedial action plan (PRAP). These modifying criteria include:

- **State Acceptance –** This criterion considers the state's technical and administrative issues and concerns regarding each alternative, including comments on ARARs or proposed use of waivers. This criterion is evaluated following comment on the RI/FS report and the PRAP and will be addressed once a final decision is made and the ROD is being prepared.

- **Community Acceptance –** This criterion considers the issues and concerns the community may have regarding each alternative. This criterion is evaluated following comment on the RI/FS report and the PRAP and will be addressed once a final decision is made and the ROD is being prepared.

4.1 ESTIMATED REMEDIAL ALTERNATIVE EFFECTIVENESS AND DURATION

As part of the detailed analysis, the effectiveness of each remedial alternative to meet the RAO and the associated duration of remedial construction and operations was estimated. Estimates of duration and effectiveness of were developed based on discussions with vendors who specialize in the particular remedial technology, review of technical literature, and/or completion of FS-level modeling. Estimating the potential ability of each remedial alternative to achieve the RAO can be performed with a reasonable degree of certainty due to the relatively permeable and relatively homogeneous DNAPL bearing zone at the Site.

Accurate estimations of the duration to meet the RAO for DNAPL recovery remedies (Alternatives D4 through D7) cannot be performed with a reasonable degree of certainty at this time. The recovery of DNAPL is highly complex and highly dependent on DNAPL flow properties that are not easily measured or modeled. Many of these DNAPL flow properties not only vary spatially throughout the Site but also vary with time, based on volume of DNAPL recovered.

The challenge of modeling a DNAPL recovery system is typically addressed by calibrating an oil flow model with a field-refined-flow-path-permeabilities-ratio to provide results similar to actual DNAPL recovery rates. Calibration of an oil flow model with a field-refined-flow-path-permeabilities-ratio was used to model a physically enhanced recovery system at a creosote site in Wyoming (Sale et al., 1997). The selected ratio at this Wyoming Creosote Site varied based on different site zones to best fit the actual field recovery data at each zone. A similar generic oil flow model modified with an estimated flow-path-permeabilities-ratio was used to estimate the durations of the DNAPL recovery alternatives presented in this report (Appendix C). The resulting duration estimates are appropriate to compare relative magnitudes between alternatives; however, accurate estimates of duration can only be developed based on field recovery rates for a pilot-scale or full-scale recovery events.

In addition, the durations included in these sections account for the construction and operation of the alternatives. Prior to construction activities, all of the implemented alternatives will also require completion of a remedial design and securing access agreements for work to be performed on properties not owned by NSG.

For purposes of the Focused FS, estimated durations to achieve the RAO were based on field data, the best available vendor estimates, and the most applicable feasibility study level modeling. These duration estimates may be increased or decreased based on results from field pilot-scale studies and full-scale implementation. Therefore, rather than placing a disproportionate degree of consideration on duration to achieve the RAO, remedy selection should appropriately balance all evaluation criteria.

4.2 D1 – No Action

Consistent with NCP requirements, a No Action alternative was considered. This alternative does not include remediation or monitoring to minimize potential exposures related to DNAPL itself, DNAPL to groundwater, or DNAPL to surface water pathways. The No Action alternative is used as a baseline for comparisons of other remedial alternatives. In accordance with CERCLA, Site reviews will be performed every five years for Alternative D1.

4.2.1 Overall Protection of Human Health and the Environment

Alternative D1 will not meet the requirement for overall protection of human health and the environment. Potential risks to human health and the environment will remain due to the presence of DNAPL. Further, this alternative does not provide protection to human health or the environment because institutional controls, monitoring programs, or contingencies will not be implemented.

4.2.2 Compliance with ARARs

Alternative D1 will partially comply with or attain the ARARs identified in Table 1 and NCP requirements. The USEPA views the DNAPL present at the Site as a principal threat waste. The NCP, in 40 CFR 300.430(a)(1)(iii), states the following:

- EPA expects to use treatment to address the principal threats posed by a site, wherever practicable. Principal threats for which treatment is most likely to be appropriate include liquids, areas contaminated with high concentrations of toxic compounds, and highly mobile materials.
- EPA expects to use engineering controls, such as containment, for waste that poses a relatively low long-term threat or where treatment is impracticable.

Alternative D1 does not involve treatment or engineering controls to address DNAPL and therefore, Alternative D1 does not comply with NCP requirements. Location and action-specific ARARs are not relevant because there is no action associated with this alternative.

4.2.3 Long-Term Effectiveness and Permanence

Alternative D1 will not provide long-term effectiveness and permanence because no remedial action will be taken and the DNAPL present at the site is not expected to attenuate naturally. Therefore, the degree of risk will not be reduced. Further, because this alternative will not achieve the RAO or include monitoring or contingency actions, the long-term effectiveness and permanence of this alternative cannot be assured. Alternative D1 will not treat or remove any contaminated media and therefore, the residual risk will be comparable to the current risk.

4.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative D1 will not reduce the toxicity, mobility, or volume of the DNAPL through treatment because no remedial action is implemented. The DNAPL present at the Site is not expected attenuate naturally, therefore, this alternative will not achieve the RAO.

4.2.5 Short-Term Effectiveness

Alternative D1 will not present any short-term risks to the community or workers because there is no remedial activity associated with this alternative. Additionally, there will be no short-term impacts to the environment as the result of Alternative D1.

4.2.6 Implementability

Alternative D1 will be easily implemented because there are no activities to perform.

4.2.7 Cost

The only costs associated with Alternative D1 relate to the five-year review requirements. The five-year reviews are estimated to be $19,000 per review event over a 30-year monitoring period, resulting in a total present worth cost of approximately $50,000.

4.3 D2 – Institutional Controls

Alternative D2 will rely on institutional controls to minimize human exposure to DNAPL through non-engineered administrative and legal controls. The primary mechanism for exposure to DNAPL will be though potential consumption of groundwater, which is currently impacted by DNAPL. Alternative D2 will rely on institutional controls to restrict the use of groundwater as a drinking water source until the drinking water standards are met. To promulgate a groundwater institutional control, an ordinance will be developed in accordance with 35 Illinois Administrative Code (35 Ill. Adm. Code) 742.1015. The USEPA or IEPA may also require this ordinance to be supplemented with the an Uniform Environmental Covenant (*765 ILCS Chapter 22)* to provide additional assurances that the institutional control will continue to be enforced in the event of property transfer, adjustments in land use, etc. Upon approval by the IEPA and adoption by the Council of the City of Waukegan, a restricted groundwater zone will be created, thus prohibiting the use of DNAPL-affected groundwater as a potable water supply.

In addition, Alternative D2 will involve implementation of additional institutional controls to protect current workers and potential future construction workers against exposure to subsurface DNAPL. The specific institutional control methods will be refined during the remedial design. For the purpose of this FS Report, institutional controls to protect against exposure to subsurface DNAPL will be accomplished through a combination of land use controls and highway authority agreements as specified in 35 Ill. Adm. Code 742, Subpart J. These institutional controls will involve development of an Intrusive Activities Management Plan, which will require a safety plan to be implemented to control any intrusive activities at Site locations affected by DNAPL. The institutional controls will be referenced in the No Further Remediation Letter, provided by the IEPA to IBS. IBS will file this No Further Remediation Letter with the county deed recorder and the county deed recorder will attach the letter with the referenced institutional controls to the deeds of the affected properties.

An Institutional Control Implementation Plan will be developed during the design phase to detail groundwater use, land use, and intrusive activity limitations. Institutional controls for will be implemented within the area shown on Figure 10. For cost estimating purposes, it is assumed that the adequacy of institutional controls will be assessed in the five-year reviews for a 30-year duration.

4.3.1 Overall Protection of Human Health and the Environment

Alternative D2 will be protective of human health by implementing controls to prevent the use of Site groundwater, restricting land use, and limited intrusive activities. Alternative D2 does not prevent DNAPL or impacted groundwater from migrating to adjacent surface water resources (Waukegan River and Lake Michigan). As a result, Alternative D2 is not protective of the potential ecological receptors.

4.3.2 Compliance with ARARs

Alternative D2 will partially comply with or attain the ARARs identified in Table 1 and NCP requirements. The USEPA views the DNAPL present at the Site as a principal threat waste. The NCP, in 40 CFR 300.430(a)(1)(iii), states the following:

- EPA expects to use treatment to address the principal threats posed by a site, wherever practicable. Principal threats for which treatment is most likely to be appropriate include liquids, areas contaminated with high concentrations of toxic compounds, and highly mobile materials.
- EPA expects to use engineering controls, such as containment, for waste that poses a relatively low long-term threat or where treatment is impracticable.

Alternative D2 does not involve treatment or engineering controls to address DNAPL and therefore Alternative D2 does not comply with NCP requirements. Alternative D2 will meet the requirements of the location and action-specific ARARs.

4.3.3 Long-Term Effectiveness and Permanence

Alternative D2 will provide long-term effectiveness and permanent control of potential human health risk by legally restricting groundwater use, land use, and intrusive activities, thereby preventing human exposure to DNAPL. A potential challenge for long-term effectiveness of Alternative D2 is the multiple properties impacted by MGP residuals. In the absence of other remedial actions, Alternative D2 will not provide long-term effectiveness or permanent control of potential environmental risk.

4.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative D2 will not reduce the mobility or volume of the MGP-residuals through treatment because no remedial action is implemented. The toxicity of MGP-residuals is reduced through implementing institutional controls to reduce human exposure.

4.3.5 Short-Term Effectiveness

Alternative D2 will not present any short-term risks to the community or workers during implementation because no intrusive remedial action is taken. Likewise, there will be no short-term impacts to the environment because of this remedy. Obtaining the necessary institutional controls is estimated to take up to six months.

4.3.6 Implementability

Alternative D2 is technically and administratively implementable. Mechanisms to obtain a groundwater ordinance within the State of Illinois are in place and, as of March 2014, at least seven similar ordinances have been implemented in the City of Waukegan. However, Alternative D2 considers six independent impacted properties that are subject to the potential groundwater ordinance, resulting in increased complexity. Alternative D2 will require third party consent to registering the necessary controls on the deeds of these six individual properties. Coordination and negotiation with multiple property owners, who will be impacted by the proposed institutional control, could complicate the implementation of Alternative D2.

4.3.7 Cost

The capital cost of Alternative D2 will be approximately $79,000. The five-year reviews are estimated to be $19,000 per review event over a 30-year monitoring period, resulting in a total present worth cost for operations and maintenance of approximately $50,000. Therefore, the present worth cost of Alternative D2 will be approximately $129,000. Appendix B provides costs for each remedial alternative and Table 4 provides a summary of the overall cost to implement each alternative.

4.4 D3 – Vertical Engineered Barrier

4.4.1 Introduction

Alternative D3 will involve installation of a low permeability vertical engineered barrier around the delineated DNAPL limits. The vertical engineered barrier will be keyed into the underlying confining clay layer a minimum of three feet. This engineered barrier will contain the groundwater and DNAPL, thereby achieving the reduced mobility component of the RAO. The confining clay layer will limit downward migration of DNAPL and the low permeability vertical engineered barrier will limit the lateral migration of DNAPL.

Vertical barriers are typically constructed from soil-bentonite, high-density polyethylene (HDPE), or steel sheet pile. Each barrier type has inherent advantages and disadvantages, as summarized in **Table B**.

Table B - Comparison of Advantages and Disadvantages of Vertical Engineered Barriers Types

Type	Advantage	Disadvantage
Soil-Bentonite Slurry Wall	■ Low construction costs ■ Relatively simple adjustment to varying depths ■ Relatively simple installation of utilities through barrier ■ Relatively simple post construction repair ■ Relatively easy verification that wall is successfully keyed into confining layer	■ Requires field permeability testing ■ May be more permeable than other barriers ■ Dependent on properties of subsurface soil ■ Trenching and mixing requires more set-up space and is comparatively "dirty" to driving sheets. ■ Requires structural modification where increased load bearing capacity is needed
HDPE Barrier	■ Moderate construction costs ■ Low permeability ■ Not dependent on properties of subsurface fill ■ Relatively clean installation	■ Complex utility installation through barrier ■ Installation can be affected by subsurface obstructions ■ Complex post construction repair ■ Potential for damage/penetration during installation ■ Difficult to verify wall is successfully keyed into confining layer ■ Requires verification of barrier seals
Steel Sheet Pile	■ Low permeability ■ Not dependent on properties of subsurface soil ■ Relatively clean installation ■ Capable of sustaining imbalanced lateral earth loads	■ High construction costs ■ Complex utility installation through barrier ■ Installation can be affected by subsurface obstructions ■ Complex post construction repair ■ Difficult to verify wall is successfully keyed into confining layer ■ Requires verification of sheet pile seals

4.4.2 Remedial Alternative Description

For cost estimating purposes, a soil-bentonite slurry wall was selected as the representative vertical barrier technology. This selection was made based on comparatively low construction costs, and increased ease of utility penetrations. Once installed, a soil-bentonite slurry wall will have limited bearing capacity. In locations where vehicular traffic or other loading is anticipated, structural modification to the soil-bentonite slurry wall will be required to increase the bearing capacity. For cost purposes of this Focused FS, it was assumed that 50 percent of the soil-bentonite slurry wall alignment would require structural modification using Portland cement to sufficiently increase the bearing capacity of the wall to accommodate current land use.

Installing a vertical engineered barrier into a confining layer will result in a “bathtub” effect within the area encompassed by the wall. The groundwater within the vertical engineered barrier will no longer flow or discharge to surface water. As a result, precipitation that infiltrates through the overburden soil/pavement will accumulate within the confines of the vertical engineered barrier. Precipitation can accumulate within the vertical engineered barrier and locally elevate the groundwater head, causing an outward gradient, possibly to a point where water will surface or overtop the vertical engineered barrier. To reduce the potential head differential, a limited groundwater extraction system will be installed concurrent with the vertical engineered barrier to remove excess accumulated water.

Typically, an infiltration model is used to estimate the required groundwater extraction rate. The model inputs include weather data as well as slope, type, and permeability of the ground surface. The ground surface covering the proposed area encompassed by the vertical engineered barrier varies between grass, gravel, asphalt parking lots, and buildings. Model simulations are not capable of accurately determining infiltration for these various cover scenarios. For FS-level cost estimating purposes, the following assumptions were made:

- 36.89 inches of precipitation per year (Climate Zone, 2014)
- 25% of precipitation infiltrates into groundwater (Engineer estimate)
- 16 acres contained by vertical engineered barrier (measured surface area on Figure 11)
- 80% annual operations of treatment system to account for system maintenance and downtime (Engineer estimate)

Using the above assumptions, the total volume of water requiring extraction will be approximately 4.01 million gallons per year. The resulting minimum extraction rate will be approximately 9.5 gpm. The actual extraction rate should be further evaluated during remedial design. Groundwater extraction activities will likely be required throughout the 30-year monitoring period for this alternative.

Presumptive elements of Alternative D3 include:

- A subsurface geotechnical investigation to determine presence and location of subsurface obstructions, document depth to groundwater, and document thickness and geotechnical properties of encountered lithology (overburden and confining layer).

- A bench-scale slurry wall mix design and compatibility study to determine the most effective soil-bentonite mix to contain MGP-residuals.
- A bench-scale treatability study to determine the most effective treatment approach for removing MGP-residuals from extracted groundwater prior to discharge to NSSD. Based on a desktop review of the groundwater impacts, the installed system is assumed to consist of phase separation, particulate removal, contaminant specific adsorption media vessels, and inorganic treatment as needed to meet discharge criteria.
- Coordination of barrier installation with various property and utility owners. Due to inherent difficulties of coordination of construction with railroads, it is assumed that two separate containment areas will be required, one to the east and one to the west of the EJ&E Railroad.
- Installation and restoration associated with soil-bentonite slurry wall at the location identified on Figure 11.
- Installation of extraction wells, to target the excess accumulated water within the vertical engineered barrier. Electric and discharge piping will be installed in trenches connecting each well to the centrally located treatment building located on the former MGP property.

Alternative D3 assumes discharge of extracted groundwater to NSSD. The NSSD ordinance for environmental remediation wastewater provides limits for concentration of solids, organics, and inorganics discharged to the NSSD. In order to meet the NSSD limits, extracted groundwater will require pretreatment prior to discharge to NSSD. The NSSD standard rate for environmental remediation wastewater is $0.10 per gallon (rate quoted at the time of report preparation and is subject to change). Preliminary discussions with NSSD indicated that there is some flexibility to reduce the rate for significant quantities; however, no firm rate could be provided. During the remedial design phase, consideration could also be given to discharge to surface water through a National Pollutant Discharge Elimination System Permit or to groundwater through an underground injection control permit. For the purposes of this Focused FS, discharge to NSSD is assumed due to the challenges in meeting the strict limits for surface water discharge or groundwater injection.

4.4.3 Overall Protection of Human Health and the Environment

Alternative D3 is protective of human health and environment by implementing an engineered barrier to limit DNAPL from migrating to the adjacent sediment and surface water resources (Waukegan River and Lake Michigan), thereby addressing the reduction in mobility element of the RAO. Alternative D3 does not implement elements to reduce the mass of DNAPL.

4.4.4 Compliance with ARARs

Alternative D3 will partially comply with or attain the ARARs identified in Table 1 and NCP requirements. The USEPA views the DNAPL present at the Site as a principal threat waste. The NCP, in 40 CFR 300.430(a)(1)(iii), states the following:

- EPA expects to use treatment to address the principal threats posed by a site, wherever practicable. Principal threats for which treatment is most likely to be appropriate include liquids, areas contaminated with high concentrations of toxic compounds, and highly mobile materials.
- EPA expects to use engineering controls, such as containment, for waste that poses a relatively low long-term threat or where treatment is impracticable.

The practicality of treatment and/or removal of DNAPL under current site conditions is demonstrated by the periodic removal of accumulated DNAPL from vertical wells. Therefore, USEPA expects that the selected remedial alternative at this Site will involve treatment and/or removal of DNAPL. In the future, if DNAPL recovery is demonstrated to be impractical, engineering controls coupled with necessary administrative controls may be considered. Alternative D3 will meet the requirements of the location and action-specific ARARs.

4.4.5 Long-Term Effectiveness and Permanence

Alternative D3 will provide long-term effectiveness and permanent control that is potentially protective of human health and the environment. DNAPL volume will not be reduced; however, DNAPL will be contained and will be generally inaccessible for human and ecological exposure, thereby reducing risk. Vertical engineered barriers are a well-established, long-term remedy used to contain DNAPL at other former MGP sites. When properly designed, vertical engineered barriers can provide protection for in excess of 30 years.

4.4.6 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative D3 will not reduce the volume or toxicity of DNAPL, but this alternative will reduce mobility by preventing DNAPL from migrating to sediment and surface water.

4.4.7 Short-Term Effectiveness

Installation activities associated with Alternative D3 are estimated to take 12 months. During this construction period, workers may be exposed to soil and groundwater containing MGP-residuals.

However, these exposures can be controlled through best management practices (e.g., dust control) and adhering to standard health and safety procedures (e.g., personal protective equipment and observing appropriate practices for designated safety zones). Installation activities will result in short-term operational impacts to the various properties along the barrier alignment. Preference should be given to installation techniques that result in minimal short-term property disturbance.

Following construction of the vertical engineered barrier, the groundwater gradient control system will be constructed to extract and treat groundwater on-site. Workers responsible for operation and maintenance of the treatment system will be exposed to groundwater containing MGP-residuals for the duration of the treatment system operation. These exposures can be minimized through the use of enclosed tanks and piping systems in addition to task-specific health and safety procedures.

Alternative D3 involves minimal subsurface disturbance and generation of soil or groundwater, so there will be minimal impact on the surrounding community. Once Alternative D3 is fully installed, DNAPL will be prevented from migrating outside the boundaries of the barrier.

4.4.8 Implementability

Alternative D3 is technically and administratively implementable. Vertical engineered barriers have been constructed as part of remedial actions at sites throughout Illinois and have a proven and reliable record of accomplishment. The extent of vertical engineered barrier construction can be increased or decreased, should the location be modified during remedial design; however, the selected path must take into account access agreements and utility crossings. The effectiveness of the barrier can be monitored during construction using established quality control procedures and effective long-term monitoring can be performed using established groundwater monitoring techniques. Geotechnical construction firms who offer a variety of vertical barrier installation techniques are based in the surrounding area and materials required to implement Alternative D3 are readily available. The significant presence of subsurface utilities will complicate implementation of Alternative D3. If possible, the remedial design of a vertical engineered barrier should select a path that minimizes the number of utility crossings.

4.4.9 Cost

The capital cost of Alternative D3 is approximately $3,729,000. The annual costs for operation and maintenance of the groundwater gradient control system could range from $264,000 to $760,000 per year for 30 years. This extreme range in costs is dependent on the discharge rate negotiated with the NSSD. The higher end of the rate is based on the NSSD standard discharge rate of $0.10 per gallon for environmental remediation wastewaters. Preliminary discussions with NSSD indicated that there is some flexibility to reduce the rate for significant quantities; however, no firm rate could be provided. For cost estimating purposes, an order of magnitude reduction to $0.01 per gallon was used to determine the lower range of the cost. The present worth cost of Alternative D3 ranges from $7,200,000 to $13,300,000. Since there is uncertainty of the potential and magnitude of cost reduction with the NSSD, the higher end of these costs will be used for comparative analysis purposes. During remedial design, consideration could be given to alternative discharge methods discussed Section 4.4.2. Appendix B provides costs for each remedial alternative and Table 4 provides a summary of the overall cost to implement each alternative.

4.5 D4 – Horizontal Well DNAPL Recovery

4.5.1 Introduction

Alternative D4 will include installation of a network of horizontal recovery wells located above the clay-confining layer at locations that are within and down-gradient of accumulated DNAPL. DNAPL that passes through the well screen will flow via gravity within the sloped horizontal well to a collection sump from which DNAPL will be extracted.

There is a network of vertical recovery wells currently installed at the Site. These wells have removed a limited volume of DNAPL since initiating operations in 2006 as described in Section 1.2.8.2. Alternative D4 will involve installation of horizontal wells screened in the DNAPL bearing interval. Compared to the existing vertical DNAPL recovery wells, the horizontal wells will have a significantly greater screened interval within the DNAPL bearing zone; therefore, the horizontal wells will be much more effective at recovering DNAPL.

Three primary recovery well installation methods were evaluated as part of this Alternative. The following subsections provide a summary of the three primary installation methods.

Traditional Trench Construction

Traditional trench excavation will likely involve an excavator cutting a narrow trench to a depth of approximately 20 feet bgs. Traditional trenching will require saw cutting and removal of pavement along the proposed trench alignment. Due the granular nature of the Site soil and the need to excavate below the water table, a trench box or slurry will be required to temporarily stabilize the excavation sidewalls until the recovery line installation depth is achieved. Typically, washed stone is placed over the recovery line to protect the pipe and locally increase hydraulic conductivity. While potentially implementable at this Site, traditional trench excavation is better suited for a site with more cohesive soil, a depth of excavation shallower than groundwater, minimal surface improvements (e.g., pavement), and minimal subsurface utility crossings.

One-Pass Trench

One-pass trenching involves use of a specialized trenching machine that simultaneously removes soil, installs perforated pipe, and places granular backfill. The simultaneous installation avoids the need for trench stabilization. One-pass trenching can achieve depths up to 30 feet bgs. Similar to the traditional trench method, the one-pass method requires saw cutting and removal of pavement along the proposed trench alignment. Also similar to the traditional trench method, the one-pass method typically includes backfilling the trench with washed stone. While potentially implementable at this Site, one-pass trenching is better suited for site with minimal surface improvements (e.g., pavement) and minimal subsurface utility crossings.

Horizontal Directional Drilling

Horizontal directional drilling (HDD) is a trenchless horizontal well installation method. The equipment and procedures are intended to minimize temporary operational disruption, surface damage, and restoration. Surface impacts are limited to two work areas, one on the entry side and exit side. Horizontal and vertical control of the HDD drill bit between the entry and exit side is performed using magnetic steering tools in conjunction with a surface monitoring system. The locator provides information to the operator to allow real-time path corrections to follow the planned bore path. Some systems directly transmit the location information to a display on the drill rig to automatically control the drill path.

Some unique advantages of horizontal drilling include: minimal site preparation and restoration costs because disturbance is limited to entry and exit points; comparatively easy utility crossings; and reduced soil management and disposal volumes. Some unique disadvantages include: limited effectiveness in drilling through stone and cobbles and reliance on the permeability of the surrounding soil rather than installation of a high permeability granular backfill. Due to the discrete land disturbance associated with pipe installation using HDD, installation does not allow backfill around the pipe. Therefore, the pipe will be in direct contact with the subsurface soil and subject to potential pipe clogging, particularly if installed in soil containing a significant fraction of fine material. There is also some uncertainty regarding the effectiveness of a horizontal well system due to possible stratification of subsurface soil; whereas trenching overcomes stratified soil layers by cutting through the soil profile.

4.5.2 Remedial Alternative Description

While both the traditional trench and one-pass trench method are conceptually feasible recovery line installation methods at the Site, HDD was selected as the representative installation approach for purpose of the Focused FS. This selection was made due to the comparatively minimal disturbance to the existing developed property and increased ease of utility crossings. The primary disadvantage of HDD is the direct contact of the recovery line with the subsurface soil. This impact of this disadvantage is minimized because the Site geology is relatively homogenous and consists of permeable silty sand, which should allow for sufficient migration of DNAPL to the recovery line. The actual well configuration and proposed construction methods will be more fully evaluated during the remedial design phase. Key criteria that will drive the location and installation method of horizontal wells include: utility constraints, access restrictions, desire to achieve a minimum slope, and potential geological stratification in DNAPL bearing zone identified during the pre-design investigation.

<u>Presumptive elements of Alternative D4 include</u>:

- A predesign subsurface geotechnical and DNAPL presence investigation will be performed to determine presence and location of subsurface obstructions, document depth to groundwater, and document thickness and geotechnical properties of encountered lithology, and presence and thickness of DNAPL. Investigation could include use of specific optical screening technologies (e.g., Dakota Technologies TarGOST®) or visual indicating dyes (e.g., Sudan IV).

- Installation of approximately seven, 6-inch diameter slotted horizontal recovery wells using the HDD method in locations that meet the following criteria:

    - **Maximize DNAPL Collection** – Primary recovery wells in the alignments of the thickest accumulations of DNAPL to maximize DNAPL volume reduction.

    - **Prevent Further Migration of DNAPL** – Sentry recovery wells at the down gradient leading edge of the DNAPL plume to intercept DNAPL prior to further lateral DNAPL plume migration.

    - **Maintain Minimum Slope** – Maintain a minimum slope for horizontal recovery wells of 0.5 foot per 100 feet to allow accumulated DNAPL to readily flow toward collection sumps.

- Based on the above strategies and available DNAPL thickness information, the presumed location of the recovery wells is shown on Figure 12. The proposed horizontal recovery wells range in spacing from 75 feet to 150 feet and range in length from 200 feet to 450 feet. The total length of recovery well installation is approximately 2,200 feet. Well spacing will be further refined in the remedial design and will take into account utility constraints, access restrictions, and desire to achieve a minimum horizontal well slope.

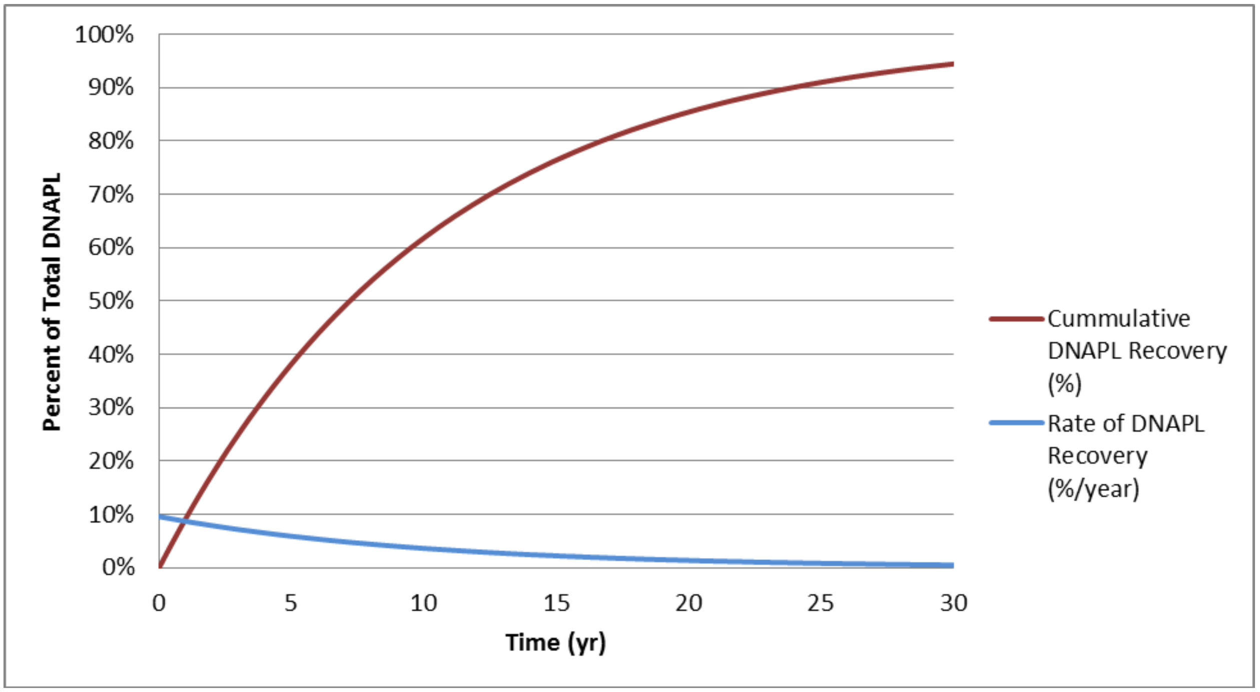
- Install a flush mounted cleanout on the up gradient end of the horizontal recovery line to allow access for well maintenance and redevelopment, as necessary.
- Install a sump consisting of a 4-foot diameter concrete manhole at the low-point of the horizontal recovery wells to allow sufficient volume of DNAPL accumulation between DNAPL recovery events.

The horizontal well DNAPL recovery approach (installed by HDD) minimizes site disruption and infrastructure associated with dedicated pumps, trenching power and recovery lines through Akzo and WPD property, and under the EJ&E Railroad.

DNAPL recovery will be performed during regularly scheduled extraction events conducted by field staff. The frequency of DNAPL recovery activities can be increased or decreased as necessary to match the DNAPL recharge rate. Initially, field crews will monitor the thickness of DNAPL accumulations in sumps. Once the elevation of DNAPL exceeds the invert of the horizontal well, DNAPL will be extracted. For purposes of this Focused FS Report, extraction activities are anticipated to be conducted approximately once per month. DNAPL extraction will be performed using a large diameter peristaltic pump, similar to the approach used to remove product from the current recovery wells. Alternatively, a vacuum truck or other extraction techniques could be employed, if determined to be more efficient during remedial design and/or implementation. Preference should be given to extraction approaches that can target exclusive removal of DNAPL and limit emulsification of DNAPL within water. Extracted DNAPL will be containerized for offsite disposal/reuse. For purposes of this Focused FS Report, it is assumed that recovered DNAPL will be disposed in the same manner as the DNAPL that is currently recovered from the existing vertical recovery wells (See Section 1.2.8.2).

For cost estimating purposes, a volumetric flow rate equation, reflecting Darcy's flow applied to oil flow in a water-wetted matrix was used to estimate duration of remedial operations. Input parameters were based on known site-specific conditions. This equation was integrated in respected to decreasing DNAPL thickness with time to determine the duration to achieve a percentage of DNAPL recovery. Based on the FS-Level modeling included in Appendix C2, a graph showing the cumulative recovery and recovery rates with respect to time is included as Figure A.

Figure A - Alternative D4 DNAPL Recovery with Respect to Time



As further discussed in Section 6.2, USEPA has requested DNAPL recovery to continue until recovery approaches 95% of the maximum theoretical recoverable volume as determined by a decline curve analysis. The FS-level calculations included in Appendix C2 and summarized in Figure A estimate that DNAPL recovery using horizontal wells will achieve 50% reduction in theoretically recoverable DNAPL in approximately seven years following commencement of system operations. Similarly, the calculations estimate that DNAPL recovery using horizontal wells will achieve 80% reduction in theoretically recoverable DNAPL in approximately 17 years and 95% in approximately 31 years following commencement of system operations. The actual quantity of DNAPL generated and frequency of extraction events will vary based on field conditions.

In addition to the predicted duration required to achieve remedial success, there is typically a startup period associated with optimizing a remedy performance. However, given the projected duration of 31 years and the lack of mechanical and treatment process that require optimization, a startup period is not considered for Alternative D4.

Natural Resource Technology

4.5.3 Overall Protection of Human Health and the Environment

Alternative D4 will be protective of human health and environment by removing DNAPL mass from the aquifer, thereby achieving the RAO. Removal of DNAPL from the aquifer will minimize the potential for DNAPL to migrate to Lake Michigan and Waukegan River. Further, DNAPL removal is expected to improve the quality of groundwater and soil vapor, to the extent that use restrictions may no longer be required. Removal of DNAPL will also reduce the risk to potential future construction workers performing excavations at the Site.

Alternative D4 does not involve physical, chemical, or thermal enhancements and thus does not result in a temporary increase in the DNAPL mobility.

4.5.4 Compliance with ARARs

Alternative D4 will comply with the chemical-specific ARARs identified in Table 1 and NCP requirements by reducing the mass and mobility of a principal threat waste. In addition, Alternative D4 will meet the requirements of the location and action-specific ARARs.

4.5.5 Long-Term Effectiveness and Permanence

Reducing DNAPL mass and mobility through DNAPL recovery will decrease the long-term potential risk to human health and environment. Remaining potential risk will consist of residual and immobile DNAPL in soil pore spaces. The magnitude of this potential risk and the associated potential for rebounding DNAPL thickness is expected to be low to moderate, provided Alternative D4 does not employ physical, chemical, or thermal enhancements to help mobilize DNAPL located in isolated pools or in areas of lower permeability.

4.5.6 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative D4 will involve installing horizontal wells above the confining clay layer to extract DNAPL from locations with significant DNAPL deposits. A significant volume of mobile DNAPL is expected to be recovered as part of Alternative D4. The FS-level modeling included in Appendix C2 estimates that 95 percent of the estimated volume of potentially mobile DNAPL would be recovered in approximately 31 years. FS-level modeling is not able to accurately quantify how much residual DNAPL might not be addressed by Alternative D4. Based on the less aggressive nature of Horizontal Well DNAPL Recovery system, it is possible to make the following qualitative assessment of remaining DNAPL upon completion of recovery activities. DNAPL will likely remain in limited quantities in isolated low-lying areas and areas of lower permeability. DNAPL recovery is permanent; however, Alternative D4 does not employ physical, chemical, or thermal enhancements to help mobilize DNAPL. As a result, there is a low to moderate potential for future accumulations of DNAPL. If these future accumulations were to occur, the nature of the system will allow for additional DNAPL recovery from the recovery system as necessary.

4.5.7 Short-Term Effectiveness

Alternative D4 will require installation of horizontal collection wells and sumps, which is anticipated to take six months. During this time, construction workers may be exposed to subsurface soil and groundwater containing MGP-residuals. However, these exposures can be controlled through best management practices (e.g., dust control) and adhering to task-specific health and safety procedures (e.g., personal protective equipment and observing appropriate practices for designated safety zones).

Following construction, DNAPL containing MGP-residuals will be extracted from the wells, containerized, and shipped offsite for disposal/reuse. Workers responsible for operation and maintenance of the recovery system will be exposed to MGP-residuals during these events. Exposures can be minimized through engineered controls in addition to task-specific health and safety procedures. As discussed in Section 4.5.2, the estimated duration to achieve the RAO is approximately 31 years.

4.5.8 Implementability

Alternative D4 will be technically and administratively implementable. The system could be constructed and operated with minimal impact on existing and future land use. Location of significant DNAPL deposits is primarily in parking lots and undeveloped parcels, and away from buried utilities, resulting in relative ease of construction. DNAPL recovery pumps are readily available and capable of extracting DNAPL. Additional length of horizontal recovery wells, frequency of sumps, and type of pumps can be easily adjusted if field conditions change during implementation. The effectiveness of the system can be monitored through the volume of recovered DNAPL, frequency of required extraction events, and thickness of residual DNAPL in surrounding monitoring wells.

4.5.9 Cost

The capital cost of Alternative D4 will be approximately $1,839,000. The annual costs for operation and maintenance of Alternative D4 will be approximately $224,000 per year for 31 years. The present worth cost of Alternative D4 will be $4,647,000. Appendix B provides costs for each remedial alternative and Table 4 provides a summary of the overall costs to implement each alternative.

4.6 D5 – Physically Enhanced DNAPL Recovery

4.6.1 Introduction

Remedial Alternative D5 will involve physically enhancing DNAPL recovery through simultaneous groundwater extraction and injection. Hydraulic injection will locally increase hydraulic gradients, thereby increasing DNAPL migration toward recovery wells. Implementation of Alternative D5 will involve installation of both injection and extraction wells, as well as a phase-separation and groundwater treatment facility. Physically enhanced recovery can be performed using a variety of methods and can be implemented using horizontal or vertical wells. A brief overview view of the two primary approaches is included below.

Separate-Phase Extraction

Separate-phase extraction involves dedicated DNAPL and dedicated groundwater extraction pumps. Extraction from these dedicated pumps can be conducted within the same well using a low flow DNAPL recovery pump at the bottom of the well and a standard groundwater pump installed above the DNAPL bearing interval. The limited volume of DNAPL extracted by the groundwater pump will be removed in a phase-separation unit prior to offsite DNAPL disposal/reuse while extracted groundwater will be treated prior to injection. Alternatively, extraction can occur in separate but collocated wells. Separate-phase extraction is most applicable to sites with relatively thick accumulations of DNAPL, as is the case for this Site.

Multi-Phase Extraction

Multi-phase extraction involves simultaneous removal of DNAPL and water from the same well using the same pump. The DNAPL/water mixture will require phase-separation followed by offsite disposal/reuse of the DNAPL, and treatment of the groundwater prior to injection. It should be noted that phase separation of the DNAPL emulsified in water is comparatively more challenging and typically results in a higher percentage of water in the separated DNAPL. The increased water content will make DNAPL reuse more challenging. Multi-phase extraction is most applicable for sites with relatively thin accumulations DNAPL, which is not typical at this Site under current conditions.

4.6.2 Remedial Alternative Description

While both multi-phase and separate-phase extraction will be conceptually feasible for the Site, separate-phase extraction using horizontal recovery and injection wells was selected as the representative method for purposes of the Focused FS. Separate-phase extraction was selected because it is most appropriate for thick accumulations of DNAPL, which are present at the Site. Horizontal wells were selected because they are more efficient than vertical wells at recovering DNAPL and horizontal wells offer decreased disturbance to the current land use.

Physically enhanced recovery is also referred to as “water flooding”, and has been successfully implemented at a creosote site in Wyoming (Sale et al., 1997). Implementation of physically enhanced oil recovery at the Wyoming site resulted in the removal of over 1.5 million gallons of a creosote DNAPL, with a similar viscosity and specific gravity to the DNAPL at the former South Plant MGP.

Presumptive elements of Alternative D5 include:

- A predesign subsurface geotechnical and DNAPL investigation to determine presence and location of subsurface obstructions, document depth to groundwater, and document thickness and geotechnical properties of encountered lithology, and presence and thickness of DNAPL. The investigation could include tar specific optical screening technologies (e.g., Dakota Technologies TarGOST®) or visual indicating dyes (e.g., Sudan IV).

- Based on the predesign information, installation of alternating horizontal groundwater injection and collocated DNAPL/groundwater extraction wells using the HDD method. The well location and alternating injection and collocated DNAPL recovery/groundwater extraction well approach is shown in Figure 13. To reduce the potential for further DNAPL migration, the well layout includes DNAPL recovery/groundwater extraction wells at the downgradient extent of the plume. The actual well configuration and proposed construction methods will be more fully evaluated during the remedial design phase.

- Installation of flush mounted cleanouts on the upgradient end of the horizontal recovery line to allow access for well maintenance and redevelopment, as necessary.

- Installation of a sump consisting of a 4-foot diameter concrete manhole at the low points of the DNAPL recovery and groundwater extraction wells to provide increased flexibility in pumping options.

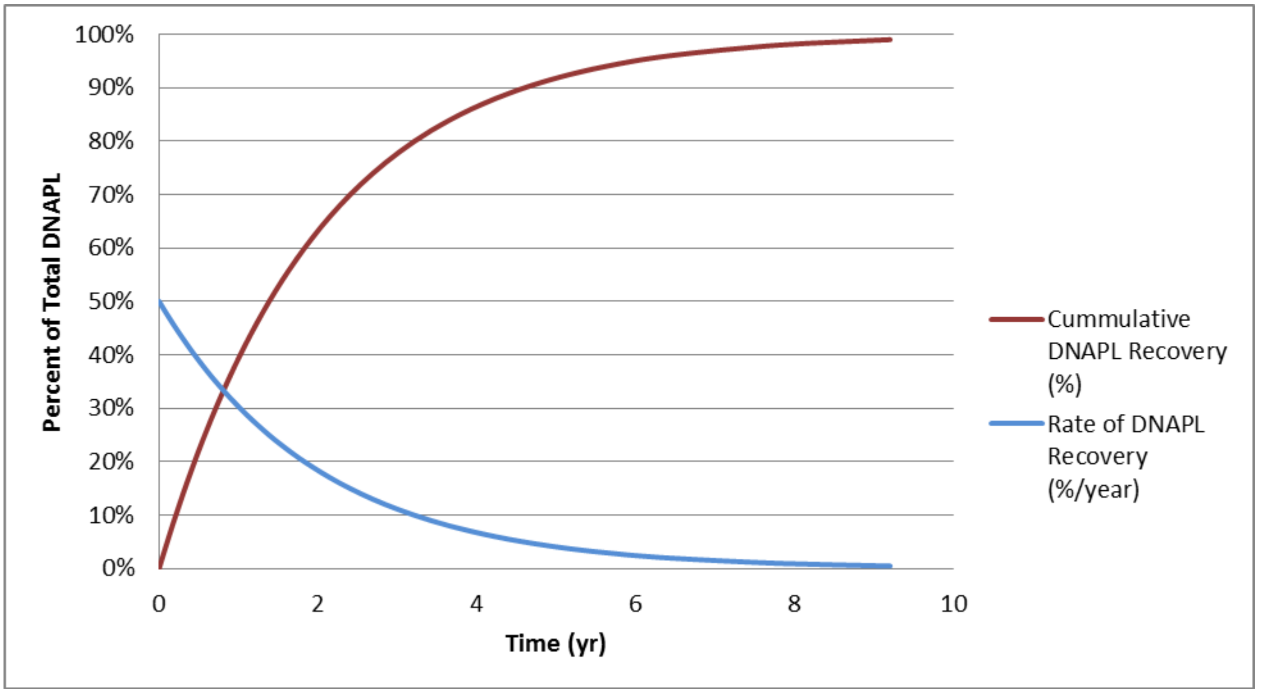
- Completion of trenches containing power, pump control, groundwater injection/extraction lines, and DNAPL recovery lines. This will include horizontal boring underneath the EJ&E Railroad to connect the system components east of the railroad to centrally located phase-separation and treatment facility located on NSG property.

- Installation of a phase-separation and groundwater treatment system capable of treating the combined DNAPL and groundwater flow.

Operation of the system will involve extraction of groundwater from a groundwater extraction line located approximately 2.5 feet above the DNAPL recovery well as shown in the conceptual cross-section on Figure 13. The extracted water will flow via subsurface piping to a centrally located treatment plant for treated prior to injection. The injection occurs from horizontal wells located in the DNAPL bearing interval approximately 150 feet on either side of the collocated DNAPL recovery/groundwater extraction wells. Injection of groundwater in this interval will assist in flushing DNAPL toward the DNAPL recovery well and increase the hydraulic gradient, further increasing DNAPL mobility. Mobilized DNAPL will be extracted from the DNAPL recovery well using low-flow recovery pumps. Extracted DNAPL will flow through subsurface piping to a centrally located phase-separation unit prior to being containerized for offsite disposal/reuse. The DNAPL recovery well pump will be expected to operate continuously, however the groundwater extraction and injection will be performed either continuously or in pulsed pumping events, as determined necessary to increase system efficiency. Extracted DNAPL will be containerized for offsite disposal/reuse. For purposes of this Focused FS Report, it is assumed that recovered DNAPL will be disposed in the same manner as the DNAPL that is currently recovered from the existing vertical recovery wells (See Section 1.2.8.2).

The pumping rates, well spacing, and DNAPL recovery rates were modeled based on a technical paper summarizing operations of a similar system for a creosote site in Wyoming (Sale et al., 1997). Calculations are included as Appendix C3. Well spacing and pumping rates will be refined in the remedial design phase and will take into account utility constraints, access restrictions, and desire to achieve a minimum horizontal well slope. Based on the assumptions included in Appendix C3, a graph showing the cumulative recovery and recovery rates with respect to time is included as Figure B.

Figure B - Alternative D5 DNAPL Recovery with Respect to Time



As further discussed in Section 6.2, USEPA has requested DNAPL recovery to continue until recovery approaches 95% of the maximum theoretical recoverable volume as determined by a decline curve analysis. The FS- level calculations included in Appendix C3 and summarized in estimate that DNAPL recovery wells will achieve 50% reduction in mobile DNAPL in approximately two years following commencement of system operations. The calculations estimate that DNAPL recovery will achieve 80% reduction in mobile DNAPL in approximately four years and 95% in approximately six years following commencement of system operations. The actual quantity of DNAPL generated and frequency of extraction events will vary based on field conditions. In addition to the predicted duration required to achieve remedial success, there is typically a startup period associated with optimizing a remedy performance. A startup period of approximately one year is assumed prior to the system being considered fully operational.

4.6.3 Overall Protection of Human Health and the Environment

Alternative D5 will be protective of human health and environment by implementing controls to remove DNAPL from the aquifer, thereby achieving the RAO. Removal of DNAPL from the aquifer will minimize the potential for DNAPL to migrate to Lake Michigan and Waukegan River. Further, DNAPL removal is expected to improve the quality of groundwater and soil vapor, such that use restrictions may no longer be required. Removal of DNAPL will also reduce the risk to potential future construction workers performing excavations at the Site. Alternative D5 will temporarily increase DNAPL mobility; however, the potential risks caused by increased DNAPL mobility will be reduced by implementing engineering controls to extract mobilized DNAPL and through regular observations for DNAPL presence in perimeter monitoring points.

In the unlikely event that DNAPL mobilizes to the perimeter monitoring wells, the increased mobilization resulting from physically enhanced recovery can be reduced by shutting down the groundwater injection and extraction system. As a result, the aquifer will attenuate to static conditions and additional offsite migration of DNAPL will be minimized. While the aquifer attenuates to static conditions, an assessment could be performed and system modifications could be developed to address DNAPL migration.

4.6.4 Compliance with ARARs

Alternative D5 will comply with chemical-specific ARARs identified in Table 1 and NCP requirements by reducing the mass of a principal threat waste. Alternative D5 will not be able to consistently meet the general IEPA Underground Injection Control standard to achieve TACO Class 1 Groundwater Remediation Objectives, as required prior to injection. Achieving the TACO Class 1 Groundwater Remediation Objectives for benzo(a)anthracene (0.13 µg/L), benzo(b)fluoranthene (0.18 µg/L), benzo(k)fluoranthene (0.17 µg/L), and benzo(a)pyrene (0.2 µg/L), dibenz(a,h)anthracene (0.3 µg/L), and indeno(1,2,3-cd)pyrene (0.43 µg/L) will require impractically high treatment plant removal efficiencies. Assuming the influent concentration of the DNAPL/ groundwater mixture is comparable to the maximum concentration of groundwater identified during RI activities; achieving the Class 1 groundwater standards for these 6 PAHs will require treatment plant removal efficiencies exceeding 99.99%.These exceptionally high removal efficiencies are technically unachievable, even with the best available treatment technologies.

Due to the interim and focused nature of the project, the IEPA expressed openness to permitting injection of water containing exceedances of the Class 1 groundwater standards under the following conditions:

- Injected groundwater has been treated using best available treatment technologies.
- Injected groundwater does not cause a greater environmental problem (e.g., cause contaminant migration).
- Injection activities are properly monitored.
- The interim action will not be inconsistent with the final remedial action goal of remediating contaminated groundwater to Illinois' Class 1 Groundwater Quality Standards.

NATURAL RESOURCE TECHNOLOGY

Formal IEPA approval for injection of water containing exceedances of the Class 1 groundwater standards will be sought during the remedial design phase of the project by submitting an Underground Injection Control (UIC) Class V Inventory Application to IEPA. This application will summarize the location and concentrations of contaminants, proposed treatment system components, anticipated contaminant concentrations in injected water, and injection well locations. The application will detail the goals of the interim action and highlight how the remaining MGP-residuals in groundwater will be evaluated in a subsequent FS following the conclusion of DNAPL recovery activities. The application will also detail the groundwater monitoring that will be completed during DNAPL recovery activities to ensure MGP-affected groundwater does not migrate beyond currently affected areas.

Consideration was given to discharging extracted groundwater to NSSD and obtaining potable water from the City of Waukegan for injection to avoid the potential for injecting extracted groundwater above Class I standards. Under this scenario, a similar phase separation and treatment system is required to meet the criteria required for discharge of environmental remediation wastewater to the NSSD sewers. Based on the discussion of NSSD discharge presented in Section 4.4.9, the assumed discharge rate to NSSD is $0.10 per gallon. Based on the assumptions in Appendix C3, the recovery system will operate at approximately 23 gpm. Over the estimated seven years of operations, the resulting NSSD Discharge fee is approximately $8.5 million. Based on an estimated $2.85 per 1,000 gallons, the estimated cost of potable water for injection is approximately $200,000. Additional costs will be incurred related to permits and piping between existing potable water and sewer infrastructure and the proposed remedial infrastructure. The magnitude of the increased costs associated with discharge to NSSD was financially impractical to consider as an alternate approach. As a result, the remaining sections of the Focused FS will assume that extracted groundwater will be treated to the best extent practical prior to injection. Based on the procedures outlined by the IEPA, treatment to the best extent practical prior to injection will be considered consistent with the action-specific ARARs for subsurface injection of water.

4.6.5 Long-Term Effectiveness and Permanence

Reducing DNAPL mass and mobility through DNAPL recovery will reduce the long-term potential risk to human health and environment. If operated effectively, the remaining potential risk will consist of residual and immobile DNAPL in soil pore spaces. The magnitude of this potential risk and the associated potential for rebounding thickness of DNAPL is expected to be low, due to the physically flushing DNAPL from the soil space.

4.6.6 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative D5 will involve installing horizontal wells above the confining clay layer to extract the significant DNAPL deposits by physically increasing the hydraulic gradient to drive DNAPL towards the DNAPL recovery wells. A significant volume of mobile DNAPL is expected to be recovered as part of Alternative D5. The FS-level modeling included in Appendix C3 estimates that 95 percent of estimated volume of potentially mobile DNAPL will be recovered in approximately seven years. FS-level modeling is not able to accurately quantify how much residual DNAPL may remain after implementation of Alternative D5. Based on the moderately aggressive nature of physically enhanced DNAPL recovery techniques, it is possible to make the following qualitative assessment of remaining DNAPL following completion of recovery activities. DNAPL will likely remain in limited quantities in isolated low-lying areas and isolated areas of lower permeability. DNAPL recovery is permanent; however, Alternative D5 relies on physically increasing DNAPL mobility and does not incorporate more aggressive chemical or thermal enhancements to help reduce the volume of residual DNAPL. As a result, there is a low potential for future accumulations of DNAPL to develop. If these future accumulations were to occur, DNAPL could be extracted if recovery well infrastructure remains in place following initial achievement of the RAO.

Although physically flushing DNAPL from the soil pore space can decrease the duration of extraction activities, recovery and injection at rates that exceed the rate of DNAPL mobilization can make DNAPL more difficult to remove, as detailed in the Source Treatment for DNAPL (Environmental Agency, 2002). If the force resulting from extraction and injection activities exceeds DNAPL interfacial tension, the DNAPL plume can separate into several DNAPL plumes. Distinct DNAPL plumes are much harder to remediate, because the interfacial tension within a singular DNAPL plume helps “pull” itself when flowing toward a central collection point. To minimize the potential for segmented DNAPL plumes from forming, flow models calibrated with pilot-scale or full-scale field results should be prepared during remedial design and field implementation.

4.6.7 Short-Term Effectiveness

Alternative D5 will require installation of horizontal DNAPL recovery wells and groundwater extraction and injection wells. In addition, trenching for power, groundwater, and DNAPL recovery lines will be required between the horizontal wells and a central treatment building. A facility capable of handling phase-separation, DNAPL storage, and groundwater treatment will be installed. Construction activities associated with this remedy are estimated to take approximately 12 months. During this time, construction workers will be exposed to subsurface soil and groundwater containing MGP-residuals. However, these

NATURAL RESOURCE TECHNOLOGY

exposures can be controlled through best management practices (e.g., dust control) and adhering to task-specific health and safety procedures (e.g., personal protective equipment and observing appropriate practices for designated safety zones).

Following construction, DNAPL will be extracted to the surface, containerized, and shipped offsite for disposal/reuse. In addition, groundwater will be extracted and treated in an onsite groundwater treatment plant prior to injection. Workers responsible for operation and maintenance of the system will be exposed to MGP-residuals for the duration the remedy. These exposures can be minimized through the engineered controls in addition to task-specific health and safety procedures. As previously discussed in Section 4.6.2, estimated duration of system start-up and remedial operations is approximately seven years.

Additional short-term effectiveness considerations related to increased DNAPL mobility resulting from physical modifications to subsurface groundwater/DNAPL flow are discussed in Section 4.6.3 as part of the Overall Protection of Human Health and Environment criterion.

4.6.8 Implementability

Alternative D5 will be technically and administratively implementable. There are limited case studies discussing water flooding for DNAPL recovery, however significant DNAPL recovery was achieved at a creosote site in Wyoming, as previously discussed in Section 4.6.2. The system could be constructed and operated with moderate impact to existing and future land use. Locations of significant DNAPL deposits are primarily in parking lots and undeveloped parcels, and away from buried utilities, resulting in relative ease in recovery and injection well and sump installation.

Pump operation and type can be adjusted if field conditions change during implementation. The effectiveness of the system can be monitored through the volume of recovered DNAPL, and thickness of residual DNAPL in surrounding monitoring wells. Contractors are readily available to install horizontal wells and provide the necessary pumps for extraction and injection. In addition, several vendors design and manufacture groundwater extraction and treatment equipment that is proven to remove MGP-residuals.

The presumed location for the centralized DNAPL storage and groundwater treatment building is on the NSG property. As a result, pump controls, power, and piping will be bored from the NSG property, under the EJ&E Railroad, and to the wells located on Akzo and WPD property. While subsurface boring is technically implementable, coordination with the property owners, particularly the EJ&E Railroad, will be an administrative challenge.

4.6.9 Cost

The capital cost of Alternative D5 will be approximately $4,446,000. The annual costs for operation and maintenance of Alternative D5 will be approximately $1,137,000 per year for seven years. The present worth cost of Alternative D5 will be $10,576,000. Appendix B provides costs for each remedial alternative and Table 4 provides a summary of the overall costs to implement each alternative.

4.7 D6 – Chemically Enhanced DNAPL Recovery

4.7.1 Introduction

Remedial Alternative D6 will involve enhancing DNAPL recovery through chemical injection. The mobilized DNAPL will be recovered using the DNAPL extraction techniques similar to those described in Remedial Alternatives D5. Therefore, implementation of Alternative D6 will involve installation of both injection and extraction wells, as well as a phase-separation and groundwater treatment facility. Typically, chemically enhanced DNAPL recovery is performed using surfactants. Surfactants share a similar molecular composition to traditional soaps and detergents (Fountain, 1998), and the chemical bonds consist of a hydrophobic end and hydrophilic end. The hydrophobic end is attracted to DNAPL and the hydrophilic end is attracted to groundwater (Longino and Kueper, 1995). As a result, the interfacial tension between DNAPL and water is decreased and mobility of DNAPL is increased.

There are varieties of surfactants available for the remediation and oil recovery market. Often surfactant injections are amended with electrolytes, polymers, co-solvents, or oxidants to further increase surfactant effectiveness. Laboratory bench-scale studies are critical to select the proper type and concentration of surfactant and amendment.

Surfactants are only effective at enhancing the recoverability when in direct contact with DNAPL. As a result, having an accurate understanding of the DNAPL plume and the subsurface geology and geochemistry is critical to determining injection zones, well spacing, and chemical volume. Application can be performed using either horizontal or vertical wells and DNAPL recovery can either be performed in the same well used for chemical injection or in a separate, downgradient recovery well.

4.7.2 Remedial Alternative Description

Several surfactant chemicals and application approaches should be evaluated in a more comprehensive manner during bench-scale studies conducted prior to remedy implementation. For purpose of the Focused FS, the presumed surfactant is Tersus Environmental's TASK, or equivalent anionic surfactant that promotes desorption and viscosity reduction by lowering interfacial tension, resulting in the greater mobility and recoverability of DNAPL.

Surfactant solutions can be applied using either vertical or horizontal wells. For the purpose of the Focused FS, it is assumed that surfactant injection and DNAPL recovery will be performed using horizontal wells. Horizontal wells will allow for more uniform distribution of surfactant in the DNAPL bearing zone and increase the potential for DNAPL to surfactant contact, thereby increasing the potential for remedy success.

Physically enhancing surfactant injection through simultaneous groundwater extraction and injection will increase surfactant distribution and provide source water for diluting the surfactant and amendments to the desired injection concentrations. Effectively, Remedial Alternative D6 is conceptually similar to Remedial Alternative D5. The primary process modification is the addition of the surfactant solution to the treated groundwater prior to injection.

<u>Presumptive elements of Alternative D6 include</u>:

- Elements identified in Alternative D5 (Section 4.6.2).
- A bench-scale test will be performed using the soil, groundwater, and DNAPL to test a range of surfactant, amendments, and concentrations to identify the optimal remedial approach.
- Chemical injection pumps will be installed on the effluent line from the groundwater treatment plant to supplement the injected water with the proper dose of electrolyte and surfactant solution. This approach is shown in the conceptual process flow diagram included on Figure 14.
- Initially, approximately one pore volume of an electrolyte solution will be circulated through the DNAPL bearing zone. Based on review of site date and experience at similar sites, a surfactant vendor (Tersus Environmental for purposes of this FS) estimates that a 1.2% sodium chloride solution will be sufficient and is assumed for purposes of this Focused FS Report. This electrolyte will establish subsurface geochemical conditions that will increase the effectiveness of the subsequent surfactant injections.
- Following successful recirculation of the electrolyte solution, approximately one pore volume of a surfactant solution will be circulated through the aquifer. Based on review of site date and experience at similar sites, a surfactant vendor (Tersus Environmental for purposes of this FS) a 1.5% surfactant solution is assumed for purposes of this Focused FS Report. This surfactant solution will lower interfacial tension and mobilized DNAPL toward recovery wells.

- Following successful recirculation of the surfactant solution, approximately four pore volumes of treated extracted water will be circulated through the DNAPL bearing zone to flush the remaining potentially recoverable DNAPL, surfactant, and electrolyte solution.

Operation of Alternative D6 will be similar to the operation of Alternative D5 (as discussed in Section 4.6.2). Based on calculations provided in Appendix C3, it is estimated that water will be extracted and injected at approximately 23 gpm, and DNAPL recovery will achieve a 95% reduction in mobile DNAPL in approximately three years following commencement of system operations. Based on the vendor experience operating similar extraction, phase separation, treatment of groundwater, and surfactant injection systems; a startup period of approximately one year is assumed prior to the system being considered fully operational.

This duration estimate assumes one primary round of surfactant injection. Time to achieve the specified reduction in mobile DNAPL may be increased if additional rounds of surfactant injection are required during remedy implementation. Based on information from a surfactant vendor, one round of injection is anticipated to be sufficient to achieve the RAO.

Extracted DNAPL will be containerized for offsite disposal/reuse. For purposes of this Focused FS Report, it is assumed that recovered DNAPL will be disposed in the same manner as the DNAPL that is currently recovered from the existing vertical recovery wells (See Section 1.2.8.2).

4.7.3 Overall Protection of Human Health and the Environment

Alternative D6 will be protective of human health and environment by implementing controls to remove DNAPL mass from the aquifer, thereby achieving the RAO. Removal of DNAPL from the aquifer will minimize the potential for DNAPL to migrate to Lake Michigan and the Waukegan River. Further, DNAPL removal is expected to improve the quality of groundwater and soil vapor, such that use restrictions may no longer be required. Removal of DNAPL will also reduce the potential risk to future construction workers performing excavations at the Site. Alternative D6 will temporarily result in increased mobility of DNAPL to allow for enhanced DNAPL recovery; however, the potential risks created by increased DNAPL mobility will be reduced by implementing engineering controls to extract mobilized DNAPL and through regular observations for DNAPL presence in perimeter monitoring points.

Further, the injection of chemical recovery enhancements has the potential to increase the dissolution rate of DNAPL constituents from the non-aqueous phase to the dissolved phase. Once DNAPL mass transitions from non-aqueous to dissolved phase, that mass can no longer be addressed by the DNAPL recovery remedies presented in this Focused FS Report. Rather, the additional dissolved mass will need to be addressed as part of the upcoming FS addressing the remaining MGP-affected media following DNAPL recovery.

The potential risks caused by increased DNAPL mobility and constituent dissolution rate will be managed by implementing engineering controls to extract mobilized DNAPL and groundwater as well as through regular monitoring of DNAPL and groundwater in perimeter monitoring points. However, mobilization of DNAPL and the dissolved phase concentrations resulting from chemically enhanced recovery is not easily reduced or reversed.

4.7.4 Compliance with ARARs

Alternative D6 will comply with chemical-specific ARARs identified in Table 1 and NCP requirements by reducing the mass and mobility of a principal threat waste. In addition, based on the discussion presented in Section 4.6.4 regarding, Alternative D6 will also achieve location- and action-specific ARARs.

4.7.5 Long-Term Effectiveness and Permanence

Reducing DNAPL mass through DNAPL recovery will reduce the potential long-term risk to human health and environment. If operated effectively, the remaining potential risk will consist of residual and immobile DNAPL in soil pore spaces. The magnitude of the potential long-term risk and the associated potential for rebounding thickness of DNAPL is expected to be minimal, due to the combination of chemically increasing the solubility and physically flushing DNAPL from the soil pore space.

4.7.6 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative D6 will involve installing horizontal wells above the confining clay layer to extract DNAPL from locations with significant DNAPL deposits. DNAPL will be mobilized towards recovery wells through a combination of chemical and physical enhancements. A significant volume of mobile DNAPL is expected to be recovered as part of Alternative D6. Surfactant vendors contacted as part of this Focused FS estimate that 95 percent of estimated volume of potentially mobile DNAPL would be recovered in approximately four years. FS-level modeling is not able to accurately quantify how much residual DNAPL may be unable to be addressed by Alternative D6. Based on the aggressive nature of chemically and physically enhanced DNAPL recovery techniques, it is possible to make the following qualitative assessment of remaining DNAPL upon completion of recovery activities. Immobile DNAPL will likely remain in limited quantities in isolated low-lying areas and areas of low permeability. DNAPL recovery is permanent and Alternative D6 incorporates the combination of chemically increasing the solubility and physically flushing DNAPL from the soil pore space to help reduce the volume of residual DNAPL. As a result, there is minimal potential for future accumulations of DNAPL to develop. If these future accumulations were to occur, DNAPL could be extracted if recovery well infrastructure remains in place following achievement of the RAO.

4.7.7 Short-Term Effectiveness

Alternative D6 will require installation of horizontal DNAPL recovery and groundwater extraction and injection wells. In addition, trenching for power, groundwater, and DNAPL recovery lines will be required between the horizontal wells and a central treatment building. A facility capable of handling phase-separation, DNAPL storage, a groundwater treatment system, and surfactant chemical addition will be installed. Construction activities associated with this remedy are estimated to be completed in approximately 12 months. During this time, construction workers may be exposed to subsurface soil and groundwater containing MGP-residuals. However, these exposures can be controlled through best management practices (e.g., dust control) and adhering to task-specific health and safety procedures (e.g., personal protective equipment and observing appropriate practices for designated safety zones).

Following construction, DNAPL will be extracted to the surface, containerized, and shipped offsite for disposal/reuse. In addition, groundwater will be extracted and treated in an onsite groundwater treatment plant prior to injection. Workers responsible for operation and maintenance of the system will be exposed to MGP-residuals for the duration the remedy. These exposures will be minimized through engineered controls in addition to standard health and safety procedures. As previously discussed in Section 4.7.2, the estimated duration for system start-up and remedial operations is approximately four years.

Additional short-term effectiveness considerations related to increased DNAPL mobility and potentially increased constituent dissolution rates resulting from surfactant injections are discussed in Section 4.7.3 as part of the Overall Protection of Human Health and Environment criterion.

4.7.8 Implementability

Alternative D6 will be technically and administratively implementable. The historic success of surfactant injections is highly variable; however, the relatively uniform geology with a relatively high hydraulic conductivity increases the potential for remedy success at this Site. The location of significant DNAPL deposits is primarily in parking lots and undeveloped parcels, and away from buried utilities, resulting in relative ease in recovery and injection well and sump installation. Type of surfactant and number of injections can be adjusted if field conditions change during implementation. The effectiveness of the system can be monitored through the volume of recovered DNAPL, and thickness of residual DNAPL in Site monitoring wells.

Contractors are readily available to install horizontal wells and provide the necessary pumps for extraction and injection. In addition, several vendors design, supply, and operate groundwater extraction and treatment equipment and surfactant chemicals that are proven to address MGP-residuals. Similar to Alternative D5, the presumed location for the centralized DNAPL storage and groundwater treatment building is on the NSG property. As a result, pump controls, power, and piping will have to be bored from the NSG property, under the EJ&E Railroad, and to the wells located on Akzo and WPD property. While trenching is technically implementable, coordination with the impacted property owners, particularly the EJ&E Railroad will be an administrative challenge.

4.7.9 Cost

The capital cost of Alternative D6 will be approximately $8,845,000. The annual costs for operation and maintenance of Alternative D6 will be approximately $1,619,000 per year for four years. The present worth cost of Alternative D6 will be $14,335,000. Appendix B provides costs for each remedial alternative and Table 4 provides a summary of the overall cost to implement each alternative.

4.8 D7 – Thermally Enhanced Recovery

4.8.1 Introduction

Thermally enhanced recovery involves increasing the temperature of the subsurface to enhance DNAPL recovery or thermally destroy DNAPL in-situ. Typical thermal treatment technologies include steam enhanced extraction, conductive heating, and electric resistance heating (ERH). Each type of thermal treatment technology, as it applies to recovery of DNAPL, is summarized below.

Steam Enhanced Extraction

Steam enhanced extraction for DNAPL recovery involves producing steam in boilers located on the surface and then injecting the steam under pressure into the subsurface through injection wells. The injected steam increases the subsurface temperature, thereby mobilizing and displacing DNAPL, which can then be recovered using multi-phase extraction wells (as described in Section 4.6). In addition, the more volatile DNAPL constituents, (benzene, toluene, ethylbenzene, xylenes, and naphthalene), will have a secondary volatilization removal mechanism resulting from the increased subsurface temperature.

Steam enhanced extraction primarily relies on conductive and convective heat transfer to increase subsurface temperature. As a result, this technology is best suited for soil with moderate to high permeability and limited subsurface obstructions, as is the case for this Site. Steam Enhanced Extraction is not able to efficiently heat areas of low permeably or areas where subsurface flow paths are restricted by subsurface obstructions. The maximum subsurface temperature is limited by the temperature of the injected steam (approximately 100 degrees Celsius at atmospheric pressure).

Conductive Heating

Conductive heating involves installing heater elements within subsurface wells. The heat from the element radiates through the soil by thermal conduction. The primary mechanisms for recovery of DNAPL with conductive heating are steam-stripping of contaminants and reduced DNAPL viscosity and density, which allow the DNAPL to be more easily recovered by a multi-phase extraction system. In addition, the more volatile DNAPL constituents (benzene, toluene, ethylbenzene, and xylenes) will have a secondary volatilization removal mechanism resulting from the increased subsurface temperature. Unlike steam-enhanced extraction, thermal conduction heat transfer occurs relatively uniformly throughout a targeted treatment zone, even in areas of low permeability, which is often where DNAPL accumulates.

Conductive heating is not limited by the boiling point of water and can achieve temperatures up to 500 degrees Celsius, unlike steam enhanced extraction and ERH, described below. As a result, conductive heating is able to thermally degrade both volatile constituents, as well as PAHs that are more recalcitrant. A range of temperatures can be achieved by varying the power supplied to the conductive heating elements. Temperatures exceeding the boiling point of water are only achievable in the unsaturated soil.

Electric Resistance Heating

ERH is a thermal remediation technology that involves applying electrical current through soil and groundwater using an array of subsurface horizontal or vertical electrodes. The soil moisture conducts electrical current and the soil's natural resistance to the flow of electrical current results in the generation of heat. Similar to conductive heating, the heat distribution from ERH is relatively uniform, even in areas of low permeability. The maximum temperature of ERH is generally limited to the boiling point of water (100 degrees Celsius). The primary mechanisms for recovery of DNAPL are steam stripping of contaminants and reduced DNAPL viscosity and density, which allows the DNAPL to be more easily recovered by a multi-phase extraction system. In addition, the more volatile DNAPL constituents, (benzene, toluene, ethylbenzene, xylenes, and naphthalene), will have a secondary volatilization removal mechanism resulting from the increased subsurface temperature.

4.8.2 Remedial Alternative Description

While both steam enhanced extraction and conductive heating will be conceptually feasible thermally enhanced recovery technologies for the Site, ERH was selected as the representative technology for purposes of the Focused FS. This selection was made due to a greater availability of vendors offing ERH, as well as proven results for recovery of DNAPL at MGP sites. If retained as the preferred remedy, the actual thermally enhanced DNAPL recovery technology will be further evaluated during the remedial design. Unlike horizontal well DNAPL recovery, physically enhanced, or chemically enhanced DNAPL recovery, thermally enhanced recovery can increase indoor vapor intrusion risks. Increasing soil and groundwater temperature not only increases the mobility of DNAPL, but also has the potential to increase diffusion of MGP and non-MGP COPCs from soil and groundwater to vapor. This increased diffusion rate is of particular concern for the primary non-MGP soil vapor COPC, chloroform, which has a low vapor pressure and boiling point of approximately 62 degrees Celsius (Sigma, 2014).

Due to the increased risk of vapor intrusion of non-MGP COPCs associated with thermally enhanced DNAPL recovery, the DNAPL plume has been divided into the East and West Treatment Areas shown on Figure 15. As a result, ERH treatment under the Akzo facility or the WPD Maintenance Building is not proposed as part of Alternative D7. It should be noted that the multi-phase (vacuum) extraction component of ERH will be operating for an estimated four years and will help to mobilize DNAPL from underneath buildings to the adjacent treatment area. As a result, the volume of residual DNAPL under the buildings not included in the ERH treatment area is expected to be minimal.

In addition, consideration must be given to the effect of increased subsurface temperature on subsurface infrastructure. A typical thermal remediation approach for dissolved phase contamination involves heating to 100 degrees Celsius, which exceeds the working temperature for common subsurface utility materials. As described in the following bullets, ERH for the purpose of DNAPL recovery will involve heating to 35 to 40 degrees Celsius. This lower operating temperature will reduce the potential for damaging subsurface infrastructure; however, a thermal compatibility study should be performed during the remedial design phase of the project if thermally enhanced recovery is selected as an appropriate remedy.

There are several approaches to installing an ERH system. Presumptive elements of Alternative D7 are summarized below and have been used for successful recovery of DNAPL at similar former MGP sites.

Future refinement of spacing, separation and treatment technologies, temperature, and configurations should be analyzed during the remedial design phase.

Presumptive elements of Alternative D7 include:

- An array of 12-inch diameter borings will be advanced on approximately an 18-foot grid within the target treatment area. Borings will be advanced to the top of the confining clay. A steel electrode and a 4-inch diameter well screen with riser pipe will be installed within each boring (electrode/multi-purpose well). The wells will be designed to function as groundwater injection wells or multi-phase extraction wells, as necessary to support ERH treatment. An estimated 372 electrode/wells will be advanced in the East Treatment Area and 355 in the West Treatment Area.

- The electrode/multipurpose wells will be supplemented by direct push subsurface temperature sensor wells, which will measure subsurface temperature using thermal couples. An estimated 150 temperature sensor wells will be advanced in the West Treatment Area and 142 in the East Treatment Area.

- A power supply unit, located on NSG property will step down the transmission voltage for controlled distribution into the subsurface. Power cables direct power from the power supply unit to the vertical subsurface electrode wells, which are set to different electrical phases to promote flow of electrical current through the DNAPL interval between adjacent electrodes.

- Subsurface temperature sensor wells will relay subsurface temperature back to the power supply unit to allow the system to operate in a constant temperature mode targeting 35 to 40 degrees Celsius. This temperature range allows for a sufficient reduction in viscosity without risking volatilization of the lower range DNAPL components (benzene) which act as a co-solvent carrier for the higher range DNAPL components. A higher temperature will risk volatizing the lower end DNAPL components, resulting in the immobilization of the higher range DNAPL components in an asphalt-like substance.

- It is estimated to take approximately 50 days to achieve target temperature, at which point multi-phase extraction wells will be activated to extracted the mobilized DNAPL, groundwater, and vapors. The vapor and fluids streams will be separated and treated in a centralized treatment facility.

- The DNAPL will be containerized for offsite disposal/reuse and the treated water will be injected into the DNAPL treatment area. The residual heat of the treated groundwater will help maintain subsurface temperatures and the injection of groundwater will provide hot water flushing to enhance further DNAPL mobility.

The ERH system will be operated until the RAO is achieved. An engineer with Current Environmental System, who has design and operated ERH systems for multiple MGP sites and was contacted for purposes of this FS, stated that ERH start-up and system operations, similar to the system above, are likely to range between three and five years. For purpose of this FS, it is assumed that the system will require four years to achieve the RAO.

Extracted DNAPL will be containerized for offsite disposal/reuse. For purposes of this Focused FS Report, it is assumed that recovered DNAPL will be disposed in the same manner as the DNAPL that is currently recovered from the existing vertical recovery wells (See Section 1.2.8.2).

4.8.3 Overall Protection of Human Health and the Environment

Alternative D7 will be protective of human health and environment by implementing controls to aggressively remove DNAPL mass from the aquifer, thereby achieving the RAO. Removal of DNAPL from the aquifer will minimize the potential for DNAPL to migrate to Lake Michigan and the Waukegan River. Further, DNAPL removal is expected improve the quality of groundwater and decrease soil vapor, such that use restrictions may no longer be required. Removal of DNAPL will also reduce the potential risk to future construction workers performing excavations at the Site. Alternative D7 will temporarily increase the mobility of DNAPL to allow for enhanced DNAPL recovery. Further, the increased subsurface temperature will also increase the dissolution rate of DNAPL constituents from the non-aqueous phase to the dissolved phase. Once DNAPL mass transitions from non-aqueous to dissolved phase, that mass can no longer be addressed by the DNAPL recovery remedies presented in this Focused FS Report. Rather, the dissolved phase mass will have to be addressed as part of future FS Report.

The potential risks caused by increased DNAPL mobility and dissolved mass will be managed by implementing engineering controls to extract mobilized DNAPL and groundwater as well as through regular monitoring of DNAPL and groundwater in Site monitoring points. However, the increased mobilization of DNAPL and the increased dissolved phase concentrations resulting from thermally enhanced recovery is not easily reduced or reversed in a timely manner.

4.8.4 Compliance with ARARs

Alternative D7 will comply with chemical-specific ARARs identified in Table 1 and NCP requirements by reducing the mass and mobility of a principal threat waste. In addition, based on the discussion presented in Section 4.6.4, Alternative D7 will also achieve location- and action-specific ARARs.

4.8.5 Long-Term Effectiveness and Permanence

Reducing DNAPL mass and mobility through aggressive DNAPL recovery will reduce the long-term potential risk to human health and environment. Remaining potential risk will consist of residual and immobile DNAPL in soil pore spaces. The magnitude of potential risk and the associated potential for rebounding thickness of DNAPL is expected to be minimal, provided the aggressive nature of Alternative D7.

4.8.6 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative D7 will involve installing electrodes into the DNAPL zone to heat the groundwater and DNAPL to enhance DNAPL recovery in multi-phase extraction wells. A significant volume of mobile and previously immobile DNAPL is expected to be recovered as part of Alternative D7. The ERH vendor/contractor contacted as part of this Focused FS estimated that 95 percent of estimated volume of potentially mobile DNAPL would be recovered in approximately four years. FS-level modeling is not able to accurately quantify how much residual DNAPL may be unable to be addressed by Alternative D7. Based on the aggressive nature of thermally enhanced recovery techniques, it is possible to make the following qualitative assessment of remaining DNAPL upon completion of recovery activities. Due to the aggressive nature of the remedy, there are anticipated to be minimal residuals and minimal potential for DNAPL rebound as part of Alternative D7.

4.8.7 Short-Term Effectiveness

Alternative D7 will require installation of vertical wells for electrodes, injection, and extraction wells, which will take approximately 12 months. During this time, construction workers will be exposed to subsurface soil and groundwater containing MGP-residuals. However, these exposures can be controlled through best management practices (e.g., dust control) and adhering to task-specific health and safety procedures (e.g., personal protective equipment and observing appropriate practices for designated safety zones).

Electrodes, wells, and associated piping and power/control infrastructure can be installed below grade; however, installation of ERH equipment will temporarily affect the Akzo and WPD logistics and operations associated with the paved areas.

Following construction, DNAPL containing MGP-residuals will be extracted to the surface, containerized, and shipped offsite for disposal/reuse. In addition, extracted vapor and groundwater containing MGP-residuals will also be treated prior to discharge or injection. Workers responsible for operation and maintenance of the recovery system will be exposed to MGP-residuals for the duration throughout system operations. In addition, increasing the subsurface temperature does increase the potential for generating unacceptable concentrations of MGP-COPCs in the indoor air of buildings adjacent to the treatment areas (vapor intrusion). However, these exposures can be minimized by not heating DNAPL located underneath existing buildings and implementing a soil vapor and indoor air monitoring program. As previously discussed in Section 4.8.2, the estimated duration to achieve the RAO is approximately four years.

Natural Resource Technology

Additional short-term effectiveness considerations related to increased DNAPL mobility and potentially increased constituent dissolution rates resulting from increased subsurface temperatures are discussed in Section 4.8.3 as part of the Overall Protection of Human Health and Environment criterion.

4.8.8 Implementability

Alternative D7 will be technically implementable. Thermal enhanced recovery has been implemented at many sites throughout Illinois and is a proven and reliable approach. Thermal treatment is a reliable means of mobilizing and collecting DNAPL because it reduces DNAPL viscosity, regardless of subsurface conditions. Installation and operation of the system will require careful coordination and access agreements with Akzo and WPD to allow electrode and recovery infrastructure to be installed on their properties. Typically, the electrodes need to be located on a 15-20-foot spacing, so there is limited flexibility to accommodate access restrictions within a desired treatment zone. The limited flexibility to adjust well locations is particularly relevant to active roadways, railroads, and industrial buildings. In these instances, wells may be able to be installed horizontally, which could be evaluated during the remedial design phase of the project.

Expanding or decreasing the size of the ERH treatment areas is relatively easily performed, should the location and size of the desired treatment area be modified throughout the remedial design phase. The effectiveness of the system at heating the subsurface can be monitored using subsurface thermal probes and the success of monitoring DNAPL recovery can be monitored through standard field observation of wells and borings as well as measurement of the volume of recovered DNAPL. Multiple vendors provide ERH system design, construction, and operation, allowing for an array of options and competitive pricing during the procurement process.

4.8.9 Cost

The capital cost of Alternative D7 will be approximately $26,968,000. The annual costs for operation and maintenance of Alternative D7 and groundwater monitoring will be approximately $2,006,000 per year for four years. The present worth cost of Alternative D7 will be $33,768,000. Appendix B provides unit cost of each remedial alternative and Table 4 provides a summary of the overall costs to implement.

5 COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

The purpose of this comparative analysis is to evaluate the remedial alternatives presented in Section 4 against seven of the nine specific evaluation criteria. The state acceptance and community acceptance criteria are excluded from the comparative analysis until formal public comments on the PRAP are received. This analysis highlights advantages, disadvantages, and key differences of the alternatives, thereby providing a framework for selection of the preferred remedy. The following subsections compare the alternatives relative to one another with respect to each criterion. Table 5 summarizes the detailed and comparative analysis of the alternatives.

5.1 Overall Protection of Human Health and the Environment

Alternative D1 will provide no protection to human health and the environment in comparison to DNAPL remedial Alternative D2, D3, D4, D5, D6, and D7. Therefore, Alternative D1 will no longer be considered in this analysis.

Alternative D2 will provide a partial degree of protection of human health by preventing consumption of Site groundwater, restricting land use, and controlling intrusive activities, but will provide no protection to potential ecological receptors exposed because engineering controls will not be implemented to remove or contain a principal threat waste, as required by the NCP.

Alternative D3 will provide a full degree of protection for human health and environment by installing a permanent barrier between DNAPL and adjacent sediment and surface water resources. The barrier installed as part of Alternative D3 is the most predictable of all evaluated alternatives at preventing offsite mobilization of DNAPL into the adjacent sediment and surface water resources in both the short- and long-term. Alternative D3 does not implement any measures to reduce the mass of DNAPL and the protection is based on containment rather than permanent removal.

Alternative D4 will provide a full degree of protection of human health and environment by implementing horizontal well DNAPL recovery measures to prevent further migration of DNAPL using sentry recovery wells and remove DNAPL with primary recovery wells. Alternative D4 does not involve artificially increasing DNAPL mobility to enhance recovery rates, and therefore there has limited potential to cause uncontrolled migration of DNAPL to previously un-impacted areas.

Alternative D5 will provide a full degree of protection of human health and environment by implementing physical measures to remove DNAPL with active pumping from recovery wells. Alternative D5 will involve artificially increasing DNAPL mobility through water flushing and gradient manipulation to enhance recovery rates. Because of these enhancements, there is potential for unforeseen migration of DNAPL to previously un-impacted areas. The increased mobility resulting from implementation of Alternative D5 can be minimized by ceasing groundwater extraction and injection activities and allowing the aquifer to attenuate to static conditions.

Alternative D6 will provide a full degree of protection of human health and environment by implementing chemical measures to remove DNAPL with active pumping from recovery wells. Alternative D6 will involve artificially increasing DNAPL mobility to through water flushing, gradient manipulation, and surfactant injection to enhance recovery rates. Because of these enhancements, there is potential for unforeseen migration of DNAPL to previously un-impacted areas. In addition, chemical injection can also increase the dissolution rate of DNAPL constituents into groundwater. Chemically increased DNAPL mobility and increased DNAPL dissolution rates resulting from implementation of Alternative D6 cannot be easily reduced or reversed.

Alternative D7 will provide a full degree of protection of human health and environment by implementing thermal measures to remove DNAPL with active pumping from recovery wells. Alternative D7 will involve artificially increasing DNAPL mobility to through water flushing, gradient manipulation, and thermal treatment to enhance recovery rates. Because of these enhancements, there is potential for unforeseen migration of DNAPL to previously un-impacted areas. Similar to Alternative D6, increase subsurface temperatures can also increase the dissolution rate of DNAPL constituents into groundwater. Thermally increased DNAPL mobility and increased DNAPL dissolution rates associated with Alternative D7 cannot be easily reduced or reversed in a timely manner.

5.2 Compliance with ARARs

Alternatives D2 and D3 will partially comply with the ARARs and NCP requirements, as neither alternative involves treatment of a principal threat waste that is practical to address. Alternatives D2 and D3 will meet the requirements of the location and action-specific ARARs.

Alternative D4 will remove a principal threat waste to the extent practicable, as required by the NCP. Full compliance with the chemical-specific ARAR will be addressed under the future groundwater remedy. In addition, Alternative D4 will meet the requirements of the location and action-specific ARARs.

Alternative D5, D6, and D7 will remove a principal threat waste to the extent practicable, as required by the NCP. Full compliance with the chemical-specific ARAR will be addressed under the future groundwater remedy. Provided IEPA approval of the Class V injection permit is consistent with the approach outlined in Section 4.6.4, Alternative D5, D6, and D7 will also meet the location and action-specific ARARs.

5.3 Long-Term Effectiveness and Permanence

Alternative D2 will partially meet the long-term effectiveness and permanence criterion. Control of potential human health risk is achieved by restricting groundwater use, land use, and intrusive activities, thereby preventing human exposure to DNAPL. Alternative D2 will provide no long-term effectiveness or permanent control of potential environmental risk.

Alternative D3 will fully achieve long-term effectiveness and permanent control of potential human health and environment. The volume of DNAPL will not be reduced; however, the DNAPL will be contained and inaccessible for human and ecological exposure, thereby reducing risk of human exposure. Vertical engineered barriers are a well-established, long-term remedy used to contain DNAPL at former MGP sites and can provide protection in excess of 30 years.

Alternative D4 will fully meet the long-term effectiveness and permanence criterion. Alternative D4 will reduce DNAPL mass and mobility through horizontal well DNAPL recovery, which will reduce the long-term potential risk to human health and environment. Remaining potential risk will consist of residual and immobile DNAPL in soil pore spaces. The magnitude of this potential risk and the associated potential for rebounding thickness of DNAPL is expected to be low-moderate.

Alternative D5 will fully meet long-term effectiveness and permanence criteria. Alternative D5 will reduce DNAPL mass and mobility through active DNAPL recovery, which will reduce the long-term potential risk to human health and environment. If operated effectively, the remaining potential risk will consist of residual and immobile DNAPL in soil pore spaces. The magnitude this potential risk and the associated potential for rebounding thickness of DNAPL is expected to be low, due to the physically flushing of DNAPL from the soil pore space.

Alternatives D6 and D7 will fully meet the long-term effectiveness and permanence criterion. Alternatives D6 and D7 will reduce DNAPL mass and mobility through aggressive DNAPL recovery, which will reduce the long-term potential risk to human health and environment. Remaining potential risk will consist of residual and immobile DNAPL in soil pore spaces. The magnitude of potential risk and the associated potential for rebounding thickness of DNAPL is expected to be minimal, provided the by aggressive recovery enhancements included in Alternatives D6 and D7.

5.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative D2 will not meet the reduction of toxicity, mobility, or volume through treatment criterion. Alternative D2 will not reduce the mobility or volume of the MGP-residuals through treatment because no active remediation is implemented. Alternative D3 will partially meet the reduction of toxicity, mobility, or volume through treatment criterion. Alternative D3 will not reduce the volume or toxicity of DNAPL, but this alternative will reduce mobility by preventing DNAPL from migrating to sediment and surface water.

Alternative D4 will fully meet the reduction of toxicity, mobility, or volume through treatment criterion. Alternative D4 will involve installing horizontal wells above the confining clay layer to extract DNAPL from locations with significant DNAPL deposits. A significant volume of mobile DNAPL is expected to be recovered as part of Alternative D4. DNAPL will likely remain in limited quantities in isolated low-lying areas and areas of low permeability. DNAPL recovery is permanent; however, Alternative D4 does not employ physical, chemical, or thermal enhancements to help mobilize DNAPL. As a result, there is a low-moderate potential for future accumulations of DNAPL.

Alternative D5 will fully meet the reduction of toxicity, mobility, or volume through treatment criterion. Alternative D5 will involve installing horizontal wells above the confining clay layer to extract the significant DNAPL deposits by physically increasing the hydraulic gradient to drive DNAPL towards the horizontal recovery well. A significant volume of mobile DNAPL is expected to be recovered as part of Alternative D5. Immobile DNAPL will likely remain in limited quantities in isolated low-lying areas and areas of low permeability. DNAPL recovery is permanent; however, Alternative D5 relies on physically increasing DNAPL mobility and does not incorporate more aggressive chemical or thermal enhancements to help reduce the volume of residual DNAPL. As a result, there is a low potential for future accumulations of DNAPL.

Alternatives D6 and D7 will fully meet the reduction of toxicity, mobility, or volume through treatment criterion. Alternatives D6 and D7 will involve installing horizontal wells above the confining clay layer to extract DNAPL locations with significant DNAPL deposits. DNAPL will be mobilized towards recovery wells using chemical enhancements for Alternative D6 and physical enhancements for Alternative D7. A significant volume of mobile DNAPL is expected to be recovered as part of these alternatives. Immobile DNAPL will likely remain in limited quantities in isolated low-lying areas and areas of low permeability. DNAPL recovery is permanent and the aggressive enhanced recovery implemented by these alternatives is expected to reduce the volume of residual DNAPL. As a result, there is minimal potential for future accumulations of DNAPL.

5.5 Short-Term Effectiveness

Alternative D2 will full meet short-term effectiveness criteria. It is estimated that six months will be required to obtain necessary permissions for institutional controls. The objective of this remedy will be achieved immediately and workers and community will not be exposed to MGP-residuals during implementation.

Alternative D3 will fully meet short-term effectiveness criteria. It is estimated that 12 months will be required to install vertical engineered barrier and groundwater gradient control system. The objective of limiting the offsite migration of DNAPL will be immediately achieved. The community will be exposed to minimal MGP-residuals through implementation of Alternative D3 while workers will be moderately exposed during construction, operations, and maintenance.

Alternative D4 will fully meet short-term effectiveness criteria. It is estimated that six months will be required to install the horizontal recovery well and sump system. The objective of achieving the RAO requirement to reduce the mass and mobility of recoverable DNAPL to the extent practicable is estimated to be achieved following 31 years of system operations. The community will be exposed to minimal MGP-residuals through implementation of Alternative D4 while workers will be moderately exposed during construction, operations, and maintenance.

Alternative D5 will fully meet short-term effectiveness criteria. It is estimated that 12 months will be required to install the horizontal recovery wells, groundwater injection and extraction wells, install the treatment plant and necessary recovery/power lines. The objective of achieving the RAO requirement to reduce the mass and mobility of recoverable DNAPL to the extent practicable is estimated to be achieved following seven years of system operations. The community will be exposed to minimal MGP-residuals through implementation of Alternative D5 while workers will be moderately exposed during construction, operations, and maintenance.

Alternative D6 will fully meet short-term effectiveness criteria. It is estimated that 12 months will be required to install the horizontal recovery wells, groundwater injection and extraction wells, install the treatment plant, surfactant injection system, and necessary recovery/power lines. The objective of achieving the RAO requirement to reduce the mass and mobility of recoverable DNAPL to the extent practicable is estimated to be achieved following four years of system operations. The community will be exposed to minimal MGP-residuals through implementation of Alternative D6 while workers will be moderately exposed during construction, operations, and maintenance. Additional short-term effectiveness considerations related to increased DNAPL mobility and potentially increased constituent dissolution rates are discussed in Section 5.1 as part of the Overall Protection of Human Health and Environment criterion.

Alternative D7 will fully meet short-term effectiveness criteria. It is estimated that 12 months will be required to install the thermally enhanced recovery system. The objective of achieving the RAO requirement to reduce the mass and mobility of recoverable DNAPL to the extent practicable is estimated to be achieved following four years of system operations. The community will be exposed minimal MGP-COPCs and potential non-MGP-COPCs through increased contaminated diffusion relate to increased subsurface temperature. This risk will be minimized by not heating underneath occupied buildings and implementing vapor controls and monitoring. Workers will be moderately exposed during construction, operations, and maintenance of Alternative D7. Additional short-term effectiveness considerations related to increased DNAPL mobility and potentially increased constituent dissolution rates are discussed in Section 5.1 as part of the Overall Protection of Human Health and Environment criterion.

5.6 Implementability

Alternative D2 will fully meet implementability criteria. Coordination with the various impacted property owners may present some administrative challenges. However, the proposed institutional controls will not affect the current land use and therefore the coordination issues should not be overly challenging. Alternative D3 will partially meet implementability criteria. Soil-bentonite slurry walls are typically easily installed, but the implementation will be more challenging at this Site due to extensive utility crossings, working adjacent to the railroad, and coordination with existing property owners.

Alternative D4 will fully meet implementability criteria. Recovery trench alignments and proposed HDD construction methods were selected to minimize or avoid utility and property owner conflict.

Alternatives D5 and D6 will partially meet implementability criteria. Recovery trench alignments and proposed construction methods were selected to minimize or avoid utility and property owner conflict. However, pump controls, power, and piping will require connection to the treatment plant proposed on NSG property. This connection will be completed through directionally drilled borings under the EJ&E Railroad, and trenching through Akzo and WPD property to each of the wells. Coordination of directional drilling under EJ&E Railroad and trenching through Akzo and WPD property is technically implementable but will be an administrative challenge.

Alternatives D7 will partially meet implementability criteria. Thermally enhanced extraction is technically implementable; however, there are several administrative implementation challenges at the Site. Installation and operation of the system will require careful coordination and access agreements with Akzo and WPD to allow electrode and recovery infrastructure to be installed on their properties. Typically, the electrodes need to be located on a 15-20-foot spacing, so there is limited flexibility to accommodate access restrictions within a desired treatment zone. The limited flexibility to adjust well locations is particularly relevant to active roadways, railroads, and industrial buildings. In these instances, wells may be able to be installed horizontally, which could be evaluated during the remedial design phase of the project.

5.7 Cost

Table 4 provides a comparative summary of costs for the remedial alternatives, including capital costs, O&M costs, and total costs. Detailed cost estimates are presented in Appendix B.

6 ADDITIONAL CONSIDERATIONS FOR REMEDY SELECTION AND IMPLEMENTATION

Sections 1-5 of this Focused FS report present the Site history, detail DNAPL extent, and evaluate a range of potential DNAPL remedial alternatives. Evaluation of DNAPL remedial alternatives was performed by comparing each remedy against the standard USEPA threshold and balancing criteria. While developing remedial alternatives and completing the standard evaluation, additional considerations specific to remediation of DNAPL at this Site were identified. This section presents additional considerations for selection and implementation of a potential DNAPL remedy at the Site.

6.1 Stepped Remedial Approach

Remediation of DNAPL is critical to the success of a comprehensive Site remedy. Artificially increasing DNAPL mobility using physical, chemical, or thermal enhancements can increase DNAPL recovery rates, but also risks spreading DNAPL beyond the current extents. Increasing DNAPL mobilization to facilitate recovery is of particular concern at this Site due to the presence of approximately 4 feet of DNAPL located within 200 feet of Lake Michigan.

In addition, any DNAPL remedial activity that involves aggressive groundwater extraction and injection for the purposes of mobilizing DNAPL also risks breaking the DNAPL interfacial tension thus dividing a singular DNAPL plume into multiple isolated plumes. This risk is referred to as “snapping off” in the oil field recovery industry and is well documented (Environmental Agency, 2002).

In order to maximize DNAPL recovery and minimize the potential to spread DNAPL to uncontaminated areas, consideration should be given to the stepped approach as described below. This approach takes advantage of the benefits of up to three of the evaluated remedial alternatives. However, by implementing these remedies in a stepped approach, rather than individually, the potential risks of enhanced recovery techniques can be reduced significantly.

6.1.1 Step 1 - Alternative D4 - Horizontal Well DNAPL Recovery

This step will consist of constructing of Alternative D4. Horizontal wells will be installed above the top of clay layer to maximize DNAPL recovery potential. DNAPL extraction will be conducted by removing accumulated DNAPL from recovery sumps during extraction events. Extracted DNAPL will be containerized and sent for offsite recycling/disposal, eliminating the need for onsite storage and treatment facilities. Additional description of Alternative D4 is included in Section 4.5.2. Due to construction efficiencies, Step 1 will also include installation of horizontal groundwater extraction wells that are collocated along the same alignment as the horizontal DNAPL recovery wells that may be required for future remedial steps. As determined to be practical and allowable by access agreements during the remedial design phase, installation the conduit/piping required for future remedial steps may also be constructed.

Step 1 will allow for removal of readily recoverable DNAPL and will reduce the volume of DNAPL that may need to be mobilization using more aggressive enhanced recovery alternatives. As previously stated in Section 4.5.2, it is estimated that 50 percent of recoverable DNAPL will be recovered during the initial seven years of operation. As a result, the potential for uncontrolled migration of DNAPL resulting from enhanced recovery will be significantly reduced. Once effectiveness of this alternative no longer meets predetermined metrics presented in Section 6.2, remedy operations will transition to Step 2.

Alternative D4 does not require the complex design and construction of a phase separation and water treatment system, potentially lengthy negotiation with the EJ&E Railroad, and significant disturbance to adjacent property owners. As a result, Alternative D4 can be designed, implemented, and operational significantly more quickly than enhanced recovery alternatives.

The more complex design and negotiation elements of enhanced recovery alternatives can then be completed while Alternative D4 is operational and actively removing DNAPL. Initial implementation of a horizontal well DNAPL recovery system associated with Alternative D4 will also allow for the collection of actual field recovery data, resulting in a more effective and efficient design of a potential enhanced recovery system.

6.1.2 Step 2 – Alternative D5 - Physically Enhanced DNAPL Recovery

As presented in Section 6.2 and on Figure 16, if field conditions indicate that transition from Step 1 to Step 2 is required, consideration should be given to performing a supplemental investigation to assess the presence and mobility of the remaining DNAPL. This investigation could identify the location, relative magnitude, and significance of the remaining DNAPL that was unable to be fully addressed by Step 1. Information from this assessment could be used to guide decisions regarding the necessity, location, and scope of the transition.

Natural Resource Technology

Step 2 will supplement the infrastructure installed as part of Step 1 with the groundwater injection/extraction and continuous recovery DNAPL infrastructure required for Alternative D5. In accordance with IEPA correspondence, a groundwater treatment system will be installed to treat extracted groundwater, to the extent practical, prior to injection. Step 2 will involve installing dedicated DNAPL recovery pumps and associated infrastructure as summarized in Section 4.6.2.

Step 2 will involve physically enhanced DNAPL recovery through groundwater flushing and increased gradient will help mobilize DNAPL that was not addressed in a time efficient manner by Step 1. Enhanced mobilization of DNAPL resulting from physical means is easier to control than enhanced mobilization through chemical or thermal approaches. Should DNAPL migrate beyond a desired boundary, the mobilization can be decreased by ceasing injection and/or extraction activities in that area. As a result, by implementing additional volume reduction as part of Step 2 prior to Step 3, the risk of uncontrolled mobilization from chemically enhanced recovery will be significantly reduced. Once effectiveness of this alternative no longer meets predetermined metrics presented in Figure 16 and in Section 6.2, remedy operations will transition to Step 3, if necessary.

6.1.3 Step 3 – Alternative D6 - Chemically Enhanced DNAPL Recovery

This step will re-purpose the infrastructure and approach used as part of Alternative D5; however, the injected water will be amended with a surfactant to further enhance DNAPL mobility and recovery as described in Section 4.7.2. This step will help mobilize and recover DNAPL that was not addressed by Step 1 and Step 2. This step may be used as a polishing step and may exceed the RAO and performance standard requirements.

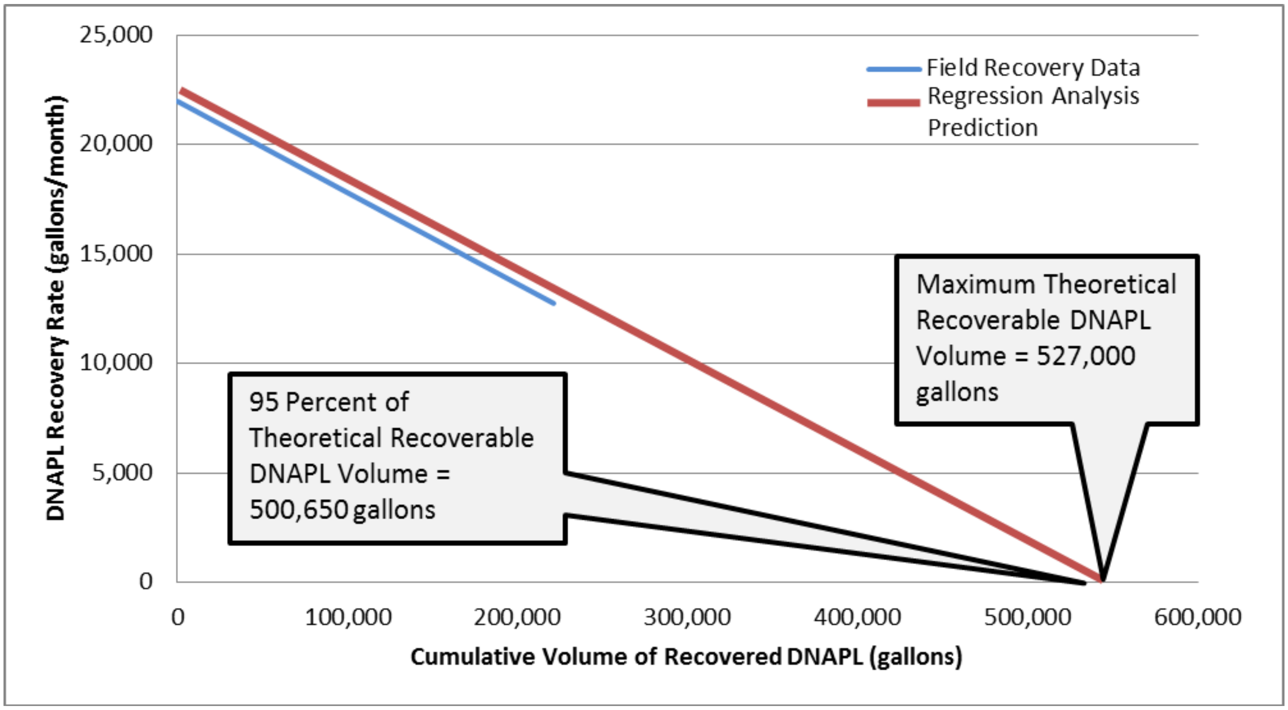
6.2 Performance Standard

The RAO presented in Section 2.4 provides a general project objective for DNAPL remediation; however, it lacks the specificity to sufficiently determine DNAPL remedy success. The method to document achievement of project objectives and define the endpoint of remedial activities is defined by a performance standard. Although various approaches exist to estimate the volume of DNAPL that may be recovered, it is technically impractical to calculate the quantity of recoverable DNAPL with the accuracy required for a mass removal-based performance standard. Therefore, developing a performance standard tied to a pre-remediation DNAPL volume estimate will not adequately characterize remedial success. To eliminate the potential volume misrepresentation inherent with a performance standard based on a pre-remediation DNAPL volume estimate, the performance standard for the Site will be based on measurable field observations that will document DNAPL removal success. In addition, given the Agency's preference of the Stepped Approach presented in Section 6.1, the performance standard must also outline a framework to define if and when transition to a subsequent step is necessary.

A decline curve analysis will be applied for the purposes of endpoint determination for each remedial alternative implemented for removal of DNAPL. The decline curve analysis was developed in the Petroleum Production Handbook (Frick and Taylor, 1962), as an approach for estimating future recovery performance and the maximum theoretical yield. A decline curve analysis is a graphical tool, where the DNAPL recovery rate is plotted on the vertical axis and cumulative volume of recovered DNAPL is plotted on the horizontal axis. Under field conditions, the rate of DNAPL recovery for any type of extraction system typically exhibits a rapid increase before reaching a relative maximum value; with increasing operation time, DNAPL recovery rates typically decrease in a linear fashion until it approaches zero.

Through field measurements of DNAPL recovery rates and cumulative recovery volumes, a regression analysis will be performed to estimate the slope of the declining DNAPL recovery rate. Once a reliable declining slope has been determined, the line is projected to estimate the cumulative volume of DNAPL at a recovery rate of zero. This projected volume is considered the maximum theoretical volume of DNAPL that can be recovered by the current system. Field recovery data will be integrated as collected to refine the maximum theoretical volume projected by the decline curve analysis. Operation of a DNAPL recovery system until the maximum theoretical volume is reached is not practical. Therefore, the DNAPL recovery system will be operated until the selected remedy removes the maximum practical volume of DNAPL from the treatment areas. For the purposes of this Focused FS, the maximum practical DNAPL volume is defined as approaching or exceeding 95 percent of the maximum theoretical recoverable volume based on the decline curve analysis. Using Alternative D5 modeled recovery rates included in Appendix C3, a conceptual decline curve analysis is depicted in Figure C.

Figure C – Alternative D5 Conceptual Decline Curve Analysis



It is worth noting that Figure C presents a FS-level model as the inputs for recovery rates and cumulative volumes. The actual field recovery data collected during operation of any DNAPL recovery remedy is anticipated to have a generally declining trend; however, there are minor increases or decreases in the DNAPL recovery rate based on actual subsurface and operational conditions.

A preliminary framework flow chart demonstrating how these performance standards will be applied is included as Figure 16. Modifications to this preliminary framework may be incorporated based on additional analysis performed during the remedial design. Any modification to this framework will be mutually agreed to by USEPA, IEPA, and IBS. As indicated on Figure 16, stakeholders will meet following the initial 2 years of Alternative D4 operations (following shake down period) to review DNAPL recovery rates and evaluate supporting lines of evidence documenting system performance. Pending stakeholder concurrence, operation of Alternative D4 would be continued in its initial configuration. Thereafter, performance of the selected remedy would be reviewed annually by stakeholders to allow for potential improvements in system operation, or transition to a different DNAPL recovery alternative. The same review process is proposed for Alternative D5 (should implementation be deemed necessary by stakeholders).

Decline curves may be developed on a site wide or individual extraction well basis, as agreed upon by project stakeholders. The maximum theoretical recoverable volume of DNAPL is determined directly from field recovery data and reflects the volume of DNAPL, which can be extracted by a given remedial alternative. For this reason, the maximum theoretical volume which may be recovered by remedial alternatives in consideration (e.g., D4, modified D4, D5, or D6) will also vary.

Regardless of the alternative implemented under the stepped approach, subsurface DNAPL extraction will be continued until the maximum practical volume, approaches or exceeds 95% of the volume predicted by a decline curve analysis. As described above, periodic stakeholder reviews will also evaluate system performance through supporting lines of evidence, such as field observation, thickness measurements, and temporal changes in lateral distribution of subsurface DNAPL. As determined necessary by stakeholders, the potential for continued system operation, system modification, alternative enhancement or termination of extraction efforts will be evaluated to optimize the DNAPL remedy performance.

Selection and implementation of the future site groundwater remedy is predicated upon successful and timely completion of the selected DNAPL remedial action; therefore, modification of recovery endpoints may be necessary if DNAPL extraction system performance data indicate reaching the performance standard cannot be achieved without significant delay to implementation of the selected groundwater remedy. Modification of the established DNAPL recovery performance standard may be considered if mutually agreed to by USEPA, Illinois EPA, and IBS, should site-specific operations data demonstrate that achieving the performance standard is not attainable or beneficial for restoring site groundwater.

6.3 Conclusion

Remediation of DNAPL is critical to the success of a comprehensive South Plant remedy. Implementing the most aggressive DNAPL remedy may initially appear to result in the most efficient and timely approach to reducing the mass and mobility of DNAPL; however, these aggressive approaches also involve increasing DNAPL mobility, and therefore increasing the potential for additional offsite migration of DNAPL. The unique nature of DNAPL recovery and the unique location of the South Plant site merit consideration to this stepped recovery approach to increase potential volume of DNAPL that can be recovered while minimizing the risks inherent to more seemly aggressive DNAPL remedial alternatives.

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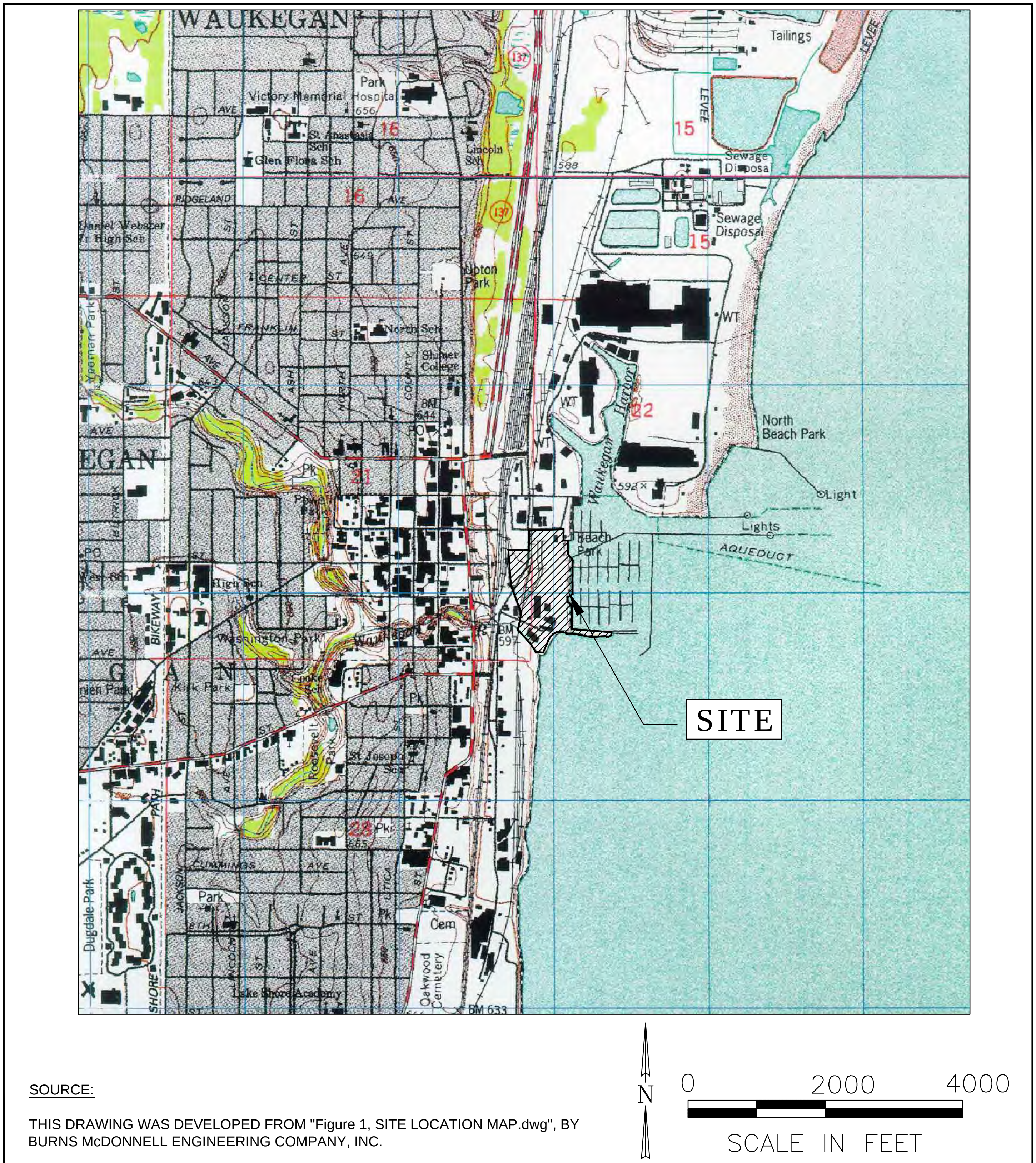
FIGURES



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SITE LOCATION MAP

NATURAL RESOURCE TECHNOLOGY

FOCUSED FEASABILITY STUDY REPORT
FORMER SOUTH PLANT MGP
NORTH SHORE GAS COMPANY
WAUKEGAN, ILLINOIS

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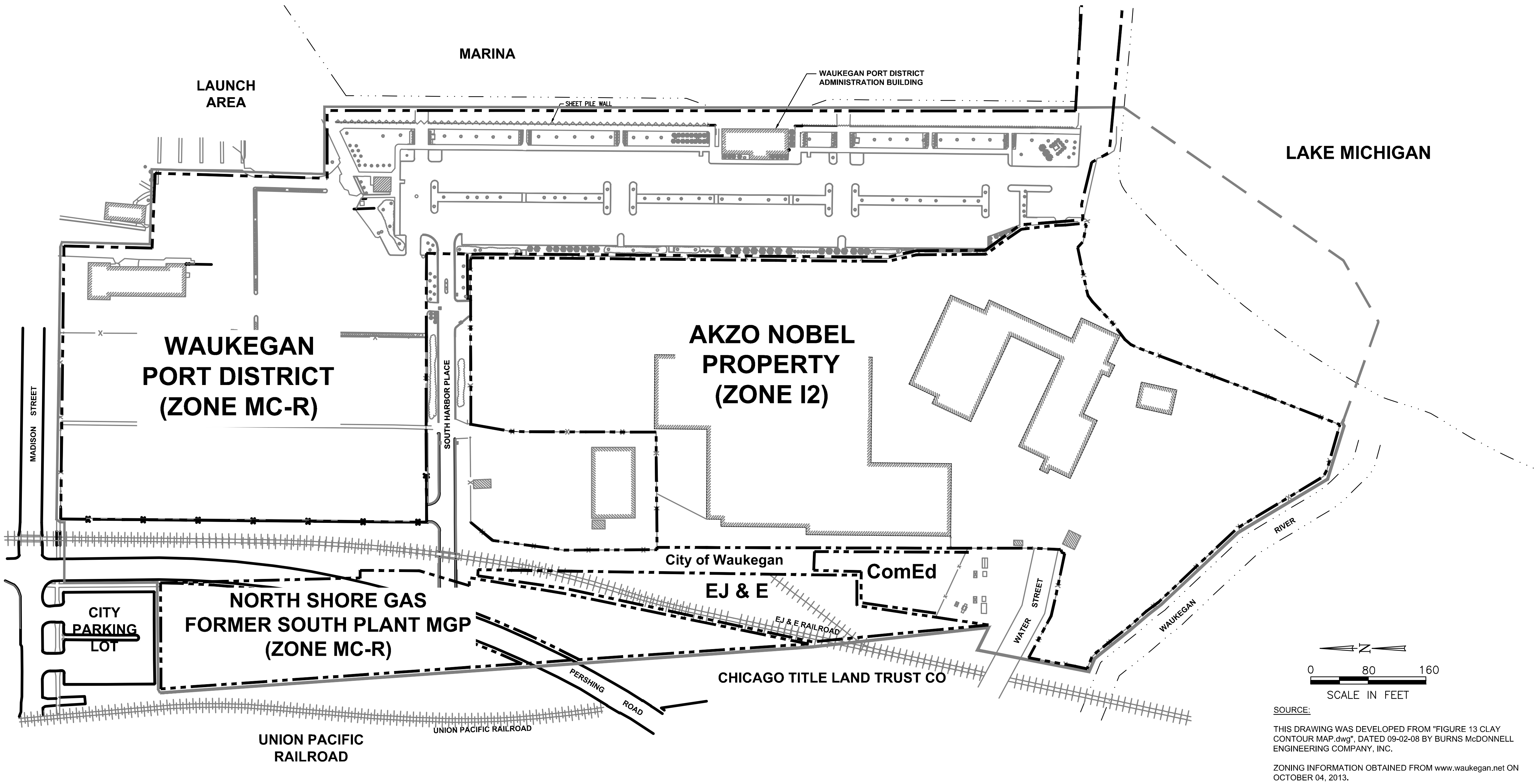
FIGURE NO. 1



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ZONING INFORMATION OBTAINED FROM www.waukegan.net ON OCTOBER 04, 2013.

APPROXIMATE PROPERTY LINES

APPROXIMATE SITE BOUNDARY

EXISTING FENCE

RAILROAD TRACKS

M-CR MARINE-COMMERCIAL RECREATION

I2 GENERAL INDUSTRIAL

EXISTING BUILDING

SHEETPILE WALL

APPROXIMATE LOCATION OF WATER LINE

DRAWN BY: RLH DATE: 05/09/14

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CURRENT SITE LAYOUT AND ZONING MAP

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FORMER SOUTH PLANT MGP
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WAUKEGAN, ILLINOIS

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FIGURE NO.
2

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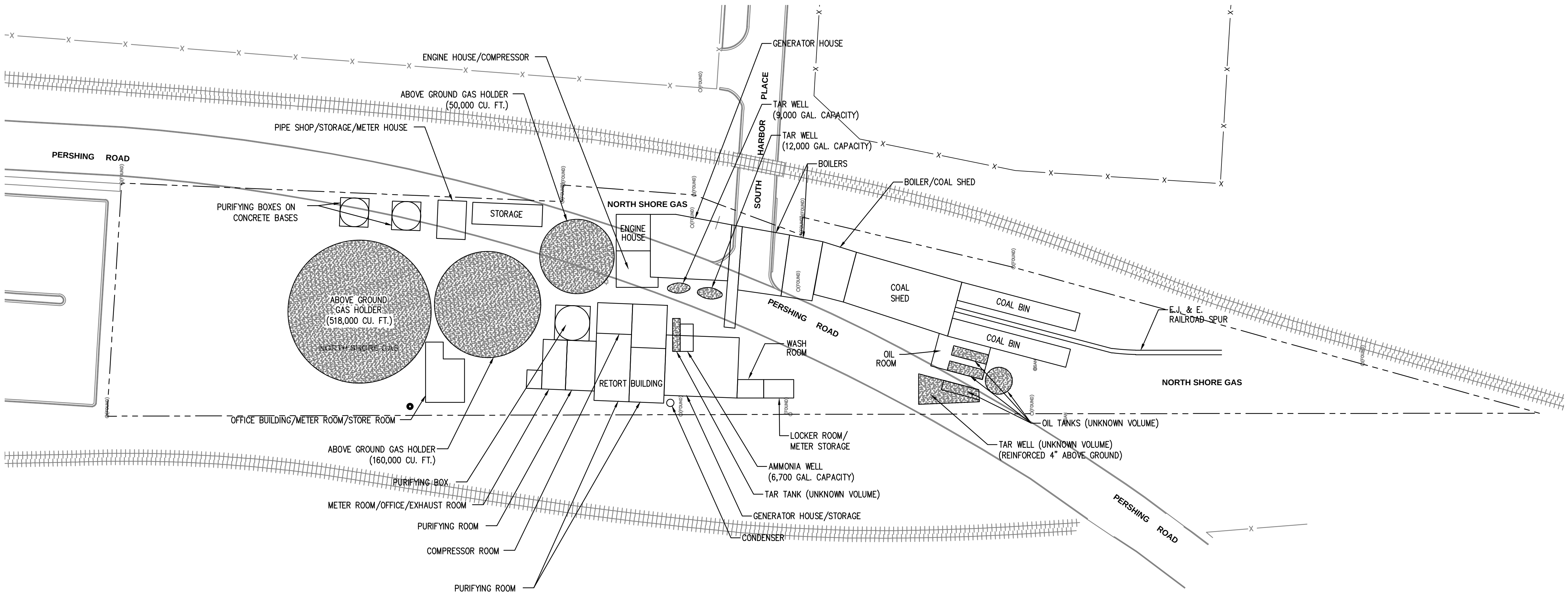

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APPROXIMATE PROPERTY LINE OF FORMER SOUTH PLANT

EXISTING FENCE

RAILROAD TRACKS

HISTORICAL STRUCTURES

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HISTORIC MGP LAYOUT

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FORMER SOUTH PLANT MGP
NORTH SHORE GAS COMPANY
WAUKEGAN, ILLINOIS

NATURAL RESOURCE TECHNOLOGY

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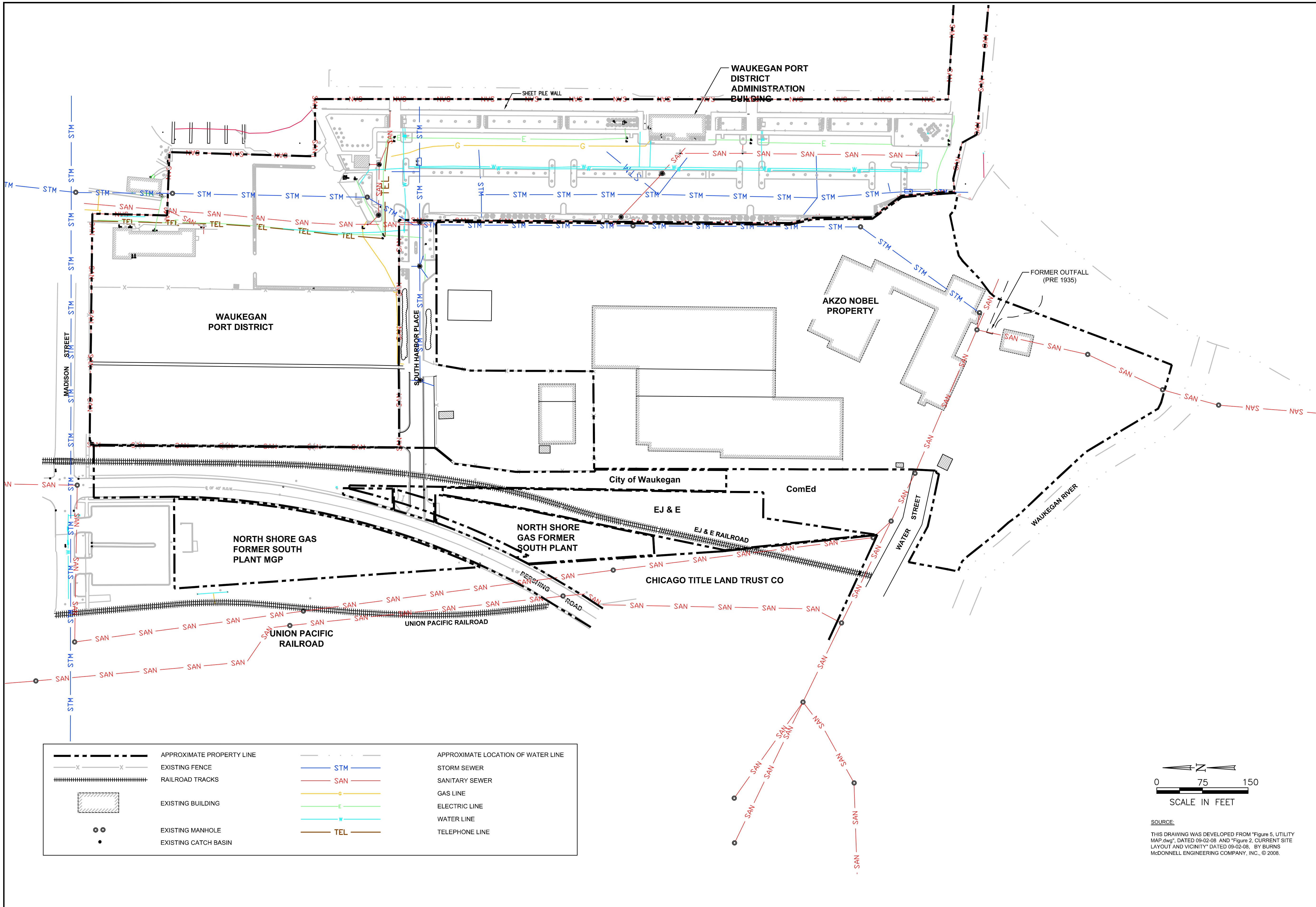
1983/9.2

FIGURE NO.
3



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SITE UTILITIES

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FORMER SOUTH PLANT MGP
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NATURAL RESOURCE TECHNOLOGY

PROJECT NO.
1983/9.2

FIGURE NO.
4

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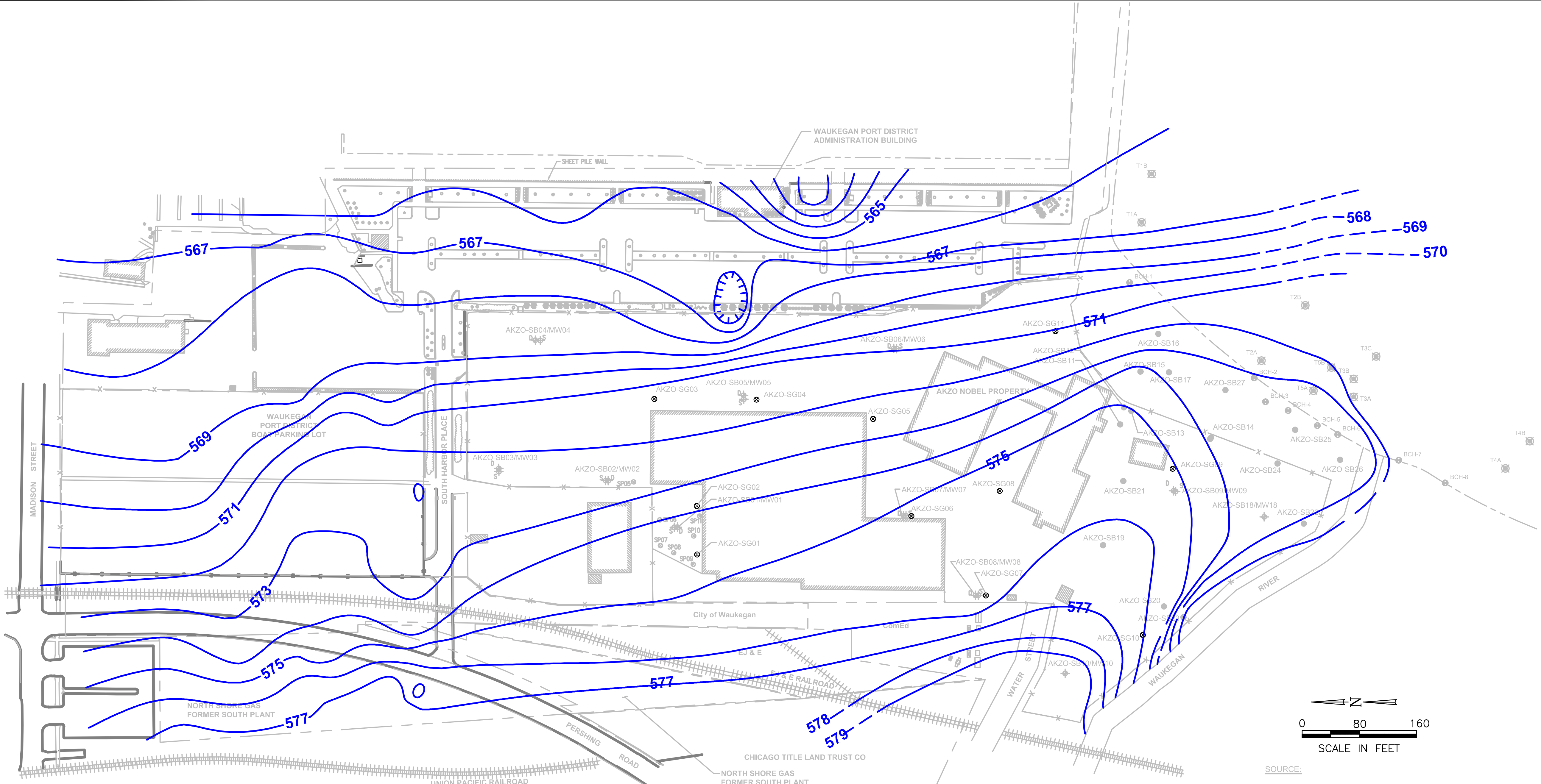

SOURCE:
THIS DRAWING WAS DEVELOPED FROM "FIGURE 13 CLAY CONTOUR MAP.dwg", DATED 09-02-08 BY BURNS McDONNELL ENGINEERING COMPANY, INC.

- APPROXIMATE PROPERTY LINE OF AKZO NOBEL
- EXISTING FENCE
- RAILROAD TRACKS
- SHEETPILE WALL
- APPROXIMATE LOCATION OF WATER LINE
- 571 TOP OF CONFINING CLAY, DASHED WHERE INFERRED
- WATER LEVEL/DNAPL MEASUREMENT ONLY
- PVOC's, PAHs, ARSENIC ANALYSIS WITH WATER LEVEL/DNAPL MEASUREMENT
- SOIL BORING LOCATION
- SOIL VAPOR PROBE LOCATION
- SEDIMENT SAMPLE LOCATION
- BEACH SAMPLE LOCATION
- EXISTING BUILDING

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REFERENCE:	

TOP OF CONFINING CLAY LAYER

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FORMER SOUTH PLANT MGP
NORTH SHORE GAS COMPANY
WAUKEGAN, ILLINOIS

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FIGURE NO.
5

Sep 10, 2014 9:38am PLOTTED BY: ddudo SAVED BY: ddudo FIG05
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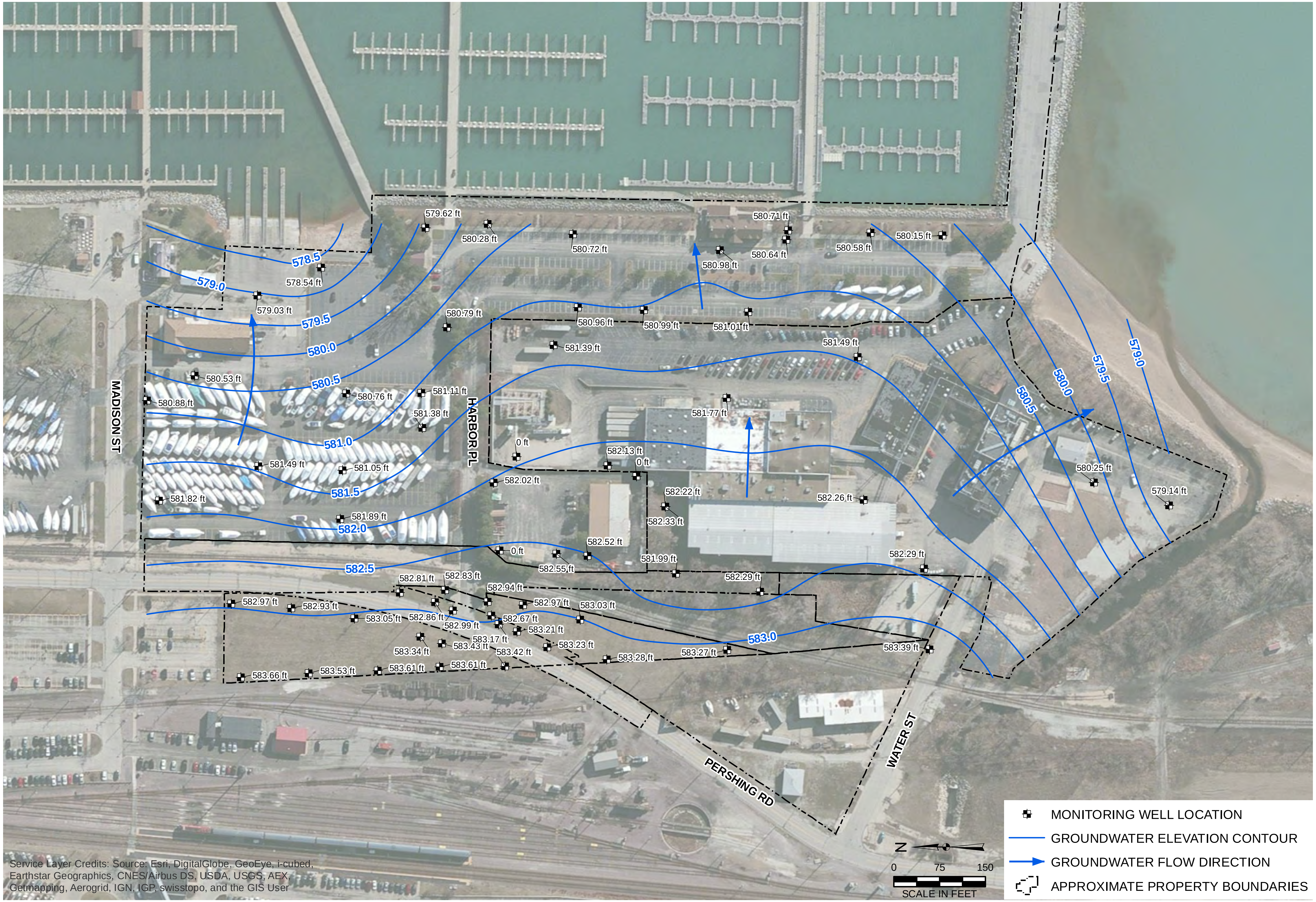

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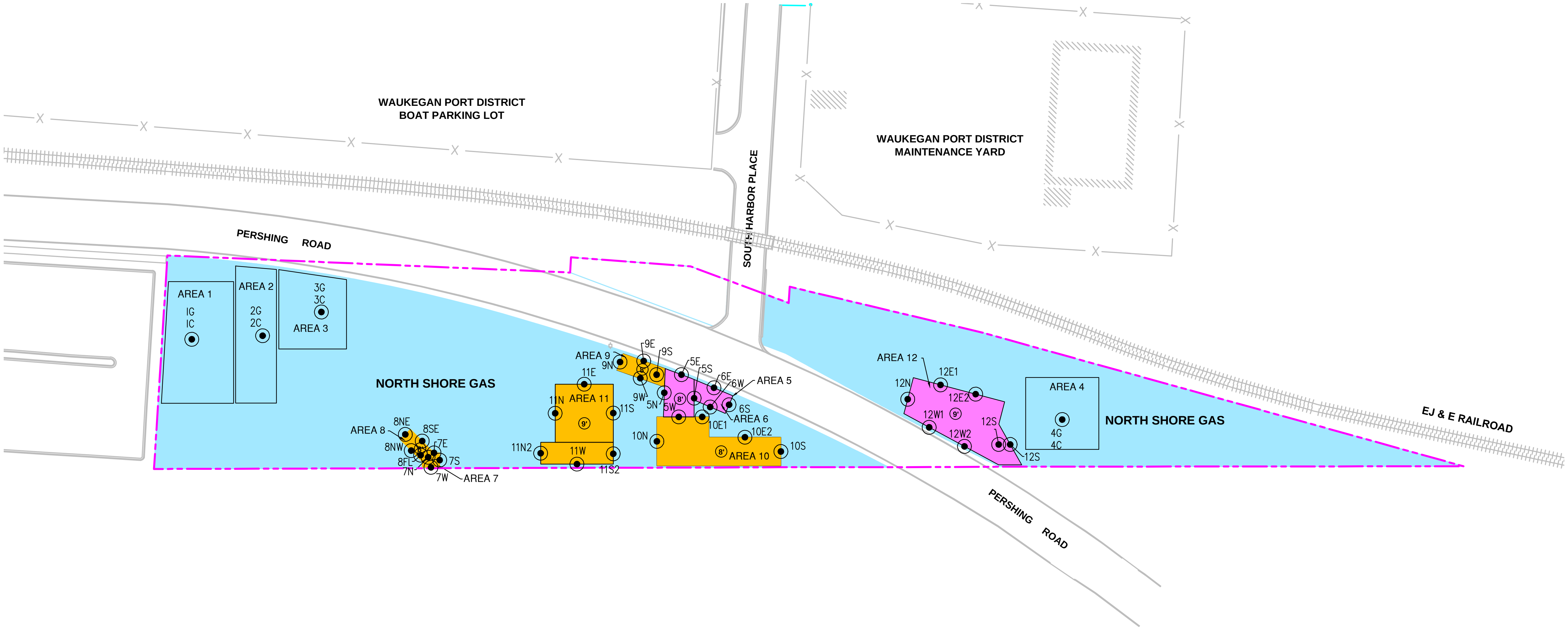
TYPICAL GROUNDWATER ELEVATION CONTOURS

FOCUSED FEASABILITY STUDY
FORMER SOUTH PLANT MGP
NORTH SHORE GAS COMPANY
WAUKEGAN, ILLINOIS

PROJECT NO: 1983

FIGURE NO: 6

NATURAL RESOURCE TECHNOLOGY



APPROXIMATE PROPERTY LINE OF FORMER SOUTH PLANT

SOIL EXCAVATED TO 3.5' BGS

IMPACTED MATERIAL EXCAVATED ABOVE WATER TABLE

ADDITIONAL DEEP EXCAVATION ABOVE WATER TABLE

11W SOIL CONFIRMATION SAMPLING LOCATIONS

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PREVIOUS SOIL REMOVAL ACTIONS AT FORMER MGP

FOCUSED FEASIBILITY STUDY REPORT
FORMER SOUTH PLANT MGP
NORTH SHORE GAS COMPANY
WAUKEGAN, ILLINOIS

NATURAL RESOURCE TECHNOLOGY

PROJECT NO.
1983/9.2

FIGURE NO.
7

ESTIMATED EXTENT OF DNAPL CONTAMINATION

FOCUSED FEASABILITY STUDY
FORMER SOUTH PLANT MGP
NORTH SHORE GAS COMPANY
WAUKEGAN, ILLINOIS

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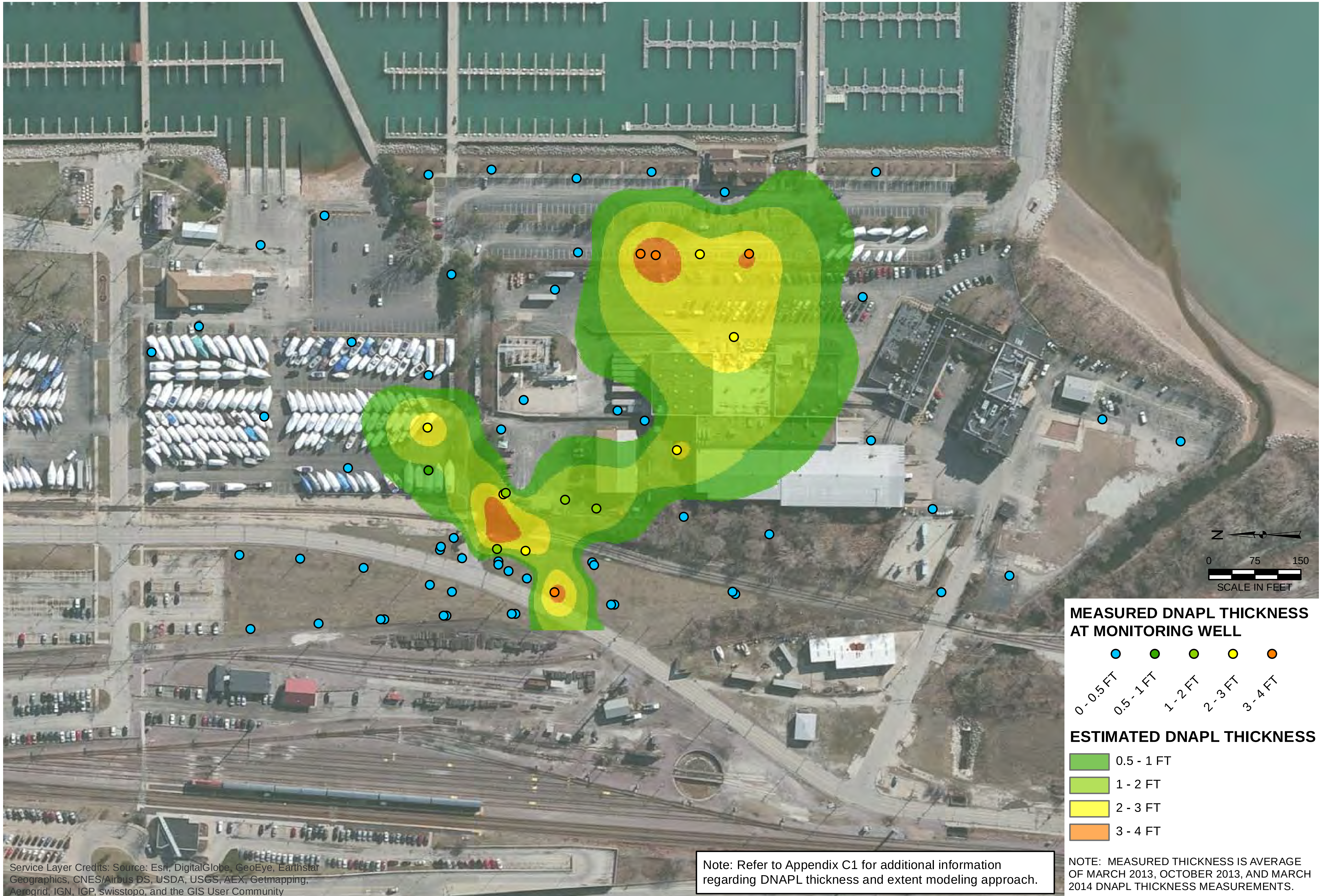


MEASURED DNAPL THICKNESS AT MONITORING WELL

- 0 - 0.5 FT
- 0.5 - 1 FT
- 1 - 2 FT
- 2 - 3 FT
- 3 - 4 FT

ESTIMATED DNAPL THICKNESS

- 0.5 - 1 FT
- 1 - 2 FT
- 2 - 3 FT
- 3 - 4 FT

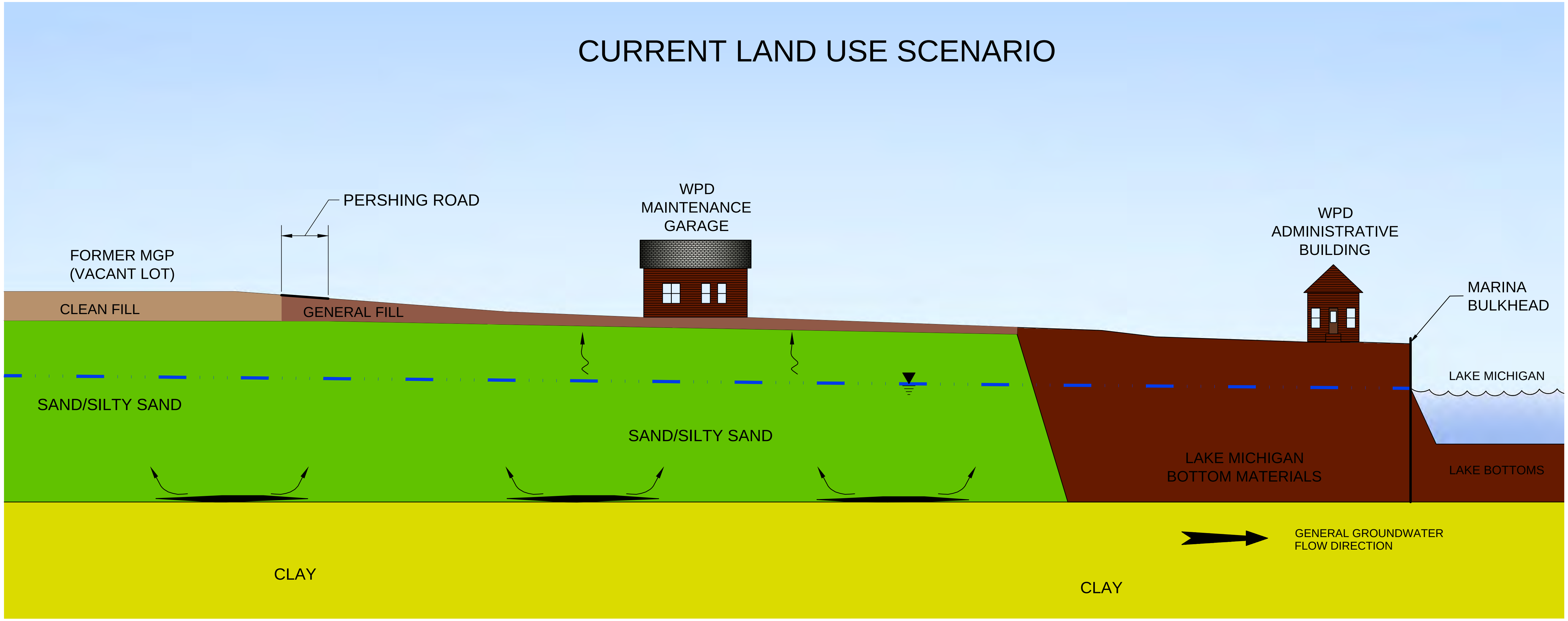
Note: Refer to Appendix C1 for additional information regarding DNAPL thickness and extent modeling approach.

NOTE: MEASURED THICKNESS IS AVERAGE OF MARCH 2013, OCTOBER 2013, AND MARCH 2014 DNAPL THICKNESS MEASUREMENTS.

PROJECT NO: 1983

FIGURE NO: 8

NATURAL RESOURCE TECHNOLOGY



	CLEAN FILL
	GENERAL FILL
	FILL - LAKE MICHIGAN BOTTOM MATERIALS
	SAND/SILTY SAND
	CLAY
	DNAPL
▼	GROUNDWATER TABLE

NOT TO SCALE

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DRAWING NO: 1983-92-B09C
REFERENCE:

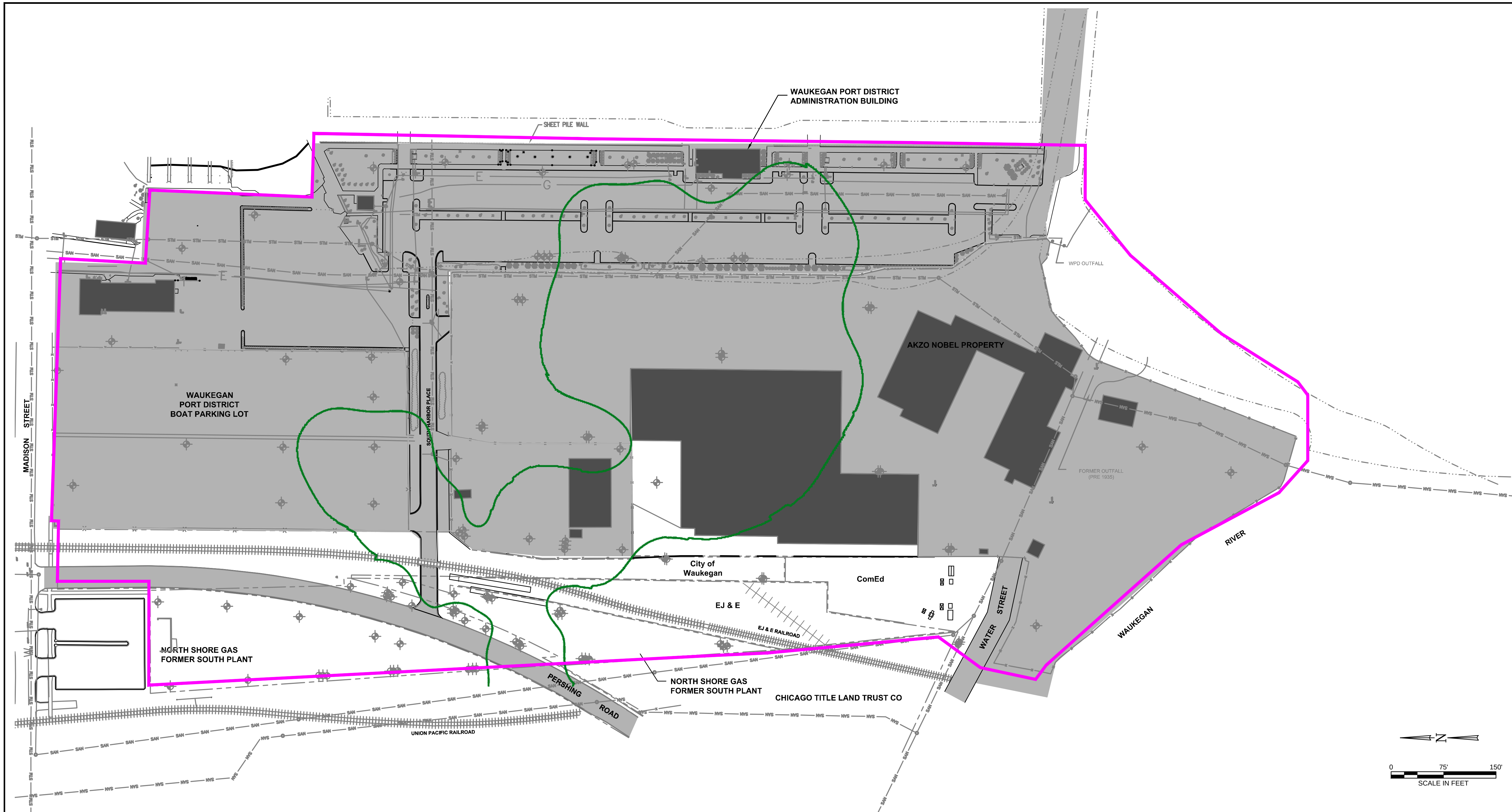
GRAPHICAL CONCEPTUAL SITE MODEL

FOCUSED FEASIBILITY STUDY REPORT
FORMER SOUTH PLANT MGP
NORTH SHORE GAS COMPANY
WAUKEGAN, ILLINOIS

NATURAL RESOURCE TECHNOLOGY

PROJECT NO.
1983/9.2

FIGURE NO.
9



APPROXIMATE PROPERTY LINE

EXISTING FENCE

RAILROAD TRACKS

EXISTING STORM SEWER (APPROXIMATE)

EXISTING SANITARY SEWER (APPROXIMATE)

EXISTING BUILDINGS WITH CONCRETE SLAB FLOORS

EXISTING PAVEMENT

SHEETPILE WALL

EXISTING MANHOLE

EXISTING CATCH BASIN

APPROXIMATE LOCATION OF WATER LINE

MONITORING WELL LOCATION

PROPOSED EXTENT OF INSTITUTIONAL CONTROLS

ESTIMATED EXTENT OF DNAPL BASED ON MODELING APPROACH DETAILED IN APPENDIX C1

SOURCE:

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DRAWING NO: 1983-92-10C	
REFERENCE:	

ALTERNATIVE D2 - CONCEPTUAL LIMITS OF INSTITUTIONAL CONTROLS

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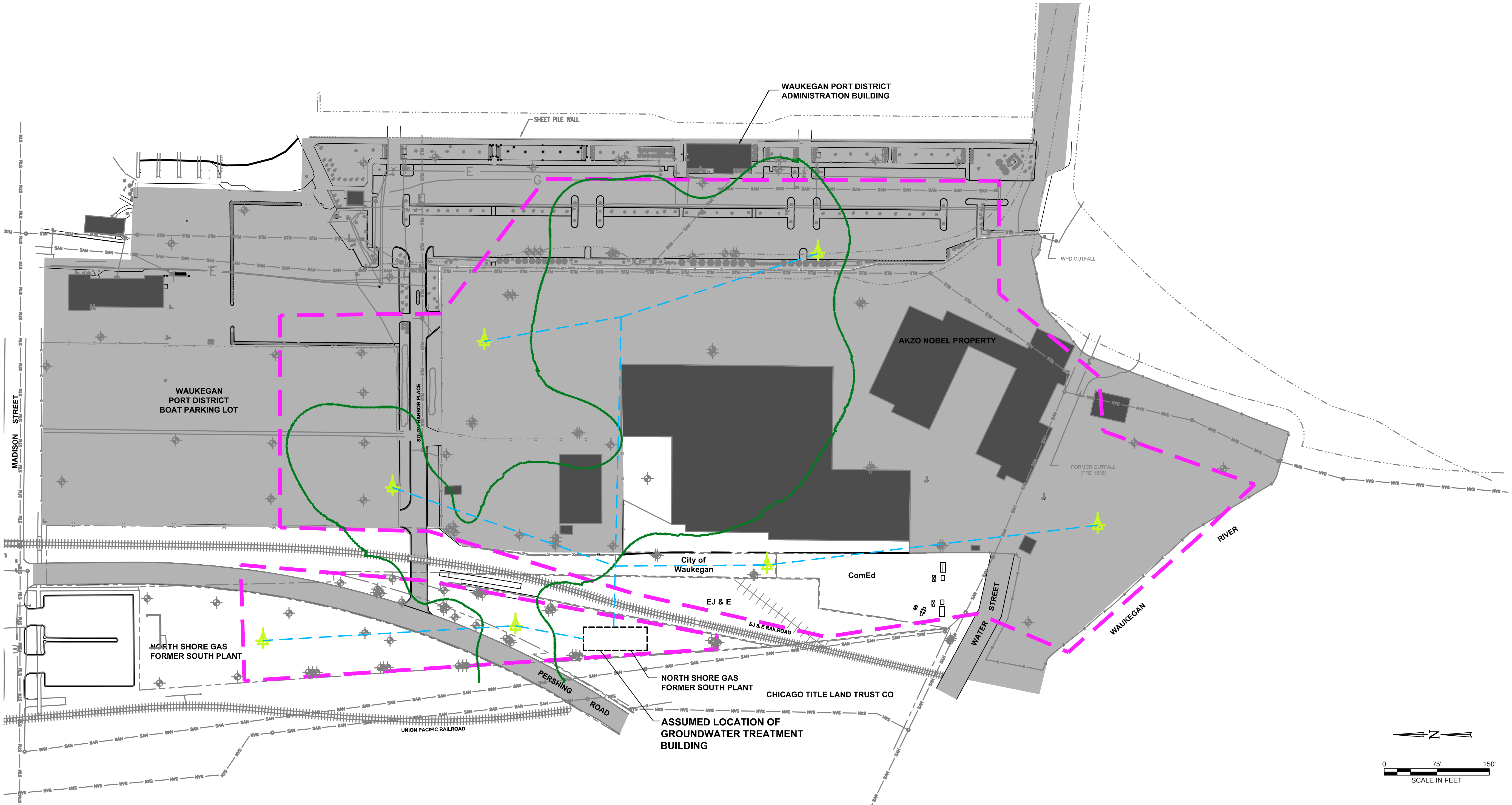
NATURAL RESOURCE TECHNOLOGY

PROJECT NO.
1983/9.2

FIGURE NO.
10



APPROXIMATE PROPERTY LINE
EXISTING FENCE
RAILROAD TRACKS
EXISTING STORM SEWER (APPROXIMATE)
EXISTING SANITARY SEWER (APPROXIMATE)
EXISTING BUILDINGS WITH CONCRETE SLAB FLOORS
EXISTING PAVEMENT
SHEETPILE WALL
EXISTING MANHOLE
EXISTING CATCH BASIN
APPROXIMATE LOCATION OF WATER LINE

MONITORING WELL LOCATION
PROPOSED EXTRACTION WELL
PROPOSED SOIL-BENTONITE SLURRY WALL ALIGNMENT
ESTIMATED EXTENT OF DNAPL BASED ON MODELING APPROACH DETAILED IN APPENDIX C1
ESTIMATED ALIGNMENT OF SUBSURFACE PIPING AND ELECTRIC

SOURCE:
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Y:\ACADdata\Projects\19\1983\9-2\1983-92-B11C.dwg FIG11
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REFERENCE:

ALTERNATIVE D3 - CONCEPTUAL VERTICAL ENGINEERED BARRIER

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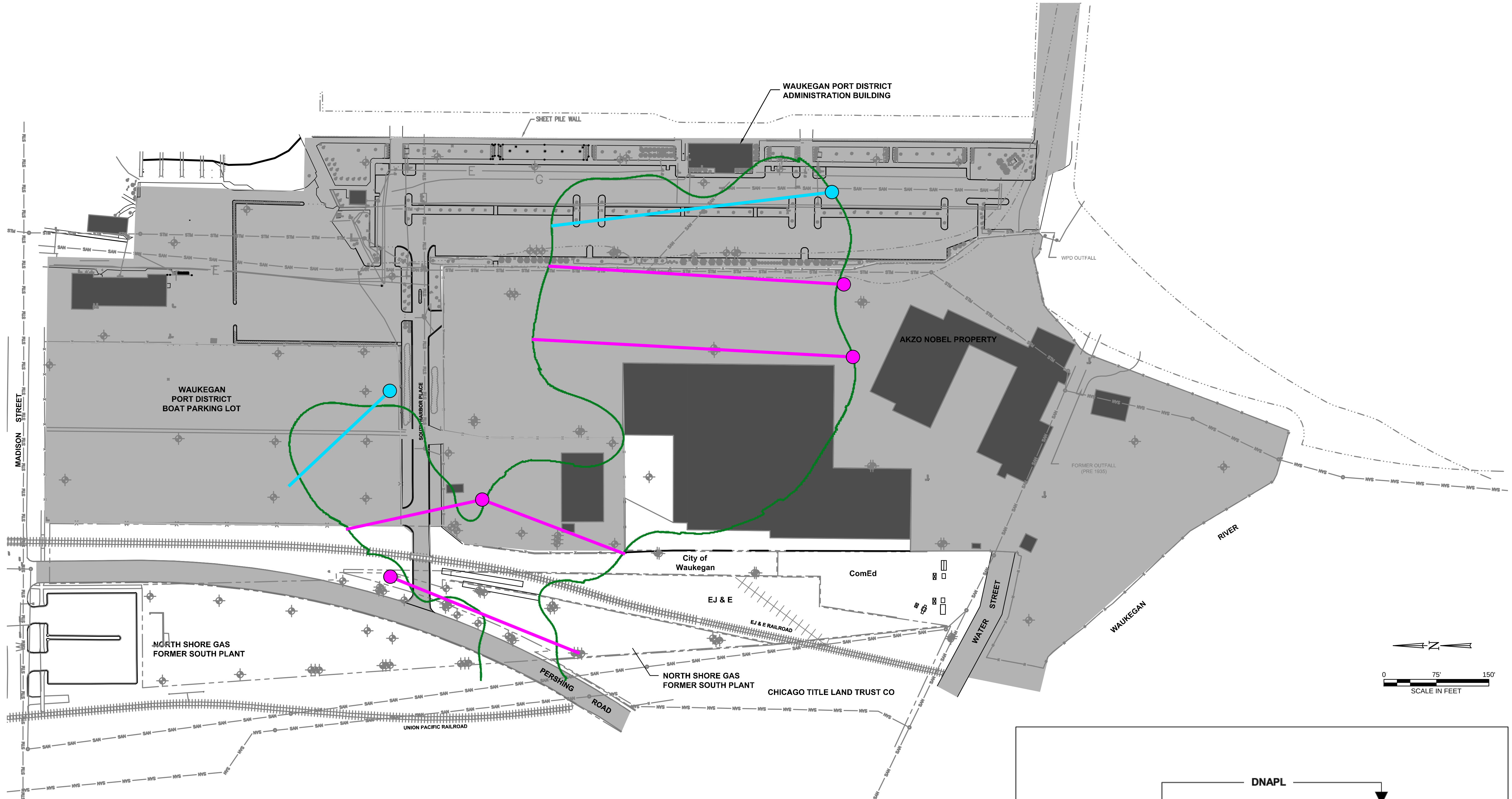
FORMER SOUTH PLANT MGP
NORTH SHORE GAS COMPANY
WAUKEGAN, ILLINOIS

NATURAL RESOURCE TECHNOLOGY

PROJECT NO.
1983/9.2

FIGURE NO.
11



APPROXIMATE PROPERTY LINE
EXISTING FENCE
RAILROAD TRACKS
EXISTING STORM SEWER (APPROXIMATE)
EXISTING SANITARY SEWER (APPROXIMATE)
EXISTING BUILDINGS WITH CONCRETE SLAB FLOORS
EXISTING PAVEMENT
SHEETPILE WALL
EXISTING MANHOLE
EXISTING CATCH BASIN
APPROXIMATE LOCATION OF WATER LINE

MONITORING WELL LOCATION
ESTIMATED EXTENT OF DNAPL BASED ON MODELING APPROACH DETAILED IN APPENDIX C1
PROPOSED PRIMARY HORIZONTAL DNAPL RECOVERY WELL
PROPOSED SENTRY HORIZONTAL DNAPL RECOVERY WELL
PROPOSED DNAPL COLLECTION SUMP (PRIMARY HORIZONTAL)
PROPOSED DNAPL COLLECTION SUMP (SENTRY HORIZONTAL)

SOURCE:
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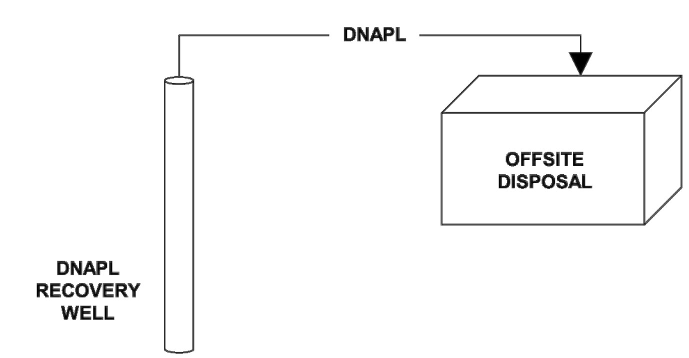

CONCEPTUAL PROCESS FLOW DIAGRAM

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APPROVED BY: JMH DATE: 09/26/14
DRAWING NO: 1983-92-B12C
REFERENCE:

ALTERNATIVE D4 - CONCEPTUAL HORIZONTAL WELL DNAPL RECOVERY SYSTEM

FOCUSED FEASIBILITY STUDY REPORT
FORMER SOUTH PLANT MGP
NORTH SHORE GAS COMPANY
WAUKEGAN, ILLINOIS

NATURAL RESOURCE TECHNOLOGY

PROJECT NO.
1983/9.2

FIGURE NO.
12

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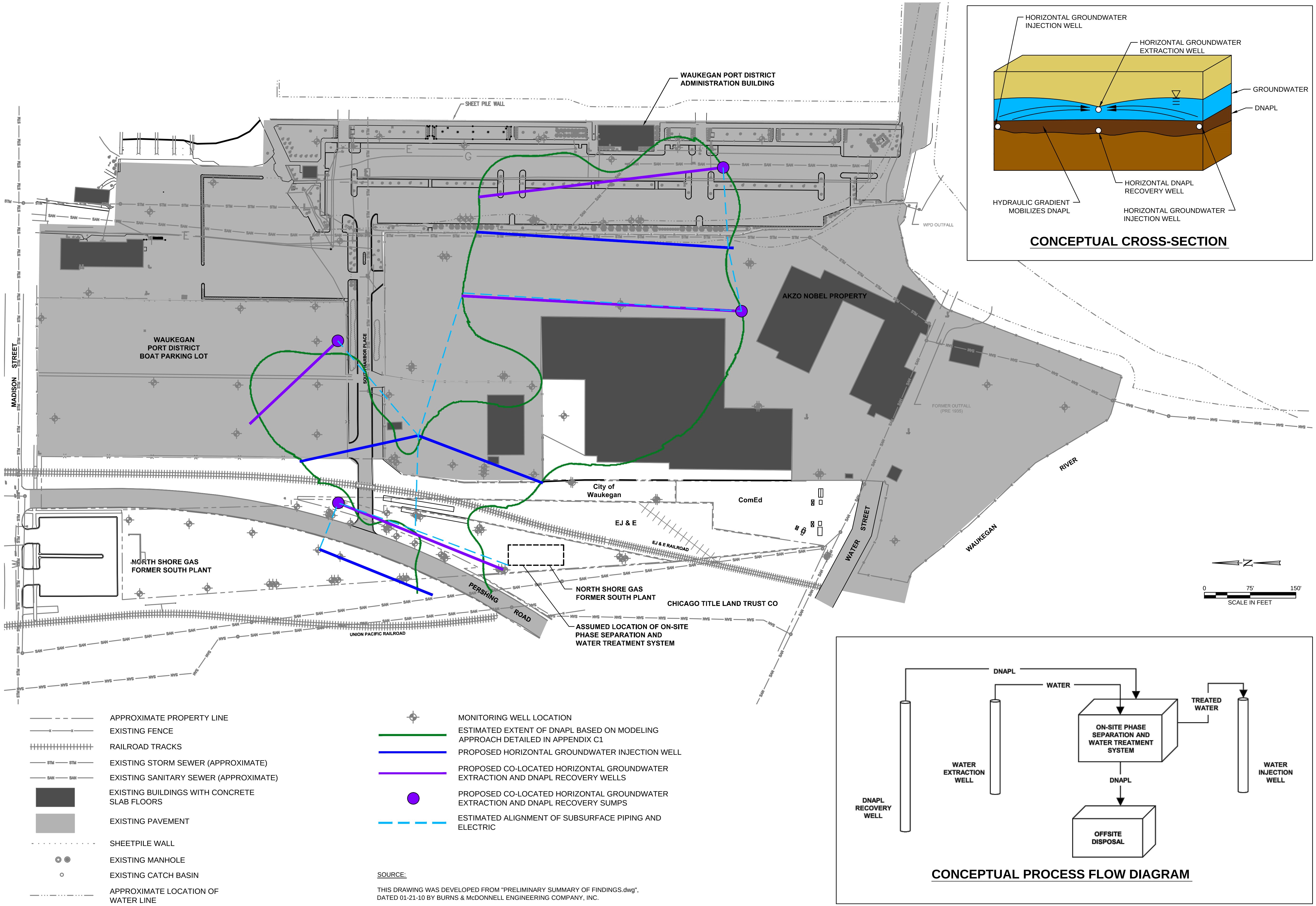

CONCEPTUAL CROSS-SECTION

CONCEPTUAL PROCESS FLOW DIAGRAM

- APPROXIMATE PROPERTY LINE
- EXISTING FENCE
- RAILROAD TRACKS
- EXISTING STORM SEWER (APPROXIMATE)
- EXISTING SANITARY SEWER (APPROXIMATE)
- EXISTING BUILDINGS WITH CONCRETE SLAB FLOORS
- EXISTING PAVEMENT
- SHEETPILE WALL
- EXISTING MANHOLE
- EXISTING CATCH BASIN
- APPROXIMATE LOCATION OF WATER LINE
- MONITORING WELL LOCATION
- ESTIMATED EXTENT OF DNAPL BASED ON MODELING APPROACH DETAILED IN APPENDIX C1
- PROPOSED HORIZONTAL GROUNDWATER INJECTION WELL
- PROPOSED CO-LOCATED HORIZONTAL GROUNDWATER EXTRACTION AND DNAPL RECOVERY WELLS
- PROPOSED CO-LOCATED HORIZONTAL GROUNDWATER EXTRACTION AND DNAPL RECOVERY SUMPS
- ESTIMATED ALIGNMENT OF SUBSURFACE PIPING AND ELECTRIC

SOURCE:
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DRAWING NO: 1983-92-B13C
REFERENCE:

ALTERNATIVE D5 - CONCEPTUAL PHYSICALLY ENHANCED DNAPL RECOVERY SYSTEM

FOCUSED FEASIBILITY STUDY REPORT
FORMER SOUTH PLANT MGP
NORTH SHORE GAS COMPANY
WAUKEGAN, ILLINOIS

NATURAL RESOURCE TECHNOLOGY

PROJECT NO.
1983/9.2

FIGURE NO.
13

Mar 30, 2015 11:37am PLOTTED BY: ddudo SAVED BY: ddudo FIG13
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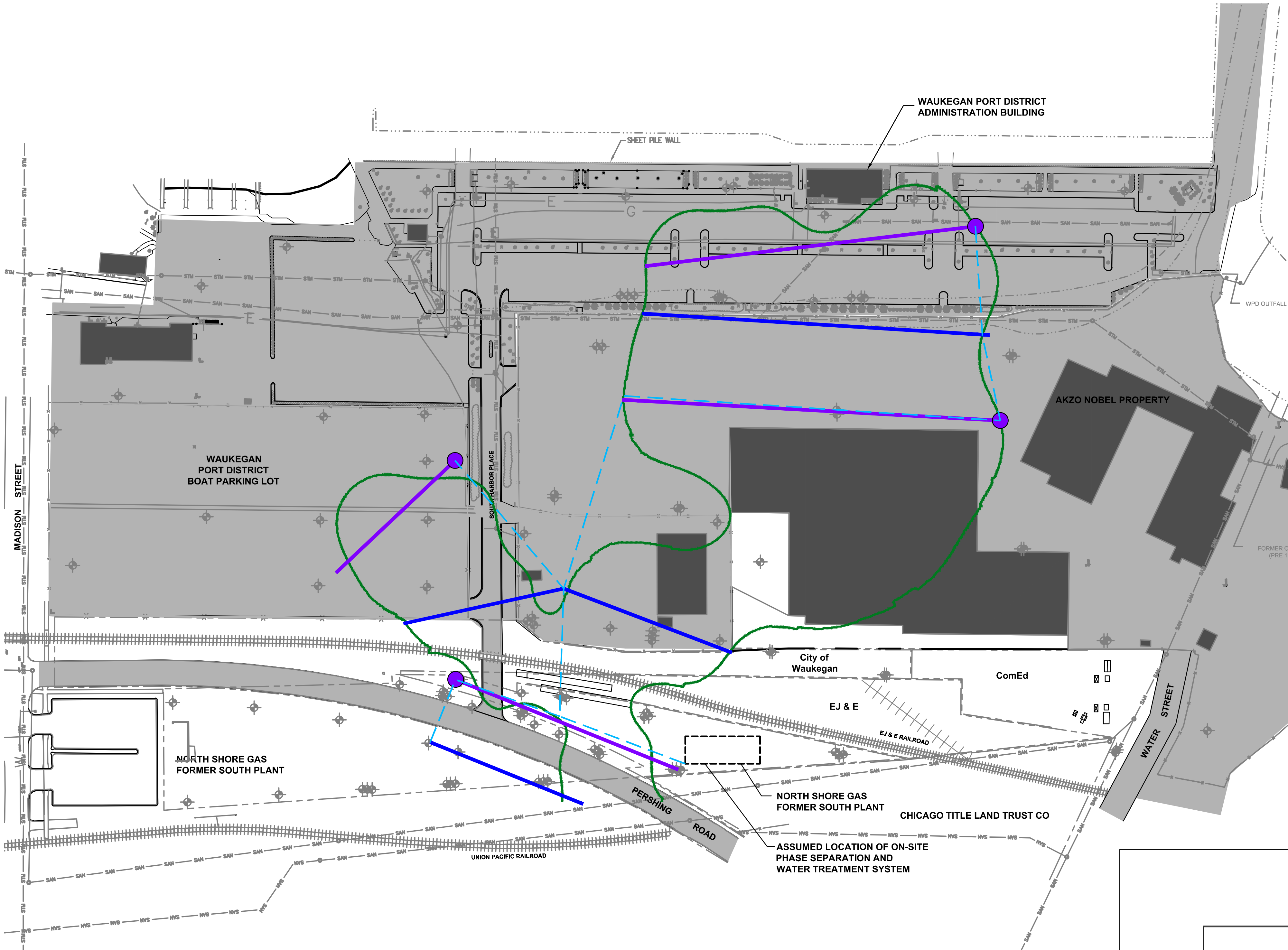
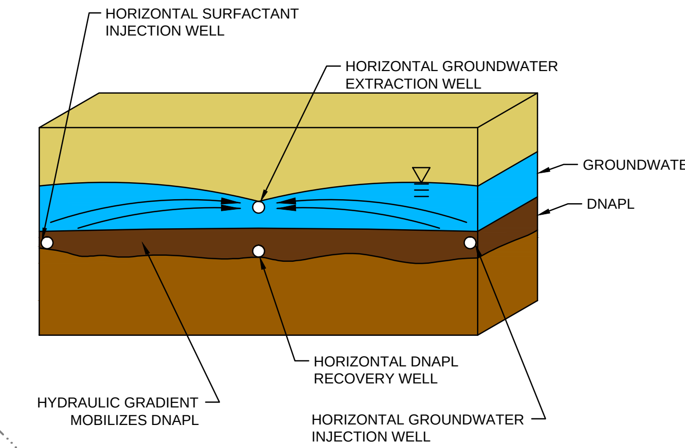
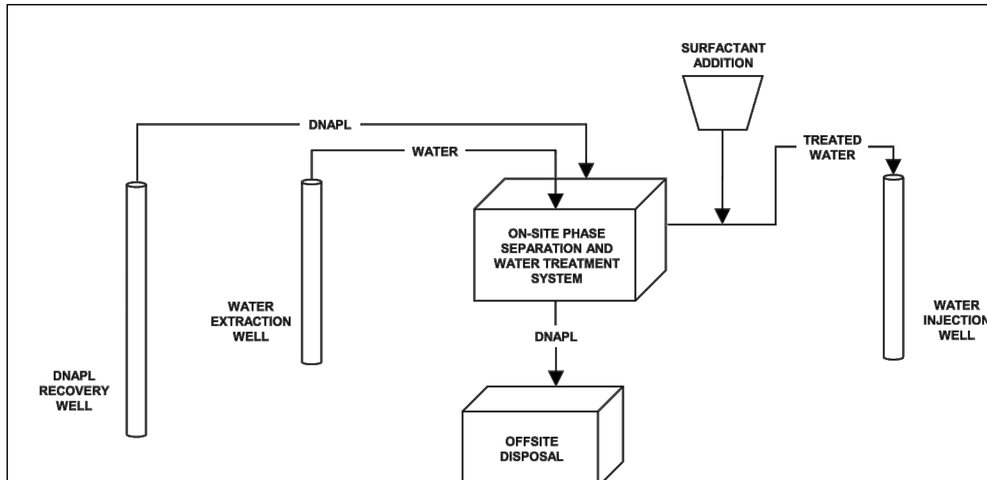




CONCEPTUAL CROSS-SECTION



CONCEPTUAL PROCESS FLOW DIAGRAM

	APPROXIMATE PROPERTY LINE
	EXISTING FENCE
	RAILROAD TRACKS
STM	EXISTING STORM SEWER (APPROXIMATE)
SAN	EXISTING SANITARY SEWER (APPROXIMATE)
	EXISTING BUILDINGS WITH CONCRETE SLAB FLOORS
	EXISTING PAVEMENT
	SHEETPILE WALL
	EXISTING MANHOLE
	EXISTING CATCH BASIN
	APPROXIMATE LOCATION OF WATER LINE
	MONITORING WELL LOCATION
	ESTIMATED EXTENT OF DNAPL BASED ON MODELING APPROACH DETAILED IN APPENDIX C1
	PROPOSED HORIZONTAL SURFACTANT INJECTION WELL
	PROPOSED CO-LOCATED HORIZONTAL GROUNDWATER EXTRACTION AND DNAPL RECOVERY WELLS
	PROPOSED CO-LOCATED HORIZONTAL GROUNDWATER EXTRACTION AND DNAPL RECOVERY SUMPS
	ESTIMATED ALIGNMENT OF SUBSURFACE PIPING AND ELECTRIC

SOURCE:

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Mar 30, 2015 2:30pm PLOTTED BY: ddudo SAVED BY: ddudo FIG14
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DRAWING NO: 1983-92-B14C
REFERENCE:

ALTERNATIVE D6 - CONCEPTUAL CHEMICALLY ENHANCED DNAPL RECOVERY SYSTEM

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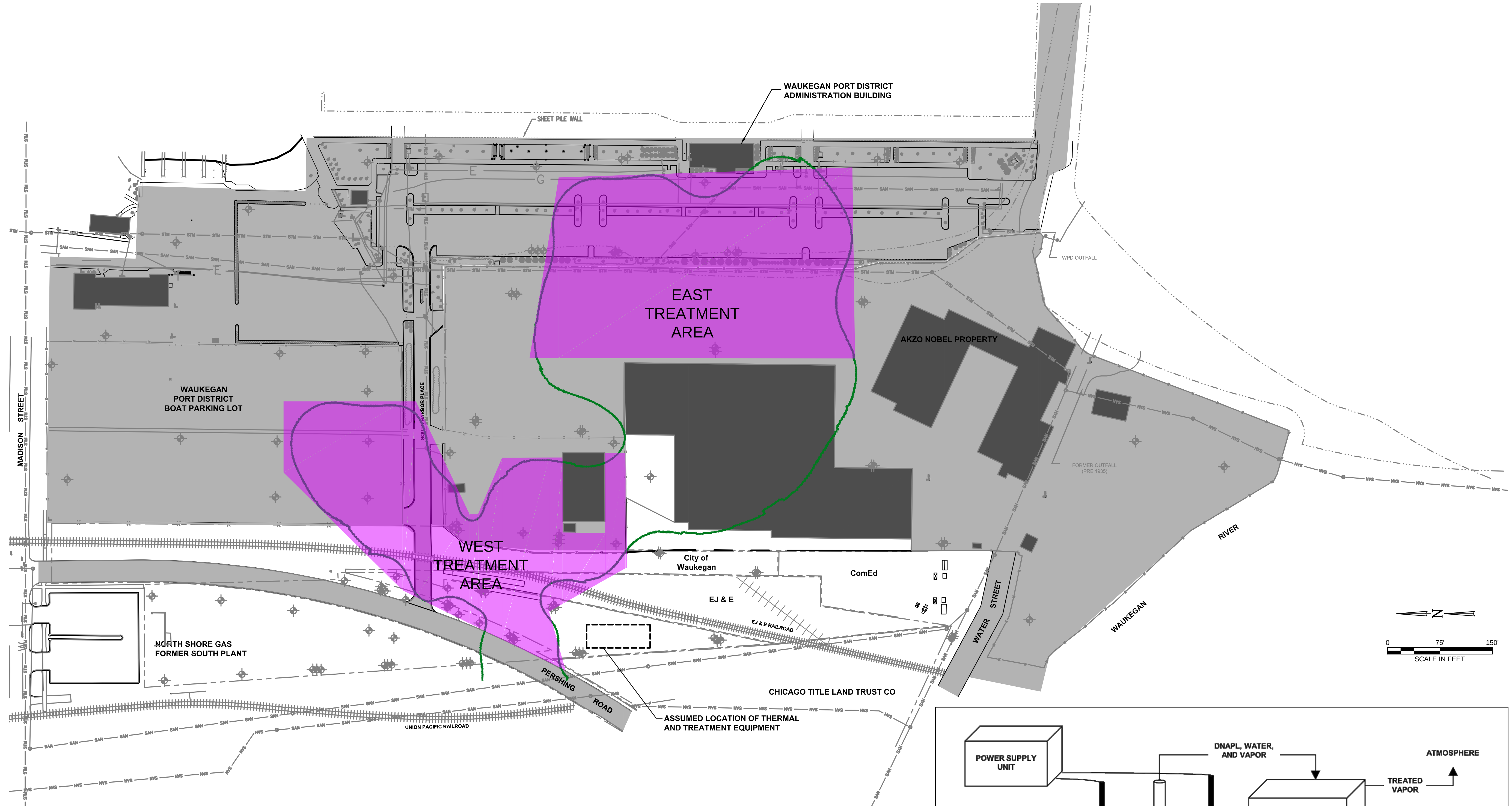
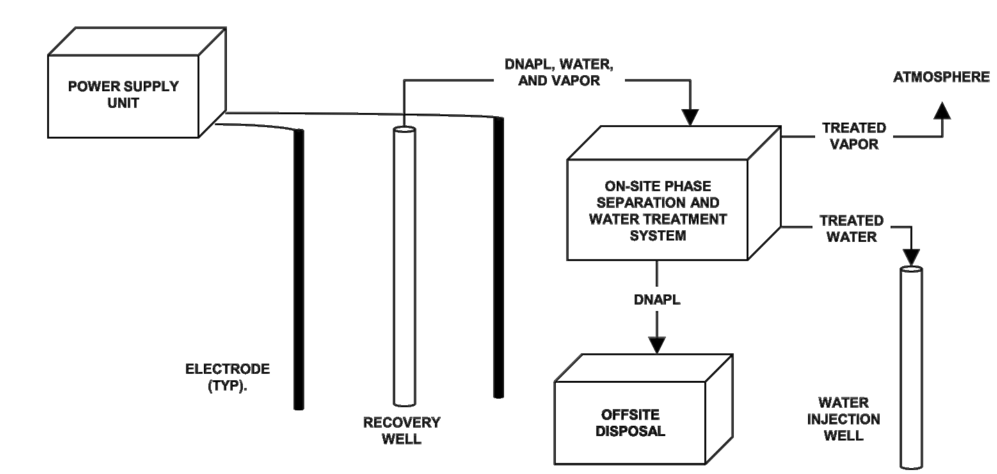
FORMER SOUTH PLANT MGP
NORTH SHORE GAS COMPANY
WAUKEGAN, ILLINOIS

NATURAL RESOURCE TECHNOLOGY

PROJECT NO. 1983/9.2

FIGURE NO. 14





CONCEPTUAL PROCESS FLOW DIAGRAM

APPROXIMATE PROPERTY LINE
EXISTING FENCE
RAILROAD TRACKS
EXISTING STORM SEWER (APPROXIMATE)
EXISTING SANITARY SEWER (APPROXIMATE)
EXISTING BUILDINGS WITH CONCRETE SLAB FLOORS
EXISTING PAVEMENT
SHEETPILE WALL
EXISTING MANHOLE
EXISTING CATCH BASIN
APPROXIMATE LOCATION OF WATER LINE

MONITORING WELL LOCATION
ESTIMATED EXTENT OF DNAPL BASED ON MODELING APPROACH DETAILED IN APPENDIX C1
PROPOSED THERMALLY ENHANCED DNAPL RECOVERY AREA USING ELECTRIC RESISTANCE HEATING

SOURCE:
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Mar 30, 2015 11:40am PLOTTED BY: ddudo SAVED BY: ddudo FIG15
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APPROVED BY: JMH DATE: 09/26/14
DRAWING NO: 1983-92-B15C.dwg
REFERENCE:

ALTERNATIVE D7 - CONCEPTUAL THERMALLY ENHANCED DNAPL RECOVERY SYSTEM

FOCUSED FEASIBILITY STUDY REPORT
FORMER SOUTH PLANT MGP
NORTH SHORE GAS COMPANY
WAUKEGAN, ILLINOIS

NATURAL RESOURCE TECHNOLOGY

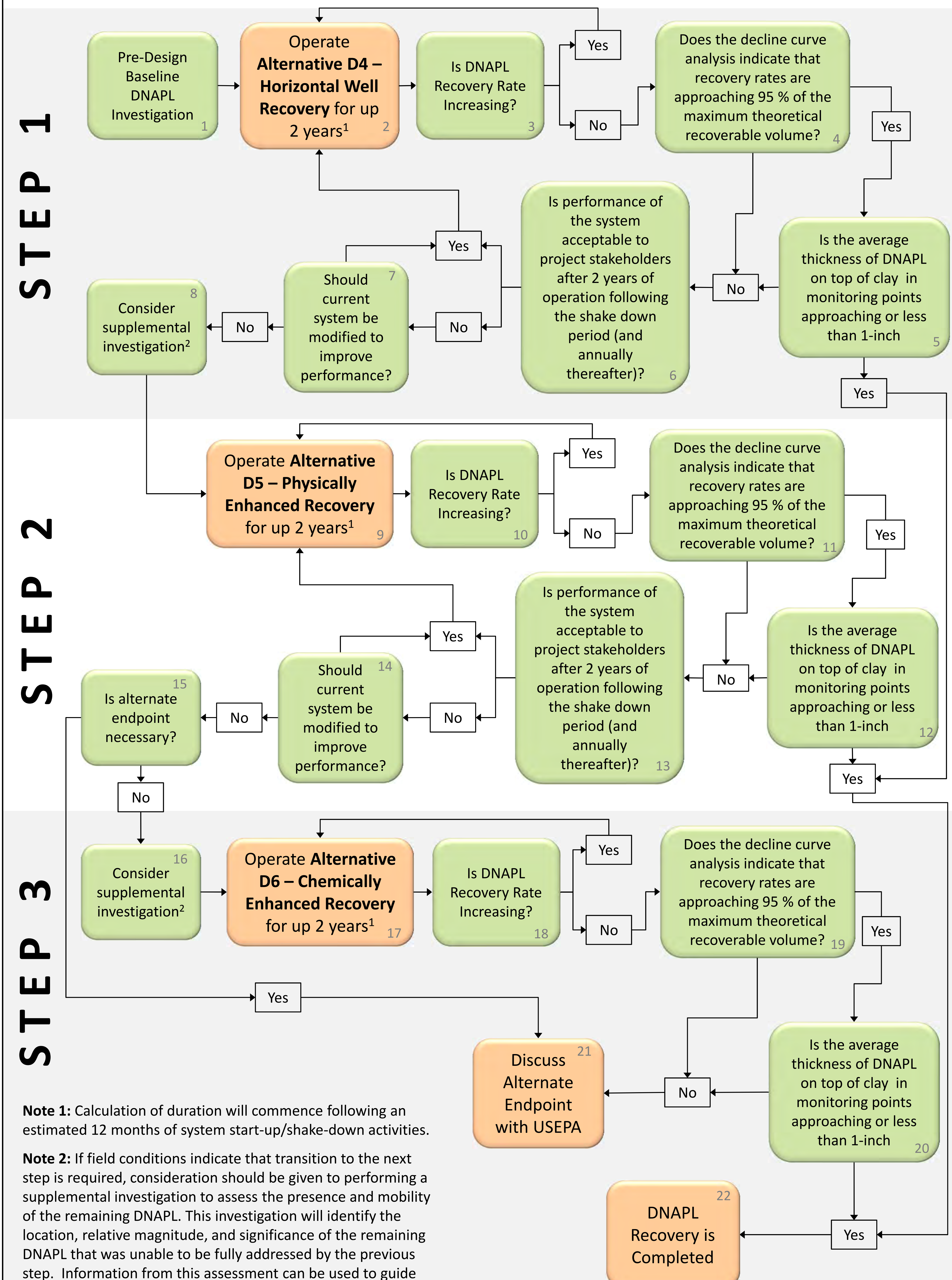
PROJECT NO.
1983/9.2

FIGURE NO.
15

Figure 16 – PRELIMINARY Framework for DNAPL Recovery Performance Standard

Former South Plant Site

North Shore Gas



Note 1: Calculation of duration will commence following an estimated 12 months of system start-up/shake-down activities.

Note 2: If field conditions indicate that transition to the next step is required, consideration should be given to performing a supplemental investigation to assess the presence and mobility of the remaining DNAPL. This investigation will identify the location, relative magnitude, and significance of the remaining DNAPL that was unable to be fully addressed by the previous step. Information from this assessment can be used to guide decisions regarding the necessity, location, and scope of the subsequent step.

TABLES

Table 1 - List of Applicable or Relevant and Appropriate Requirements
North Shore Gas - Former Waukegan South Plant Manufactured Gas Plant Site
2 North Pershing Road & 1 South Pershing Road, Waukegan, Illinois
USEPA ILD984809228 / Illinois EPA #0971900058

Chemical-Specific ARARs/TBC

STANDARD, REQUIREMENT, CRITERIA, LIMITATION	CITATION	MEDIA	POTENTIAL ARAR / TBC	APPLICABLE REMEDIAL ALTERNATIVES	REQUIREMENT/COMMENTS
ILLINOIS					
Groundwater Quality Standards	415 ILCS 55, 35 Ill. Admin. Code (IAC) 620	Groundwater	Applicable	All	Establishes groundwater quality standards; Class I standards are equivalent to federal Safe Drinking Water Act Maximum Contaminant Levels
FEDERAL					
~ None Identified ~					

Location-Specific ARARs/TBC

STANDARD, REQUIREMENT, CRITERIA, LIMITATION	CITATION	MEDIA	POTENTIAL ARAR / TBC	APPLICABLE REMEDIAL ALTERNATIVES	REQUIREMENT/COMMENTS
ILLINOIS					
Illinois Endangered Species Protection Act	520 ILCS 10/3	Endangered/ threatened Species and habitat	Potentially Applicable	All	Establishes regulations limiting the possession transportation, or removal of endangered animals or plants.
Do Not Disturb Endangered Species	17 IAC 1075	Endangered/ threatened Species and habitat	Potentially Applicable	All	Establishes regulations limiting disturbance of rare and endangered species.
FEDERAL					
Endangered Species Act (ESA)	Species/habitat protection (50 C.F.R. Parts 17 and 402)	Endangered/ threatened Species and habitat	Potentially Applicable	All	Applies if threatened and/or endangered species are present in vicinity of site
Migratory Bird Treaty Act (MBTA)	16 U.S.C. §§703-712	Migratory species	Potentially Applicable	All	Requires protection of international migratory birds by ensuring that site activities do not unnecessarily affect migratory birds.

Table 1 - List of Applicable or Relevant and Appropriate Requirements
North Shore Gas - Former Waukegan South Plant Manufactured Gas Plant Site
2 North Pershing Road & 1 South Pershing Road, Waukegan, Illinois
USEPA ILD984809228 / Illinois EPA #0971900058

Action-Specific ARARs

STANDARD, REQUIREMENT, CRITERIA, LIMITATION	CITATION	MEDIA	POTENTIAL ARAR / TBC	POTENTIALLY APPLICABLE REMEDIAL ALTERNATIVES	REQUIREMENT/COMMENTS
ILLINOIS					
Effluent Standards	415 ILCS 5/13, 35 IAC 304	Surface Waters	Potentially Applicable	Potentially Applicable to Alternatives 3,5,6,7, if remedy involves surface water discharge	Establishes maximum concentrations of various contaminants that may be discharged to the waters of the State
Odors	415 ILCS 5/13, 35 IAC 245	Air	Relevant and Appropriate	Alternatives 3,4,5,6, & 7	Establishes procedures to determine the presence of of nuisance odor
Sound Emissions Standards and Limitations for Property Line Noise Sources	415 ILCS 5/13, 35 IAC 901	Noise	Relevant and Appropriate	Alternatives 3,4,5,6, & 7	Establishes limitations on the frequency and decibel of any property-line-noise-source
Uniform Environmental Covenants Act	765 ILCS 122	Soil and Groundwater	Applicable	Alternative 2	Establishes activity and use limitations means restrictions or obligations on real property resulting from impacts resulting from an environmental response project
Control of Organic Compound Emissions	415 ILCS 5/10, 35 IAC 218	Air	Relevant and Appropriate	Alternatives 3,4,5,6, & 7	Establishes standards and limitations for emissions of organic material and volatile organic material from stationary sources.
National Pollutant Discharge Elimination System (NPDES)	415 ILCS 5/13, 35 IAC 309	Surface Waters	Potentially Applicable	Potentially Applicable to Alternatives 3,5,6,7, if remedy involves surface water discharge	Regulates discharges to navigable waterways; applicable for point source discharges occurring during remedial action
Solid Waste Management	415 ILCS 5/22, 35 IAC 807-832	Solid Waste	Applicable	Alternatives 3,4,5,6, & 7	Applies generally to the storage, transportation and disposal of solid wastes; potential ARAR for management of media containing non-hazardous waste during remedial action
Air Quality Standards	415 ILCS 5/10, 35 IAC 212, 218, 243	Air	Relevant and Appropriate	Alternatives 3,4,5,6, & 7	Establishes air quality standards; potential ARAR for control of emissions or dust from management of contaminated media during remedial action

Table 1 - List of Applicable or Relevant and Appropriate Requirements
North Shore Gas - Former Waukegan South Plant Manufactured Gas Plant Site
2 North Pershing Road & 1 South Pershing Road, Waukegan, Illinois
USEPA ILD984809228 / Illinois EPA #0971900058

STANDARD, REQUIREMENT, CRITERIA, LIMITATION	CITATION	MEDIA	POTENTIAL ARAR / TBC	POTENTIALLY APPLICABLE REMEDIAL ALTERNATIVES	REQUIREMENT/COMMENTS
Groundwater Protection Standards	415 ILCS 30, 77 IAC 920; 415 ILCS 55, 35 IAC 620	Groundwater	Applicable	Alternatives 3,4,5,6, & 7	ARAR for the design, construction, installation, abandonment and documentation of groundwater monitoring wells
RCRA and Underground Injection Control (UIC) Permit Program	35 IAC 702	Groundwater	Applicable	Alternatives,5,6, & 7	Applies to the procedure for obtaining permits required under the RCRA and UIC programs.
UIC Permit Program	35 IAC 704	Groundwater	Applicable	Alternatives,5,6, & 7	ARAR for the requirements of obtaining a UIC permit.
Procedures for Permit Issuance	35 IAC 705	Groundwater	Applicable	Alternatives,5,6, & 7	Applies to the procedure that IEPA must follow to issue RCRA and UIC permits.
UIC Operating Requirements	35 IAC 730	Groundwater	Applicable	Alternatives,5,6, & 7	ARAR for the technical criteria and standards for the UIC program.
Hazardous Waste Injection Restrictions	35 IAC 738	Groundwater	Applicable	Alternatives,5,6, & 7	Identifies hazardous wastes that are restricted from disposal into Class I injection wells and defines those circumstances under which a waste, otherwise prohibited from injection, may be injected.
FEDERAL					
Clean Air Act (CAA)	Air Quality Standards (40 C.F.R. § 50)	Air	Relevant and Appropriate	Alternatives 3,4,5,6, & 7	Establishes federal standards for various pollutants from mobile construction/remediation sources
Clean Water Act (CWA) (Section 304)	Water quality standards (40 C.F.R. 21 131)	Surface Water	TBC	Potentially Applicable to Alternatives 3,5,6,7, if remedy involves surface water discharge	Federal WQS are ARARs for point source discharges where state has not adopted standards. Federal WQS are TBC for Wisconsin and Illinois as Wisconsin and Illinois have adopted WQS applicable to point source discharges from remedial action; refer to the Illinois ARARs.
CWA	National Pollutant Discharge Elimination System (NPDES)	Surface Waters	Potentially Applicable	Potentially Applicable to Alternatives 3,5,6,7, if remedy involves surface water discharge	ARAR for any wastewater discharge of treated groundwater during course of remediation; establishes criteria and standards for imposing treatment requirements in permits
RCRA	Municipal Solid Waste Landfills (40 C.F.R. Part 258)	Offsite land disposal non-hazardous waste	Applicable	Alternatives 3,4,5,6, & 7	Applicable to remedial actions that involve generation of non-hazardous waste minimum national criteria for management on non-hazardous waste

Table 2 - Comparison of General Response Actions with the Remedial Action Objective
North Shore Gas - Former Waukegan South Plant Manufactured Gas Plant Site
2 North Pershing Road & 1 South Pershing Road, Waukegan, Illinois
USEPA ILD984809228 / Illinois EPA #0971900058

General Response Action	Remedial Technology	Process Options	Carry Forward for Screening?	Rationale
No Action	No Additional Action	Required by CERCLA for comparison purposes	**Yes**	Baseline Comparison Purposes
Institutional Controls	Deed Restrictions/Groundwater Use Restrictions	Legal controls which restrict property and/or groundwater use.	**Yes**	Legal controls could be combined with other active response actions to meet the RAO
Monitored Recovery	Monitored Natural Attenuation	DNAPL mass and mobility is monitored to demonstrate degradation.	**No**	MNA is not an effective approach to reducing the mass and mobility of free product
DNAPL Containment	Vertical Engineered Barriers	Physical barriers such as steel sheet piling, HDPE or slurry walls to limit the migration offsite migration of DNAPL.	**Yes**	Vertical engineered barriers will effectively limit DNAPL mobility
	Bottom Sealing Barrier	A horizontal barrier constructed below an impacted area to limit downward migration of DNAPL	**No**	The RI field work identified a competent confining clay layer underlying the entire site.
	Horizontal Engineered Surface Barriers	Soil, asphalt, concrete, or geosynthetic covers used to create an engineered control that limits the potential exposure to DNAPL impacted media	**No**	DNAPL is not currently accessible from the surface and the horizontal engineered barrier will not achieve the RAO
In-Situ Treatment	In-Situ Stabilization/Solidification	Mixing cement, slag, or other amendments with impacted soil/DNAPL to bind up contaminants in a monolithic mass which is resistant to leaching.	**Yes**	Strategy could be combined with other active response actions meet RAO
	Biological Treatment	Enhancing natural degradation of contaminants through injection of microorganisms, food sources, and/or amendments to adjustment of geochemistry.	**No**	In-Situ Biological Treatment is not an effective approach to remediating coal tar free product
	Chemical Oxidation	Injection of chemical oxidants to break down contaminants to inert or less toxic compounds. Common chemical oxidants include ozone, hydrogen peroxide (modified Fenton's reagent), permanganate, and persulfate. Surfactants and activators are sometimes added to enhance effectiveness.	**Yes**	In-situ chemical oxidation approaches could be effective if implemented in combination with DNAPL recovery
	Enhanced Recovery	Physically enhanced DNAPL recovery using groundwater gradient manipulation	**Yes**	Could be effective response depending on process option given site specific logistical and spatial constraints. The Site contains a large DNAPL plume extended across several portions of the Site including beneath active buildings
		Chemically enhanced DNAPL recovery using surfactant injection	**Yes**	
		Thermally enhanced DNAPL recovery using in-situ thermal technology	**Yes**	
Ex-situ Treatment	Horizontal Well Recovery	DNAPL recovery from horizontal recovery systems	**Yes**	Could be effective response depending on process option given site specific logistical and spatial constraints. The Site contains a large DNAPL plume extended across several portions of the Site including beneath active buildings

Notes:
- DNAPL - Tar and Tar Saturated soil below the groundwater table
- HDPE - High Density Polyethylene
- MNA - Monitored natural attenuation

Table 3 - Initial Screening for Applicable Response Action Remedial Technologies and Process Options for DNAPL
North Shore Gas - Former Waukegan South Plant Manufactured Gas Plant Site
2 North Pershing Road & 1 South Pershing Road, Waukegan, Illinois
USEPA ILD984809228 / Illinois EPA #0971900058

General Response Action Remedial Technology/Process Option	Description of Process Option	Effectiveness	Implementability	Relative Cost	Carry Forward for Additional Screening?	Rationale
No Action						
No Action	•No additional action	•Will not achieve the remedial action objectives in the foreseeable future	•Easily implementable as there is not remedy to implement	No Cost	**Yes**	Retained
Institutional Controls Approach						
Deed Restrictions and Groundwater Use Ordinance	•Deed Restrictions and groundwater use ordinance: Through deed restrictions, prohibit or restrict use of the site so that development or excavation are not allowed. Ordinance prevents installation of potable water supply well.	•Minimal potential short term exposure risk. •Administratively effective and reliable; relies on local government action to establish, enforce and restrict.	•Easy implementation. •Administratively implementable.	Low	**Yes**	This technology meets the criteria for effectiveness and technical implementability and is administratively implementable, depending on third party property owners.
DNAPL Containment						
Vertical Engineered Barriers	•Subsurface barriers composed of either sheet piling, HDPE or slurry walls keyed into a confining layer. Walls are used to contain and divert DNAPL.	•May be combined with another process option to treat groundwater. •Effective at containing and isolating DNAPL.	•Barrier material may degrade, deteriorate, or be damaged intentionally or over time. •Requires monitoring and limited groundwater extraction to ensure contained DNAPL and impacted groundwater does not migrate through or over the barrier wall. •Technology has been extensively and is relatively easy to implement unless openings are required for utilities, etc.	Moderate	**Yes**	This technology does meet the criteria for effectiveness and technical implementability if combined groundwater gradient control and treatment.

Table 3 - Initial Screening for Applicable Response Action Remedial Technologies and Process Options for DNAPL
North Shore Gas - Former Waukegan South Plant Manufactured Gas Plant Site
2 North Pershing Road & 1 South Pershing Road, Waukegan, Illinois
USEPA ILD984809228 / Illinois EPA #0971900058

General Response Action Remedial Technology/Process Option	Description of Process Option	Effectiveness	Implementability	Relative Cost	Carry Forward for Additional Screening?	Rationale
In-Situ Treatment						
In-Situ Stabilization/Solidification	◆ Mobility and/or toxicity of contaminants is reduced by physical bonding/chemical reactions. Most common technique for solidification is the utilization of cement to produce a monolithic mass resistant to leaching. ◆ Methods for delivery include auger, injection, or mechanical mix ◆ Has been used at coal tar/MGP sites	◆ Effective for weathered coal tar, PAHs, PVOCs, and metals. ◆ Limited effectiveness where high percentage of free product present or highly heterogeneous ◆ Monolith may deteriorate over time ◆ May provide limited, short-term risk reduction, and potentially acceptable long-term risk reduction ◆ Contaminants may become immobilized by stabilization/ solidification methods but risk "weathering" or deterioration of products that may release contaminates in the future.	◆ Implementation affected by obstructions, may require pre-excavation of material/debris. ◆ Requires monitoring to ensure performance. ◆ Most reagents and additives are widely available. ◆ Less disruptive to local residents than excavation. ◆ Can be combined with other technologies. ◆ Requires specifying optimal mix methods to achieve desired performance criteria. ◆ Limited availability of qualified contractors	Moderate	**No**	This technology does not meet the criteria for effectiveness as it only has limited effectiveness at stabilizing high percentage of free product/DNAPL, which is the focus of this feasibility study.
Chemical Oxidation	◆Injection of chemical oxidants to break down contaminants to inert or less toxic compounds. Common chemical oxidants include ozone, hydrogen peroxide (modified Fenton's reagent), permanganate, and persulfate. ◆Surfactants and activators are sometimes added to enhance the effectiveness of certain oxidants	◆ Effective for dissolved phase VOCs, and PAHs. ◆ Due to significant oxidant demand of free product, chemical oxidation has limited effectiveness in oxidizing mobile free product. ◆ Though not effective for significant thickness of mobile free product, chemical oxidation can be effective at mobilizing/remediating residual DNAPL.	◆ Extensive subsurface conditions must be known in order to assist with understanding potential ISCO reactions. Potential to generate heat and or off gassing. ◆ Requires handling, storage, distribution, and safety precautions for the large quantities of hazardous oxidizing chemicals.	Moderate to High	**No**	Due to siginigcant oxidant demand of mobile free product, this technology does not meet the criteria for effectiveness as a primary remedial option to reduce DNAPL mass and mobility. Chemical oxidization is capable of increasing the performance of DNAPL recovery systems when recovery has reached a point of diminishing returns. Implementation of chemical oxidation to address potential residual DNAPL and groundwater contamination may be evaluated as part of the future Feasibility Study.
Physically Enhanced DNAPL Recovery	◆Alternating Extraction and Injection of groundwater above and adjacent to a DNAPL recovery well. The alternating extraction and injection results in increased gradients to enhance DNAPL recovery rates	◆Effective for removal of free product, including DNAPL. ◆Can effectively reduce the quantity of product which may be difficult to remove through other remedial technologies. ◆Artificially increasing DNAPL mobility through groundwater gradient manipulation can enhance DNAPL recovery rates, but also can result in uncontrolled migration of DNAPL to previously unimpacted areas. ◆Overly aggressive physical enhancements can break interfacial tension of DNAPL, increasing challenges of DNAPL recovery.	◆Requires installation of recovery trenches, horizontal, or vertical wells to provide access to free product. ◆Requires installation of a central collection facility, underground piping, and electric utilities. ◆Requires installation of phase separation and significant water treatment infrastructure to groundwater standards for reinjection.	Moderate to High	**Yes**	This technology meets the criteria for effectiveness and technical implementability and is administratively implementable, depending on third party property owners.

Table 3 - Initial Screening for Applicable Response Action Remedial Technologies and Process Options for DNAPL
North Shore Gas - Former Waukegan South Plant Manufactured Gas Plant Site
2 North Pershing Road & 1 South Pershing Road, Waukegan, Illinois
USEPA ILD984809228 / Illinois EPA #0971900058

General Response Action Remedial Technology/Process Option	Description of Process Option	Effectiveness	Implementability	Relative Cost	Carry Forward for Additional Screening?	Rationale
In-Situ Treatment						
Chemically Enhanced DNAPL Recovery	• Surfactants are injected into the ground to reduce the interfacial tension and increase DNAPL mobility. Mobilized DNAPL is removed from substrate by actively pumping from wells, sumps trenches, or horizontal wells. Recovered DNAPL generally separated from groundwater and disposed off site • Often surfactants are amended with polymers, co-solvents, or oxidants to further increase DNAPL mobility or address DNAPL residuals.	• Effective for removal of free product, including DNAPL. • Can effectively reduce the quantity of product which may be difficult to remove through other remedial technologies. •Artificially increasing DNAPL mobility through surfactant injection can enhance DNAPL recovery rates, but also can result in uncontrolled migration of DNAPL to previously unimpacted areas. •Overly aggressive physical enhancements can break interfacial tension of DNAPL, increasing challenges of DNAPL recovery.	• Requires installation of recovery trenches, horizontal, or vertical wells to provide access to free product. • Requires installation of a central collection facility, underground piping, and electric utilities. •Requires installation of phase separation and significant water treatment infrastructure to groundwater standards for reinjection. •Separation of DNAPL and surfactant at surface can be problematic.	Moderate to High	**Yes**	This technology meets the criteria for effectiveness and technical implementability and is administratively implementable, depending on third party property owners.
Thermally Enhanced DNAPL Recovery	•The temperature of the subsurface is increased through installation of thermal wells, steam injection, and electric resistance technologies. •The resulting heat decreases the viscosity of the DNAPL, allowing greater recovery. •A SVE or multiphase system is used to extract the contaminants, for separation and treatment.	• Effectively addresses impacted soil, groundwater, and DNAPL. • Heating the subsurface can generate "cracks" which increases the ability for DNAPL to be extracted. •Heat reduces free product viscosity and increases DNAPL mobility, but also can destroy organic contaminants in place.	• Certain thermal approaches can be implemented under roadways or buildings, however consideration must be given to the resulting vapor intrusion issues. • Large number of thermal points and associated infrastructure would be required. •High energy consumption and large carbon footprint •Water influx from Lake Michigan may result in cooling and possible challenges in achieving desired temperature. • Buried metal probes and high voltages require extra safety precautions and barriers to prevent exposure. • Technology has been extensively used in the past which allows for a range of system choices and capabilities.	High	**Yes**	This technology meets the criteria for effectiveness and technical implementability and is administratively implementable, depending on third party property owners.

Table 3 - Initial Screening for Applicable Response Action Remedial Technologies and Process Options for DNAPL
North Shore Gas - Former Waukegan South Plant Manufactured Gas Plant Site
2 North Pershing Road & 1 South Pershing Road, Waukegan, Illinois
USEPA ILD984809228 / Illinois EPA #0971900058

General Response Action Remedial Technology/Process Option	Description of Process Option	Effectiveness	Implementability	Relative Cost	Carry Forward for Additional Screening?	Rationale
Ex-situ Treatment						
Horizontal Well DNAPL Recovery	•DNAPL is removed from substrate by collection from wells, sumps, or trenches. Recovered DNAPL generally disposed off site.	• Effective for removal of free product, including DNAPL. • Can effectively reduce the quantity of product which may be difficult to remove through other remedial technologies. • Does not involve increasing DNAPL mobility and thus does not risk additional migration of DNAPL. • By not increasing DNAPL mobility, recovery system durations can be lengthy. • DNAPL tends to adhere to soil particles. Free product removal or pumping often leaves behind residual contaminants, which require further remedial technologies.	•Requires trenching, excavation pits, or extraction wells to access free product. •Technology has been extensively used in the past which allows for a wide range of system choices and capabilities.	Low to Moderate	**Yes**	This technology does meet the criteria for technical implementability. DNAPL recovery duration can be reduced through installing horizontal wells or trenches in areas of significant DNAPL thickness. Pilot scale testing could be required. Administratively implementable if third party property access is secured.

Notes:
DNAPL - dense non-aqueous phase liquid
SVE - soil vapor extraction
HDPE - high density polyethylene

Table 4 - Summary of DNAPL Remedial Alternatives Cost
North Shore Gas - Former Waukegan South Plant Manufactured Gas Plant Site
2 North Pershing Road & 1 South Pershing Road, Waukegan, Illinois
USEPA ILD984809228 / Illinois EPA #0971900058

Remedial Alternative	Total Capital Cost	Duration of O&M Assumed (Years)	Total O&M Cost, No Discount Factor	Total Present Value of O&M Cost[1]	Total Present Value Cost of Alternative
Alternative D1 - No Action	***$ -***	0	***$ 120,000***	***$ 50,000***	**$ 50,000**
Alternative D2 - Institutional Controls	***$ 79,000***	30	***$ 120,000***	***$ 50,000***	**$ 129,000**
Alternative D3 - Vertical Engineered Barrier	$ 3,729,000	30	$ 23,000,000	$ 9,614,000	**$ 13,400,000**
Alternative D4 - Horizontal Well DNAPL Recovery	$ 1,839,000	31	$ 7,000,000	$ 2,808,000	**$ 4,647,000**
Alternative D5 - Physically Enhanced DNAPL Recovery	***$ 4,446,000***	7	***$ 8,000,000***	***$ 6,130,000***	**$ 10,576,000**
Alternative D6 - Chemically Enhanced DNAPL Recovery	***$ 8,845,000***	4	***$ 6,500,000***	***$ 5,490,000***	**$ 14,335,000**
Alternative D7 – Thermally Enhanced DNAPL Recovery	***$ 26,968,000***	4	***$ 8,024,000***	***$ 6,800,000***	**$ 33,768,000**

Notes:

1. At request of USEPA and consistent with USEPA's July 2000 ***A Guide for Developing and Documenting Cost Estimates Duimg the Feasibility Study,*** present values were calculated using a real discount rate of 7% for non-federally funded sites. See FS Report Section 4.0 for additional discussion.

Table 5 - Summary of DNAPL Remedial Alternatives Compared to Criteria
North Shore Gas - Former Waukegan South Plant Manufactured Gas Plant Site
2 North Pershing Road & 1 South Pershing Road, Waukegan, Illinois
USEPA ILD984809228 / Illinois EPA #0971900058

	Threshold Criteria		Balancing Criteria				
Remedial Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness (Years)**	**Implementability**	**Present Worth Cost[1]**
Alternative D1 - No Action	Does Not Meet	Does Not Meet	Does Not Meet	Does Not Meet	Does Not Meet	Does Not Meet	$ 50,000
Alternative D2 - Institutional Controls	Partially Meets	Partially Meets	Partially Meets	Does Not Meet	Fully Meets (0.5 Years)	Fully Meets	$ 129,000
Alternative D3 - Vertical Engineered Barrier	Fully Meets	Partially Meets	Fully Meets	Partially Meets	Fully Meets (1 Years)	Partially Meets	$ 13,400,000
Alternative D4 - Horizontal Well DNAPL Recovery	Fully Meets	Fully Meets	Fully Meets	Fully Meets	Fully Meets (31.5 Years)	Fully Meets	$ 4,647,000
Alternative D5 - Physically Enhanced DNAPL Recovery	Fully Meets	Fully Meets	Fully Meets	Fully Meets	Fully Meets (8 Years)	Partially Meets	$ 10,576,000
Alternative D6 - Chemically Enhanced DNAPL Recovery	Fully Meets	Fully Meets	Fully Meets	Fully Meets	Fully Meets (5 Years)	Partially Meets	$ 14,335,000
Alternative D7 – Thermally Enhanced DNAPL Recovery	Fully Meets	Fully Meets	Fully Meets	Fully Meets	Fully Meets (5 Years)	Partially Meets	$ 33,768,000

Notes:

1. At request of USEPA and consistent with USEPA's July 2000 A Guide for Developing and Documenting Cost Estimates Duirng the Feasibility Study, present values were calculated using a real discount rate of 7% for non-federally funded sites. See FS Report Section 4.0 for additional discussion.

APPENDIX A

REMEDIAL INVESTIGATION DATA

Table 9. DNAPL Thickness Measurements (2009 - 2013)

North Shore Gas - Former Waukegan South Plant Manufactured Gas Plant Site
2 North Pershing Road & 1 South Pershing Road, Waukegan, Illinois
USEPA ILD984809228 / Illinois EPA #0971900058

Well	Screened Interval (ft bgs)	Well Depth (ft bgs)	Nov. 2009	Mar. 2010	Jun. 2010	Sep. 2010	Dec. 2010	Mar. 2011	Jun. 2011	Sep. 2011	Mar. 2012	Sep. 2012	Mar. 2013	Average
AKZO-MW01D	6.75-16.75	16.83	0.02	0.83	1.17	1.40	0.80	1.85	2.14	2.83	2.75	2.88	2.56	1.75
AKZO-MW01S	5.75-10.75	11.60						Trace						Trace
AKZO-MW05D	6.6-16.6	16.59	Trace		0.50	1.05		0.50	0.03	Trace	Trace	0.39		0.23
AKZO-MW07D	6.7-16.7	16.62							2.20					0.20
AKZO-MW08D	6.75-16.75	16.87							1.17					0.11
AKZO-MW09D	3.7-13.7	13.81	Trace	0.33	1.50	1.90	0.38	1.81	Trace	Trace	2.48	2.51	2.37	1.21
AKZO-MW09S	5.75-10.75	10.75						Trace	Trace	Trace	0.32	0.66		0.09
AKZO-MW18	3.7-13.7	13.82	Trace	Trace	Trace	Trace		Trace	Trace	Trace	Trace			Trace
COW-MW02D	4.75-16.75	16.91										Trace		Trace
NSGSP-MW01	8.0-18.0	17.97		1.00										0.09
NSGSP-MW02	8.0-18.0	17.90	0.19	0.15										0.03
NSGSP-MW04	6.0-16.0	15.50	0.90	1.10	1.18	1.30	1.43	0.15	0.65	0.59	0.75	0.02		0.73
NSGSP-MW30	6.25-16.25	16.78		Trace	Trace	Trace		1.06	Trace		Trace	Trace		0.10
NSGSP-MW32	7.25-14.25	14.80								Trace	0.00			Trace
NSGSP-MW32D	11.0-16.0	16.40							Trace	Trace	0.00			Trace
NSGSP-MW34D	13.0-15.0	15.30							Trace	Trace	0.00			Trace
NSGSP-MW35	6.25-16.25	16.71			Trace									Trace
NSGSP-MW35D	11.5-16.5	17.30	2.60	2.50	2.85	4.45	3.50	3.06	2.61	3.87	3.70	5.80	2.57	3.41
NSGSP-MW35S	4.63-9.63	9.58			Trace									Trace
NSGSP-MW36	6.75-16.75	16.80	1.20		1.30	1.78	1.50	2.64	3.08	2.13	0.70	2.11	0.01	1.50
NSGSP-MW40	4.67-14.67	15.00	3.66	3.75	3.81	3.92	4.00		3.80	0.00	3.70	4.11	3.92	3.15
NSGSP-MW40S	4.67-14.67	15.00											0.14	Trace
NSGSP-MW40D	10.0-15.0	16.90	0.25	0.25	0.20	0.41	0.50		3.02	1.23	1.74	1.60	0.80	0.91
NSGSP-MW42	6.75-16.75	17.35						0.22					0.13	Trace
SPPA-MW14	8.0-23.0	22.02			Trace									Trace
SPPA-MW4	6.0-16.0	15.80	5.90		Trace									0.54
SPPA-MW44S	5.5-7.5	7.93							0.49	0.00	0.00	0.00		0.04
SPPA-MW45D	15.58-20.58	20.92	4.60	4.91	4.61	4.80	4.95	4.23	4.29	1.30	3.83	4.30	3.95	4.16
SPPA-MW45S	5.0-10.0	10.38	Trace					Trace						Trace
SPPA-MW47D	12.0-17.0	17.75	8.09	4.49	4.42	4.70	4.85	4.00	Trace	3.64	4.45	4.25	4.30	4.29
SPPA-MW48	6.5-18.5	18.71	2.80	2.71	2.55	2.80	3.10	4.68	1.73	2.91	2.11	1.88		2.48
SPPA-MW48D	15.5-20.5	20.15						Trace	Trace	Trace	Trace	Trace		Trace
SPPA-MW49	5.25-20.25	20.80							Trace	Trace	Trace	Trace		Trace
SPPA-MW5	6.0-16.0	16.35	0.10	0.10	0.27	0.10		Trace	Trace	Trace	Trace		nm	0.06
SPPA-MW52	5.5-15.5	16.11	1.31	0.20	0.63	1.80		6.24	1.86	1.36	1.21	2.33	1.61	1.69
SPPA-MW52D	13.0-15.0	15.11				Trace		Trace					0.00	Trace
SPPA-MW52S	6.0-11.0	11.40				Trace							0.01	Trace

[O-RJG 10/10/12 C-]:JG 10/10/12 C-]

Notes:
1) Product thickness collected by Burns & McDonnell from November 2009 to December 2010.
2) Natural Resource Technology, Inc. began collecting product thickness measurements in March 2011.
3) For calcuting the average thickness, zero was used for dates with no observations and 0.005 ft was used for "Trace" values.
4) "nm": well not measured due to ice.

APPENDIX B

REMEDIAL ALTERNATIVE COST ESTIMATES

Alternative D1 - No Action
Feasibility Study Cost Comparison
Former South Plant MGP - Waukegan, IL

NRT PROJECT NO.: 1983
BY: MDB | CHKD BY: RCW
DATE: 9/19/14 | REVISED BY: MDB on 1/28/2014

DESCRIPTION	QUANTITY	UNIT	UNIT COST	ITEM COST	SUBTOTAL	ASSUMPTIONS/REFERENCES
CONSULTING CAPITAL COSTS						
SUBTOTAL, CONSULTING CAPITAL COSTS					$0	
25% Estimating Contingency					$0	
TOTAL, CONSULTING CAPITAL COSTS					$0	
SUBTOTAL, CONSTRUCTION CAPITAL COSTS					$0	
25% Construction Estimating Contingency					$0	
TOTAL, CONSTRUCTION CAPITAL COSTS					$0	
TOTAL CAPITAL COSTS					**$0**	
ANNUAL OPERATIONS AND MAINTENANCE						
SUBTOTAL					**$ -**	
PERIODIC OPERATIONS AND MAINTENANCE						
Five Year Review	1	LS	$15,000	$15,000		Assumes 5 Year Review site visit and associated reporting
25% O&M Estimating Contingency				$4,000		
SUBTOTAL					**$ 19,000**	
Total Cost of Annual And Periodic Maintenance, No Discount Factor					**$ 120,000**	
Present Worth of Annual and Periodic Costs over 30 Years, 7% Rate of Return					**$50,000**	
Total Present Worth of Alternative					**$50,000**	

Alternative D2 - Institutional Controls
Feasibility Study Cost Comparison

Former South Plant MGP - Waukegan, IL

NRT PROJECT NO.: 1983
BY: MDB CHKD BY: RCW
DATE: 9/19/14 REVISED BY: MDB on 1/28/2014

DESCRIPTION	QUANTITY	UNIT	UNIT COST	ITEM COST	SUBTOTAL	ASSUMPTIONS/REFERENCES
CONSULTING CAPITAL COSTS						
Survey with Legal Description	6	Ea	$3,000	$18,000.00		Assumes Legal Description to be completed for each affected parcel to assist in implementation of Institutional Controls
Institutional Control Implementation Plan	1	LS	$15,000.00	$15,000.00		
Environmental Covenants	1	LS	$15,000.00	$15,000.00		
Groundwater Use Restriction	1	LS	$15,000.00	$15,000.00		
SUBTOTAL					**$ 63,000**	
SUBTOTAL, CONSULTING CAPITAL COSTS					$63,000	
25% Estimating Contingency					$16,000	
TOTAL, CONSULTING CAPITAL COSTS					$79,000	
SUBTOTAL, CONSTRUCTION CAPITAL COSTS					$0	
25% Construction Estimating Contingency					$0	
TOTAL, CONSTRUCTION CAPITAL COSTS					$0	
TOTAL CAPITAL COSTS					**$79,000**	
ANNUAL OPERATIONS AND MAINTENANCE						
SUBTOTAL					**$ -**	
PERIODIC OPERATIONS AND MAINTENANCE						
Five Year Review	1	LS	$15,000.00	$15,000.00		Assumes 5 Year Review site visit and associated reporting
25% O&M Estimating Contingency				$4,000.00		
SUBTOTAL					**$ 19,000**	
Total Cost of Annual And Periodic Maintenance, No Discount Factor					**$ 120,000**	
Present Worth of Periodic Costs (30 Year Analysis Period, 7% Rate of Return)					**$50,000**	
Total Present Worth of Alternative					**$129,000**	

Alternative D3 - Vertical Engineered Barrier
Feasibility Study Cost Comparison

Former South Plant MGP - Waukegan, IL

NRT PROJECT NO.: 1983
BY: MDB | CHKD BY: RCW
DATE: 9/19/14 | REVISED BY: MDB on 1/28/2014

DESCRIPTION	QUANTITY	UNIT	UNIT COST	ITEM COST	SUBTOTAL	ASSUMPTIONS/REFERENCES
CONSULTING CAPITAL COSTS						
Remedial Engineering Design	1	LS	$220,960	$221,000		Assumed at 8% based on USEPA Guide to Developing Feasibility Study Cost Estimates
SUBTOTAL					**$ 221,000**	
SUBTOTAL, CONSULTING CAPITAL COSTS					$221,000	
25% Estimating Contingency					$55,000	
TOTAL, CONSULTING CAPITAL COSTS					$276,000	
CONSTRUCTION CAPITAL COSTS						
Site Preparation						
Mob./Demob.	1	LS	$48,800	$48,800		Assumed at 2% of Construction Costs
Silt Fence Installation	6,270	LF	$1	$6,400		Assumes 3' tall silt fence, 50 percent installed in ideal conditions and 50 percent in adverse conditions
Perimeter Construction Fencing	6,270	LF	$6	$39,500		Assumes temporary fencing, plastic safety fence, 4' high, heavy duty
Stabilized Construction Entrance	100	SY	$16	$1,600		Assumes a 50 SY stabled construction entrance for each of the two distinct cap areas
Staging and Decon Area Construction	1	LS	$7,300	$7,300		Assumes 6" compacted 3/4" aggregate base course under laid by an impermeable liner
Clearing and Grubbing of Trees/Vegetation	1	Acre	$4,480	$4,500		Assumes light clearing of an area 25% larger than the proposed slurry wall footprint
Saw Cutting of Parking Lot/Roadway Pavement	3,960	LF	$4	$17,100		Assumes saw cutting pavement out of the HDD work areas. There are 7 areas that are 50' by 100'. Assumed average depth of 6 inches.
Pavement Removal	1,100	SY	$9	$9,800		Assumes removal of 5-ft wide section of pavement along 50% of proposed slurry wall alignment
SUBTOTAL					**$ 135,000**	
Slurry Wall Installation						
One Pass Mob/Demob, and Wall Install	114,000	SF	$10	$1,140,000		Assumes one pass trench installation of soil-bentonite slurry wall to an average depth of 20 ft. Assumed Trench width of 1.5 ft.
Vacuum Excavator	29	Day	$1,312	$37,400		Assumes vacuum excavator for excavation near utilities. Assumes 200 LF per day production.
Excavator	29	Day	$1,935	$55,200		Assumes excavator on standby for obstruction removal and support. Assumes 200 LF per day production.
Cement Addition	57,000	SF	$2	$114,000		Assumes cement addition to 50% of wall to accommodate load bearing requirements
Utility Crossings	20	Ea	$15,000	$300,000		Assumed based on utility map and slurry wall alignment
Transportation Excess Soil	1,900	Tons	$7	$12,900		Assumes that 20% of the volume of the slurry trench will require offsite disposal due to bulking. Assumes material density of 1.5 tons/CY
Disposal of Excess Soil	1,900	Tons	$35	$66,500		Assumes excess bulk soil is characteristically non-hazardous and will be disposed at Veolia Zion Landfill. Assumes material density of 1.5 tons/CY
SUBTOTAL					**$ 1,726,000**	
Extraction Well and Sewer Connection Construction						
Extraction Well Installation	7	EA	$6,000	$42,000		Assumes 4-inch dia. wells with flush mounted vaults and a depth of 20 ft
Extraction Well Pump	7	EA	$14,000	$98,000		Assumes materials and installation of pump, cables, and controls
Saw Cutting of Parking Lot/Roadway Pavement, and Conveyance Pipe to NSSD	4,500	LF	$4	$19,400		Assumes saw cutting on either side of the entire length of the proposed pipe alignment. Assumed average depth of 6-inches.
Trench Excavation for Electric and Plumbing	2,250	LF	$45	$101,300		
Horizontal Conduct Under Roads and Railroad	100	LF	$190	$19,000		Assumes HDD install of two, 6-inch diameter, conduits under EJ&E Railroad
Connection Fee to NSSD Sewer	1	LS	$15,000	$15,000		
Transportation of Excess Soil	188	Tons	$7	$1,300		Assumes disposal of excess soil generated during trenching, excavated soil is characteristically non-hazardous, and will be disposed of at Veolia Zion Landfill. Assumes material density of 1.5 tons/CY
Disposal of Impacted Soil	188	Tons	$35	$6,600		Assumes excavated soil is characteristically non-hazardous and will be disposed of at Veolia Zion Landfill. Assumes material density of 1.5 tons/CY
SUBTOTAL					**$ 302,600**	

Alternative D3 - Vertical Engineered Barrier
Feasibility Study Cost Comparison

Former South Plant MGP - Waukegan, IL

NRT PROJECT NO.: 1983
BY: MDB | CHKD BY: RCW
DATE: 9/19/14 | REVISED BY: MDB on 1/28/2014

DESCRIPTION	QUANTITY	UNIT	UNIT COST	ITEM COST	SUBTOTAL	ASSUMPTIONS/REFERENCES
Groundwater Treatment Plant						
Electrical Service Drop	1	LS	$15,000	$15,000		Engineers Estimate
Package Groundwater Treatment Plant	1	LS	$220,000	$220,000		Assumes package groundwater treatment plant
Treatment Plant Installation	1	LS	$10,000	$10,000		Assumes two days of a crane and crew to install and connect system
Startup and Testing	1	LS	$20,000	$20,000		
Documentation Surveying	1	LS	$3,000	$3,000		
SUBTOTAL					$ 268,000	
Site Restoration						
Aggregate Subbase	1,100	SY	$10	$11,000		Assumes 6" Compacted 3/4" aggregate subbase course under laid by a 200 lb geotextile fabric
Asphalt Wearing Surface	1,100	SY	$20	$21,600		Assumes cap consisting of 2-inch asphalt base course and 2-inch asphalt surface course
Concrete	275	SY	$32	$8,700		Assumes 8-inch concrete base
Preconstruction, Interim, and As-Built Survey	1	LS	$5,250	$5,300		Assumes 30 hours of professional land surveying to complete survey and associated deliverables
Site Restoration	1	LS	$10,000	$10,000		Engineers Estimate
SUBTOTAL					$ 56,600	
Construction Management						
Construction Oversight	1	LS	$149,292	$149,300		Assumed to be 6% of Remedial Contractor construction costs based on USEPA Guide to Developing Feasibility Study Cost Estimates
Project Management during Construction	1	LS	$124,410	$124,400		Assumed to be 5% of Remedial Contractor construction costs based on USEPA Guide to Developing Feasibility Study Cost Estimates
SUBTOTAL					$ 273,700	
SUBTOTAL, CONSTRUCTION CAPITAL COSTS					$2,762,000	
25% Construction Estimating Contingency					$691,000	
TOTAL, CONSTRUCTION CAPITAL COSTS					$3,453,000	
TOTAL CAPITAL COSTS					**$3,729,000**	
ANNUAL OPERATIONS AND MAINTENANCE						
Operations and Maintenance Labor	1	LS	$83,200	$83,200		Assumes twice a week site visits to monitor operations, change filters, etc.
Filter Media Changeout	1	EA	$20,000	$20,000		Assumes annual changeout of filter media
Capital Repair Fund	1	LS	$5,718	$5,700		Assumed at 2.5% of treatment and extraction system purchase price per year
Electric	1	LS	$10,000	$10,000		Assumes power consumption equivalent to approximately 15 HP at a rate of $0.10/KW-h
Discharge Fee to NSSD	4,415,040	Gallons	$0.10	$441,500		Assumes 1.5 GPM per well and 20% down time for maintenance.
Compliance Sampling	12	Months	$500	$6,000		Assumes monthly sampling for VOC, SVOC, and metals for discharge to NSSD
Semiannual Inspection and Reporting	2	Ea	$5,000	$10,000		Assumes semiannual site visit and compliance report to document site condition
Project Management	1	LS	$31,200	$31,200		Assumes 4 hours per week to manage project
25% O&M Estimating Contingency				$152,000		
SUBTOTAL					$ 760,000	
PERIODIC OPERATIONS AND MAINTENANCE						
Five Year Review	1	LS	$15,000.00	$15,000.00		Assumes 5 Year Review site visit and associated reporting
25% O&M Estimating Contingency				$4,000.00		
SUBTOTAL					$ 19,000	
Total Cost of Annual And Periodic Maintenance Costs, No Discount Factor					**$ 23,000,000**	
Present Worth of Annual Costs (30 Year Analysis Period and a 7% Discount Rate)					**$ 9,500,000**	
Present Worth of Periodic Costs (30 Year Analysis Period and a 7% Discount Rate)					**$ 114,000**	
Total Present Worth of Alternative					**$ 13,400,000**	

Alternative D4 - Horizontal Well DNAPL Recovery		
Feasibility Study Cost Comparison	NRT PROJECT NO.: 1983	
	BY: RJB	CHKD BY: MDB
Former South Plant MGP - Waukegan, IL	DATE: 9/19/14	REVISED BY: MDB on 1/28/2014

DESCRIPTION	QUANTITY	UNIT	UNIT COST	ITEM COST	SUBTOTAL	ASSUMPTIONS/REFERENCES
CONSULTING CAPITAL COSTS						
Remedial Engineering Design	1	LS	$108,960	$109,000		Assumed at 8% based on USEPA Guide to Developing Feasibility Study Cost Estimates
SUBTOTAL					**$ 109,000**	
SUBTOTAL, CONSULTING CAPITAL COSTS					$109,000	
25% Estimating Contingency					$27,000	
TOTAL, CONSULTING CAPITAL COSTS					$136,000	
CONSTRUCTION CAPITAL COSTS						
Site Preparation						
Mob./Demob.	1	LS	$91,000	$91,000		Assumed at 8% of construction costs
Silt Fence Installation	6,270	LF	$1	$6,400		Assumes 3' tall silt fence, 50 percent installed in ideal conditions anc 50 percent in adverse conditions
Perimeter Construction Fencing	6,270	LF	$6	$39,500		Assumes temporary fencing, plastic safety fence, 4' high, heavy duty
Stabilized Construction Entrance	100	SY	$16	$1,600		Assumes a 100 SY stabilized construction entrance
Staging and Decon Area Construction	1	LS	$7,300	$7,300		Assumes 6" compacted 3/4" aggregate base coarse under laid by a impermeable liner
Clearing and Grubbing of Trees/Vegetation	1	Acre	$4,480	$4,500		Assumes light clearing
Saw Cutting of Parking Lot/Roadway Pavement	280	LF	$4	$1,200		Assumes saw cutting each end of the 7 HDD lines: 5'x5'. Assumed average depth of 6-inches.
Pavement Removal	39	SY	$9	$300		Assumes removal of 5'x5' section of pavement.
SUBTOTAL					**$ 151,800**	
Horizontal Drainline Installation						
Horizontal Drainline (collection pipe and risers)	3,710	LF	$190	$704,900		Assumes installation of seven, 6-inch diameter slotted fiberglass pipe in sections consisting of 200' of riser pipe and 330' of slotted collection pipe to a depth of 20 ft by HDD method.
Vertical Well Sump	6	Ea	$58,000	$348,000		4' dia. concrete manhole 20' deep (supply and install).
Transportation Excess Soil	150	Tons	$7	$1,000		Assumes excavation of soil from each end of the HDD pipe: 5'x5'x4 and HDD auger cuttings from an 8" dia borehole
Disposal of Excess Soil	150	Tons	$35	$5,200		Assumes excess bulk soil is characteristically non-hazardous and wil be disposed of at Veolia Zion Landfill. Assumes material density of 1.5 tons/CY
SUBTOTAL					**$ 1,059,100**	
Site Restoration						
Aggregate Subbase	39	SY	$10	$400		Assumes 6" compacted 3/4" aggregate subbase coarse under laid by a woven geotextile fabric w/200 lb tensile strength
Asphalt Wearing Surface	39	SY	$20	$800		Assumes 2-inch asphalt base coarse and 2-inch asphalt surface coarse
Preconstruction, Interim, and As-Built Survey	1	LS	$5,250	$5,300		Assumes 30 hours of professional land surveying to complete survey and associated deliverables
Site Restoration	1	LS	$10,000	$10,000		Engineers Estimate
SUBTOTAL					**$ 16,500**	
Construction Management						
Construction Oversight	1	LS	$73,644	$73,600		Assumed to be 6% of Remedial Contractor construction costs based on USEPA Guide to Developing Feasibility Study Cost Estimates
Project Management during Construction	1	LS	$61,370	$61,400		Assumed to be 5% of Remedial Contractor construction costs based on USEPA Guide to Developing Feasibility Study Cost Estimates
SUBTOTAL					**$ 135,000**	
SUBTOTAL, CONSTRUCTION CAPITAL COSTS					$1,362,000	
25% Construction Estimating Contingency					$341,000	
TOTAL, CONSTRUCTION CAPITAL COSTS					$1,703,000	
TOTAL CAPITAL COSTS					**$1,839,000**	

Alternative D4 - Horizontal Well DNAPL Recovery						
Feasibility Study Cost Comparison					NRT PROJECT NO.: 1983	
					BY: RJB	CHKD BY: MDB
Former South Plant MGP - Waukegan, IL					DATE: 9/19/14	REVISED BY: MDB on 1/28/2014

DESCRIPTION	**QUANTITY**	**UNIT**	**UNIT COST**	**ITEM COST**	**SUBTOTAL**	**ASSUMPTIONS/REFERENCES**
ANNUAL OPERATIONS AND MAINTENANCE						
Operations and Maintenance Labor	1	LS	$75,600	$75,600		Assumes monthly visits to manually extract accumulated DNAPL at a production rate of 3 hours per sump.
Pump, Tubing, Vehicle, Misc. Equipment	36	Day	$350	$12,600		
Transportation and Disposal of DNAPL	16,150	Gal	$4	$58,800		Assumes 1400 gallons per recovery well per monthly pumping event. Drums manifested, and shipping to SET facility in Houston, Texas
Semiannual Inspection and Reporting	2	Ea	$5,000	$10,000		Assumes semiannual site visit and compliance report to document site conditions
Drainline Maintainence	3,710	LF	$2	$7,400		Annual maintainence assumed to maintain well screen function
Project Management	1	LS	$14,400	$14,400		Assumes 8 hours per month to manage project
25% O&M Estimating Contingency				$45,000		
SUBTOTAL					**$ 224,000**	
Total Cost of Annual Operations and Maintenance Costs, No Discount Factor					**$ 7,000,000**	
Present Worth of Annual Costs (31 Year Analysis Period and a 7% Discount Rate)					**$ 2,808,000**	
Total Present Worth of Alternative					**$ 4,647,000**	

Alternative D5 - Physically Enhanced DNAPL Recovery						
Feasibility Study Cost Comparison					NRT PROJECT NO.: 1983	
					BY: RJB	CHKD BY: MDB
Former South Plant MGP - Waukegan, IL					DATE: 9/19/14	REVISED BY: MDB on 1/28/2014

DESCRIPTION	**QUANTITY**	**UNIT**	**UNIT COST**	**ITEM COST**	**SUBTOTAL**	**ASSUMPTIONS/REFERENCES**
CONSULTING CAPITAL COSTS						
Remedial Engineering Design	1	LS	$263,440	$263,400		Assumed at 8 % based on USEPA Guide to Developing Feasibility Study Cost Estimates
SUBTOTAL					**$ 263,400**	
SUBTOTAL, CONSULTING CAPITAL COSTS					$263,400	
25% Estimating Contingency					$65,900	
TOTAL CONSULTING CAPITAL COSTS					$329,300	
CONSTRUCTION CAPITAL COSTS						
Site Preparation						
Mob./Demob.	1	LS	$168,500	$168,500		Assumed at 8% of construction costs
Silt Fence Installation	6,270	LF	$1	$6,400		Assumes 3' ft tall silt fence, 50 percent installed in ideal conditions and 50 percent in adverse conditions
Perimeter Construction Fencing	6,270	LF	$6	$39,500		Assumes temporary fencing, plastic safety fence, 4' high, heavy duty
Stabilized Construction Entrance	100	SY	$16	$1,600		Assumes a 50 SY stabilized construction entrance for each of the two distinct cap areas (tracking pad).
Staging and Decon Area Construction	1	LS	$7,300	$7,300		Assumes 6" compacted 3/4" aggregate base coarse under laid by a impermeable liner
Clearing and Grubbing of Trees/Vegetation	1	Acre	$4,480	$4,500		Assumes light clearing of an area 25% larger that proposed excavation footprint
Saw Cutting of Parking Lot/Roadway Pavement for HDD Pipe Install and Trenches	5,230	LF	$4	$22,600		Assumes saw cutting each end of the 11 HDD lines: 5'x5' and along the electric and plumming alignment. Assumed average depth of 6-inches.
Pavement Removal	1,126	SY	$9	$10,000		Assumes removal of 5'x5' section of pavement at each end of the HDD drainline.
SUBTOTAL					**$ 260,400**	
Horizontal Drainline Installation						
Horizontal Drainline (collection pipe and risers)	5,670	LF	$190	$1,077,300		Assumes HDD install of seven, 6-inch diameter slotted fiberglass pipe in sections consisting of 200' of riser pipe and 330' of slotted collection pipe to a depth of 20 ft and four, 6-inch dia slotted fiberglass pipe in sections consisting of 160' of riser pipe and 330' of slotted collection pipe to a depth of 15 ft.
Horizontal Conduct Under Roads and Railroad	300	LF	$190	$57,000		Assumes HDD install of two 6-inch diameter conduits under Pershing Road, EJ&E Railroad, and South Habor Place
Trench Excavation and Installation of Electric and Plumbing and Connection to NSSD	2,395	LF	$45	$107,800		Power supply and piping to wellheads
Vertical Well Sump	8	Ea	$58,000	$464,000		4' dia. concrete manhole 20' deep (supply and install).
Low-flow electric piston pump	4	Ea	$9,000	$36,000		For DNAPL recovery
Variable-speed impeller pump	7	Ea	$5,000	$35,000		For groundwater recovery and injection
Transportation Excess Soil	4,490	Tons	$7	$30,400		Assumes excavation of soil from each end of the HDD pipe: 5'x5'x4', trench for electric and plumbing, and HDD auger cuttings from an 8" dia borehole
Disposal of Excess Soil	4,490	Tons	$35	$157,100		Assumes excess bulk soil is characteristically non-hazardous and wi be disposed of at Veolia Zion Landfill. Assumes material density of 1.5 tons/CY
SUBTOTAL					**$ 1,964,600**	
Site Restoration						
Aggregate Subbase	1,126	SY	$10	$11,300		Assumes 6" compacted 3/4" aggregate subbase coarse under laid by a woven geotextile fabric w/200 lb tensile strength
Asphalt Wearing Surface	1,126	SY	$20	$22,100		Assumes 2-inch asphalt base coarse and 2-inch asphalt surface coarse
Preconstruction, Interim, and As-Built Survey	1	LS	$5,250	$5,300		Assumes 30 hours of professional land surveying to complete survey and associated deliverables
Site Restoration	1	LS	$10,000	$10,000		Engineers Estimate
SUBTOTAL					**$ 48,700**	

Alternative D5 - Physically Enhanced DNAPL Recovery
Feasibility Study Cost Comparison

Former South Plant MGP - Waukegan, IL

NRT PROJECT NO.: 1983
BY: RJB CHKD BY: MDB
DATE: 9/19/14 REVISED BY: MDB on 1/28/2014

DESCRIPTION	QUANTITY	UNIT	UNIT COST	ITEM COST	SUBTOTAL	ASSUMPTIONS/REFERENCES
Groundwater Treatment Plant						
Electrical Service Drop	1	LS	$15,000.00	$15,000		Engineers Estimate
Package Groundwater Treatment Plant	1	LS	$580,000	$580,000		Assumes package groundwater treatment plant consisting of phase separation, particle filtration, air stripping, and media specific absorption vessels
Treatment Plant Installation	1	LS	$30,000.00	$30,000		Assumes six days of a crane and crew to install and connect system
Startup and Testing	1	LS	$50,000	$50,000		
Connection Fee to NSSD Sewer	1	LS	$15,000	$15,000		
Documentation Surveying	1	LS	$3,000	$3,000		
SUBTOTAL					**$ 693,000**	
Construction Management						
Construction Oversight	1	LS	$178,002	$178,000		Assumed to be 6% of Remedial Contractor construction costs based on USEPA Guide to Developing Feasibility Study Cost Estimates
Project Management during Construction	1	LS	$148,335	$148,300		Assumed to be 5% of Remedial Contractor construction costs based on USEPA Guide to Developing Feasibility Study Cost Estimates
SUBTOTAL					**$ 326,300**	
SUBTOTAL, CONSTRUCTION CAPITAL COSTS					$3,293,000	
25% Construction Estimating Contingency					$823,300	
TOTAL CONSTRUCTION CAPITAL COSTS					$4,116,300	
TOTAL CAPITAL COSTS					**$4,446,000**	
ANNUAL OPERATIONS AND MAINTENANCE COSTS						
Transportation and Disposal of DNAPL	71,521	Gal	$3	$247,300		Drums manifested, and shipping to SET facility in Houston, Texas
GW Treatment Plant Operations and Maintenance Labor	1	LS	$208,000	$208,000		Assumes full-time O&M labor
Filter Media Changeout	2	EA	$20,000	$40,000		Assumes biannual changeout of filter media
Expendables and Capital Repair Fund	1	LS	$32,550	$32,600		Assumed at 5% of treatment and extraction system purchase price per year
Electric	1	LS	$20,000	$20,000		Assumes power consumption equivalent to approximately 30 HP at a rate of $0.10/KW-h
Compliance Sampling for DNAPL and Water Injection	12	Ea	$1,500	$18,000		Assumes monthly sampling of NAPL, and water to monitor compliance with applicable disposal, injection, and discharge permits.
Semiannual Inspection and Reporting	2	Ea	$5,000	$10,000		Assumes semiannual site visit and compliance report to document site conditions
Drainline Maintainence	5,670	LF	$2	$11,300		Annual maintainence assumed to maintain well screen function
Discharge Fee to NSSD	2,417,760	Gal	$0.10	$241,800		Assumes 20% of extracted groundwater will be discharged to NSSD at Standard Fee
Project Management & Final Report	1	LS	$80,000	$80,000		Assumes 10 hours per week to manage project plus final report preparation
25% O&M Estimating Contingency				$227,300		
SUBTOTAL					**$1,137,000**	
Total Cost of Annual Operations and Maintenance Costs, No Discount Factor					**$ 8,000,000**	
Present Worth of Annual Costs (7 Year Analysis Period and a 7% Discount Rate)					**$ 6,130,000**	
Total Present Worth of Alternative					**$ 10,576,000**	

Alternative D6 - Chemically Enhanced DNAPL Recovery		
Feasibility Study Cost Comparison	NRT PROJECT NO.: 1983	
	BY: RJB	CHKD BY: MDB
Former South Plant MGP - Waukegan, IL	DATE: 9/18/14	REVISED BY: MDB on 1/28/2014

DESCRIPTION	QUANTITY	UNIT	UNIT COST	ITEM COST	SUBTOTAL	ASSUMPTIONS/REFERENCES
CONSULTING CAPITAL COSTS						
Remedial Engineering Design	1	LS	$294,920	$295,000		Assumed at 8% based on USEPA Guide to Developing Feasibility Study Cost Estimates in addition to a pilot scale test
SUBTOTAL					**$ 295,000**	
SUBTOTAL, CONSULTING CAPITAL COSTS					$295,000	
25% Estimating Contingency					$74,000	
TOTAL CONSULTING CAPITAL COSTS					$369,000	
CONSTRUCTION CAPITAL COSTS						
Site Preparation						
Mob./Demob.	1	LS	$229,400	$229,400		Assumed at 8% of Construction Costs (Includes: laboratory surfactant screening tests, planning and document preparation, site mobilization, and site demobilization)
Silt Fence Installation	6,270	LF	$1	$6,400		Assumes 3' tall silt fence, 50 percent installed in ideal conditions and 50 percent in adverse conditions
Perimeter Construction Fencing	6,270	LF	$6	$39,500		Assumes temporary fencing, plastic safety fence, 4' high, heavy duty
Stabilized Construction Entrance	100	SY	$16	$1,600		Assumes a 50 SY stabilized construction entrance for each of the two distinct cap areas (tracking pad).
Staging and Decon Area Construction	1	LS	$7,300	$7,300		Assumes 6" compacted 3/4" aggregate base coarse under laid by a impermeable liner
Clearing and Grubbing of Trees/Vegetation	1	Acre	$4,480	$4,500		Assumes light clearing of an area 25% larger that proposed excavation footprint
Saw Cutting of Parking Lot/Roadway Pavement	5,730	LF	$4	$24,800		Assumes saw cutting each end of the 11 HDD lines: 5'x5'. Assumed average depth of 6-inches.
Pavement Removal	1,126	SY	$9	$10,000		Assumes removal of 5'x5' section of pavement at each end of the HDD drainline.
SUBTOTAL					**$ 323,500**	
Horizontal Drainline Installation						
Horizontal Drainline (collection pipe and risers)	5,670	LF	$190	$1,077,300		Assumes HDD install of seven, 6-inch diameter slotted fiberglass pipe in sections consisting of 200' of riser pipe and 330' of slotted collection pipe to a depth of 20 ft and four, 6-inch dia slotted fiberglass pipe in sections consisting of 160' of riser pipe and 330' of slotted collection pipe to a depth of 15 ft.
Horizontal Conduct Under Roads and Railroad	300	LF	$190	$57,000		Assumes HDD install of two 6-inch diameter conduits under Pershing Road, EJ&E Railroad, and South Habor Place
Trench Excavation and Installation of Electric and Plumbing and Connection to NSSD	2,395	LF	$45	$107,800		Power supply and piping to wellheads
Vertical Well Sump	8	Ea	$58,000	$464,000		4' dia. concrete manhole 20' deep (supply and install).
Low-flow electric piston pump	4	Ea	$9,000	$36,000		For DNAPL recovery
Variable-speed impeller pump	7	Ea	$5,000	$35,000		For groundwater recovery and injection
Transportation of Excess Soil	4,490	Tons	$7	$30,400		Assumes excavation of soil from each end of the HDD pipe: 5'x5'x4', trench for electric and plumbing, and HDD auger cuttings from an 8" dia borehole
Disposal of Excess Soil	4,490	Tons	$35	$157,100		Assumes excess bulk soil is characteristically non-hazardous and wil be disposed of at Veolia Zion Landfill. Assumes material density of 1.5 tons/CY
SUBTOTAL					**$ 1,964,600**	
Site Restoration						
Aggregate Subbase	1,126	SY	$10	$11,300		Assumes 6" compacted 3/4" aggregate subbase coarse under laid by a woven geotextile fabric w/200 lb tensile strength
Asphalt Wearing Surface	1,126	SY	$20	$22,100		Assumes 2-inch asphalt base coarse and 2-inch asphalt surface coarse
Preconstruction, Interim, and As-Built Survey	1	LS	$5,250	$5,300		Assumes 30 hours of professional land surveying to complete survey and associated deliverables
Site Restoration	1	LS	$10,000	$10,000		Engineers Estimate
SUBTOTAL					**$ 48,700**	

Alternative D6 - Chemically Enhanced DNAPL Recovery		
Feasibility Study Cost Comparison	NRT PROJECT NO.: 1983	
	BY: RJB	CHKD BY: MDB
Former South Plant MGP - Waukegan, IL	DATE: 9/18/14	REVISED BY: MDB on 1/28/2014

DESCRIPTION	QUANTITY	UNIT	UNIT COST	ITEM COST	SUBTOTAL	ASSUMPTIONS/REFERENCES
Groundwater Treatment Plant						
Electrical Service Drop	1	LS	$15,000	$15,000		Engineers Estimate
Package Groundwater Treatment Plant	1	LS	$580,000	$580,000		Assumes package groundwater treatment plant consisting of phase separation, particle filtration, air stripping, and media specific absorption vessels
Treatment Plant Installation	1	LS	$30,000.00	$30,000		Assumes six days of a crane and crew to install and connect system
Startup and Testing	1	LS	$50,000	$50,000		
Documentation Surveying	1	LS	$3,000	$3,000		Assumed
Surfactant Solution Chemical Cost	694,500	Lbs	$4.00	$2,778,000		
Electrolyte Solution Chemical Costs	527,500	Lbs	$0.60	$316,500		
Shipping and Handling Chemical Product	73	ton	$1,130	$82,000		Based on FedEx shipping rates
SUBTOTAL					**$ 3,772,500**	
Construction Management						
Construction Oversight	1	LS	$366,558	$366,600		Assumed to be 6% of Remedial Contractor construction costs based on USEPA Guide to Developing Feasibility Study Cost Estimates
Project Management during Construction	1	LS	$305,465	$305,500		Assumed to be 5% of Remedial Contractor construction costs based on USEPA Guide to Developing Feasibility Study Cost Estimates
SUBTOTAL					**$ 672,100**	
SUBTOTAL, CONSTRUCTION CAPITAL COSTS					$6,781,000	
25% Construction Estimating Contingency					$1,695,000	
TOTAL CONSTRUCTION CAPITAL COSTS					$8,476,000	
TOTAL CAPITAL COSTS					**$8,845,000**	
ANNUAL OPERATIONS AND MAINTENANCE COSTS						
Surfactant Injection Technical Assistance	30	Day	$4,600	$138,000		Includes flights, meals, hotels and rental car for the injection crew. Onsite labor includes Project/Site Manager, Systems Operator and Field Technician. Chemist will analyze samples sent to lab during the injection process. Off-site support includes trouble shooting, data analysis, and interpretation during injections.
Transportation and Disposal of Surfactant and DNAPL	144,413	Gal	$3	$495,400		Drums manifested, and shipping to SET facility in Houston, Texas
GW Treatment Plant Operations and Maintenance Labor	1	LS	$208,000	$208,000		Assumes full-time O&M labor
Filter Media Changeout	2	EA	$20,000	$40,000		Assumes biannual changeout of filter media
Expendables and Capital Repair Fund	1	LS	$32,550	$32,600		Assumed at 5% of treatment and extraction system purchase price per year
Semiannual Inspection and Reporting	2	Ea	$5,000	$10,000		Assumes semiannual site visit and compliance report to document site conditions
Drainline Maintainence	5,670	LF	$2	$11,300		Annual maintainence assumed to maintain well screen function
Electric	1	LS	$20,000	$20,000		Assumes power consumption equivalent to approximately 30 HP at a rate of $0.10/KW-h
Compliance Sampling for DNAPL and Water Injection	12	Ea	$1,500	$18,000		Assumes monthly sampling of NAPL, and water to monitor compliance with applicable disposal, injection, and discharge permits.
Discharge Fee to NSSD	2,417,760	Gal	$0.10	$241,800		Assumes 20% of extracted groundwater will be discharged to NSSD at Standard Fee
Project Management & Final Report	1	LS	$80,000	$80,000		Assumes 10 hours per week to manage project plus final report preparation
25% O&M Estimating Contingency				$323,800		
SUBTOTAL					**$1,619,000**	
Total Cost of Annual Operations and Maintenance Costs, No Discount Factor					**$ 6,500,000**	
Present Worth of Annual Costs (4 Year Analysis Period and a 7% Discount Rate)					**$ 5,490,000**	
Total Present Worth of Alternative					**$ 14,335,000**	

Alternative D7 – Thermally Enhanced DNAPL Recovery
Feasibility Study Cost Comparison
Former South Plant MGP - Waukegan, IL

NRT PROJECT NO.: 1983
BY: MDB | CHKD BY: RCW
DATE: 9/14/14 | REVISED BY: MDB on 1/28/2014

DESCRIPTION	QUANTITY	UNIT	UNIT COST	ITEM COST	SUBTOTAL	ASSUMPTIONS/REFERENCES
CONSULTING CAPITAL COSTS						
Remedial Engineering Design	1	LS	$423,020	$423,000		Assumed at 2%
SUBTOTAL					**$ 423,000**	
SUBTOTAL, CONSULTING CAPITAL COSTS					$423,000	
25% Estimating Contingency					$106,000	
TOTAL, CONSULTING CAPITAL COSTS					$529,000	
CONSTRUCTION CAPITAL COSTS						
Site Preparation						
Mob./Demob and Site Preparation	1	LS	$1,100,000	$1,100,000		Assumes mobilization and demobilization of ERH power supply units, treatment equipment, drill rigs, power lines, piping, etc.
General Site Maintenance and Facilities	1	LS	$80,000	$80,000		Assumes job trailer, sanitation racilities, etc
SUBTOTAL					**$ 1,180,000**	
Electric Resistence Heating System Installation						
Well Installation and Abandonment	1	LS	$9,500,000	$9,500,000		Assumes installation of 855 electrode/extraction/injection wells, and 340 thermal probe wells. Assumes 50% of wells will be flush mount.
Mechanical and Electrical Connections	1	LS	$5,800,000	$5,800,000		Extraction and injection piping, electric connections. Assumes 50% of piping will be trenched
ERH Equipment	1	LS	$2,000,000	$2,000,000		Power supply units, sensors, and remote monitoring equipment
Phase Separation and Water Treatment Equipment	1	LS	$2,000,000	$2,000,000		Multiphase extraction pumps, DNAPL, water, vapor phase separation, water and vapor treatment, and NAPL storage
SUBTOTAL					**$ 19,300,000**	
Site Restoration						
Preconstruction, Interim, and As-Built Survey	1	LS	$5,250	$5,300		Assumes 30 hours of professional land surveying to complete survey and associated deliverables
Site Restoration	1	LS	$50,000	$50,000		Assumes restoration pavement where impacted by ERH borings
SUBTOTAL					**$ 55,300**	
Construction Management						
Construction Oversight	1	LS	$410,706	$410,700		Assumed at 2%
Project Management during Construction	1	LS	$205,353	$205,400		Assumed at 1%
SUBTOTAL					**$ 616,100**	
SUBTOTAL, CONSTRUCTION CAPITAL COSTS					$21,151,000	
25% Construction Estimating Contingency					$5,288,000	
TOTAL, CONSTRUCTION CAPITAL COSTS					$26,439,000	
TOTAL CAPITAL COSTS					**$26,968,000**	
ANNUAL OPERATIONS AND MAINTENANCE						
Operations and Maintenance Labor	1	LS	$416,000	$416,000		Assumes two full time technicians working 40 hours a week to monitor and maintain system
Treatment System Expendables	2	Ea	$20,000	$40,000		Assumes replacement of particulate filters, treatment chemicals, and biannual change out of treatment system media.
Electric	6,035,000	Kw-Hrs	$0.10	$603,500		Based on power consumption model completed by ERH vendor
Expendables and Capital Repair Fund	1	LS	$32,500	$32,500		Assumed at 5% of treatment and extraction system purchase price per year
Semiannual Inspection and Reporting	2	Ea	$5,000	$10,000		Assumes semiannual site visit and compliance report to document site conditions
Transportation and Disposal of DNAPL	125,163	Gal	$4	$452,900		Assumes Annual removal of 1/5th of the total NAPL volume
Compliance Sampling for DNAPL,Vapor Emissions and Water Injection	12	Ea	$1,500	$18,000		Assumes monthly sampling of NAPL, water, and vapor to monitor compliance with applicable disposal, injection, and discharge permits.
Project Management	1	LS	$31,200	$31,200		Assumes 4 hours per week to manage project
25% O&M Estimating Contingency				$401,000		
SUBTOTAL					**$ 2,006,000**	
Total Cost of Annual Operations and Maintenance Costs, No Discount Factor					**$ 8,024,000**	
Present Worth of Annual Costs (4 Year Analysis Period and a 7% Discount Rate)					**$ 6,800,000**	
Total Present Worth of Alternative					**$ 33,768,000**	

APPENDIX C

MODELING AND CALCULATIONS

APPENDIX C1

DNAPL VOLUME ESTIMATE

Problem Statement:

Determine the approximate volume of mobile DNAPL at the Site.

The delineation included in the RI was sufficient for determinate nature and extent of DNAPL impacts and complete a Baseline Risk Assessment. However, a more comprehensive estimate surface area, thickness, and volume of DNAPL is necessary to develop conceptual remedial alternatives and associated costs.

References:

[1] NRT. 2013. *Former Waukegan South Plant MGP Remedial Investigation Report, Revision 1*. October 31, 2013.

[2] Morris, D.A. and A.I. Johnson. 1967. *Summary of hydrologic and physical properties of rock and soil materials as analyzed by the Hydrologic Laboratory of the U.S. Geological Survey*. U.S. Geological Survey Water-Supply Paper 1839-D, 42p.

[3] Pankow, J.F., Cherry, J.A. 1996. *Dense Chlorinated Solvents and Other DNAPL in Groundwater: History, Behavior, and Remediation*. Waterloo Press, Portland, OR. 522 pp.

Known:

Site-specific parameters known based on investigative data or other supporting calculations include:

- Thickness and elevation of DNAPL and the associated clay elevation at Site monitoring wells [1]. A summary of the well data is provided in the attached Table 1.
- Effective porosities of silty sand range from 0.28 (vol/vol) to 0.33 (vol/vol) [2].
- Fractional DNAPL saturation values for DNAPL range from 0.40 (vol/vol) to 0.70 (vol/vol) [3].

Assumptions:

Assumptions for the DNAPL volume calculation include:

- The difference between the top of DNAPL elevation and the top of clay elevation is representative of the thickness of DNAPL present within the aquifer in the area adjacent to each monitoring well location.

Calculations:

- **Step 1 –** Identify wells representative of the potential DNAPL bearing zone (i.e. bottom of screened interval either near to, at, or slightly into the confining clay layer). Tabulate the elevation of DNAPL as collected during the recent groundwater sampling events and import into the Site GIS database. This is presented in the attached Table 1.
- **Step 2** – Use the ESRI ArcMap GIS Geostatistical Analyst Extension to develop a surface to model the thickness of DNAPL on top of the clay layer throughout the site. Within the software, the radial basis function was selected because it honors locations where DNAPL thickness data is present. The Geostatistical Analyst Extension allowed the model to be optimized by iteratively running multiple scenarios to determine the most accurate model scenario. This optimization process is demonstrated by screen shots of the software included in Attachments 1 and 2. The predicted DNAPL surface was compared against the confining clay surface to determine the volume of media impacted by DNAPL. The resulting volume was **15,205 CY** of media impacted by DNAPL. This volume represents the total volume of soil, groundwater, and DNAPL and is presented in Figure C-1.
- **Step 3** – Multiple the total volume obtained in Step 2 by the range of literature provided porosity values for sand. The resulting volume range represents the volume of fluid in soil pore spaces impacted by DNAPL (i.e. sum of groundwater and DNAPL volumes).

- **Step 4** – Multiple the volume range obtained in Step 3 by the range of literature provided fractional DNAPL saturation values. The resulting volumes represent the range of potentially recoverable DNAPL.

Property	Low	Average	High
Volume From GIS Spatial Analysis (CY)	15,205	15,205	15,205
Effective Porosity (vol/vol) [1]	0.28	0.31	0.33
Fractional DNAPL Saturation (vol/vol) [2]	0.40	0.55	0.70
Total Volume DNAPL (CY)	1,703	2,608	3,512
Total Volume DNAPL (gallons)	**344,000**	**527,000**	**710,000**

Summary and Conclusions:

Based on the above process, the below table presents the probably range of potentially recoverable DNAPL at the site. For purpose of this focused FS, the average volume estimate of 527,000 gallons will be used as the estimated volume of DNAPL.

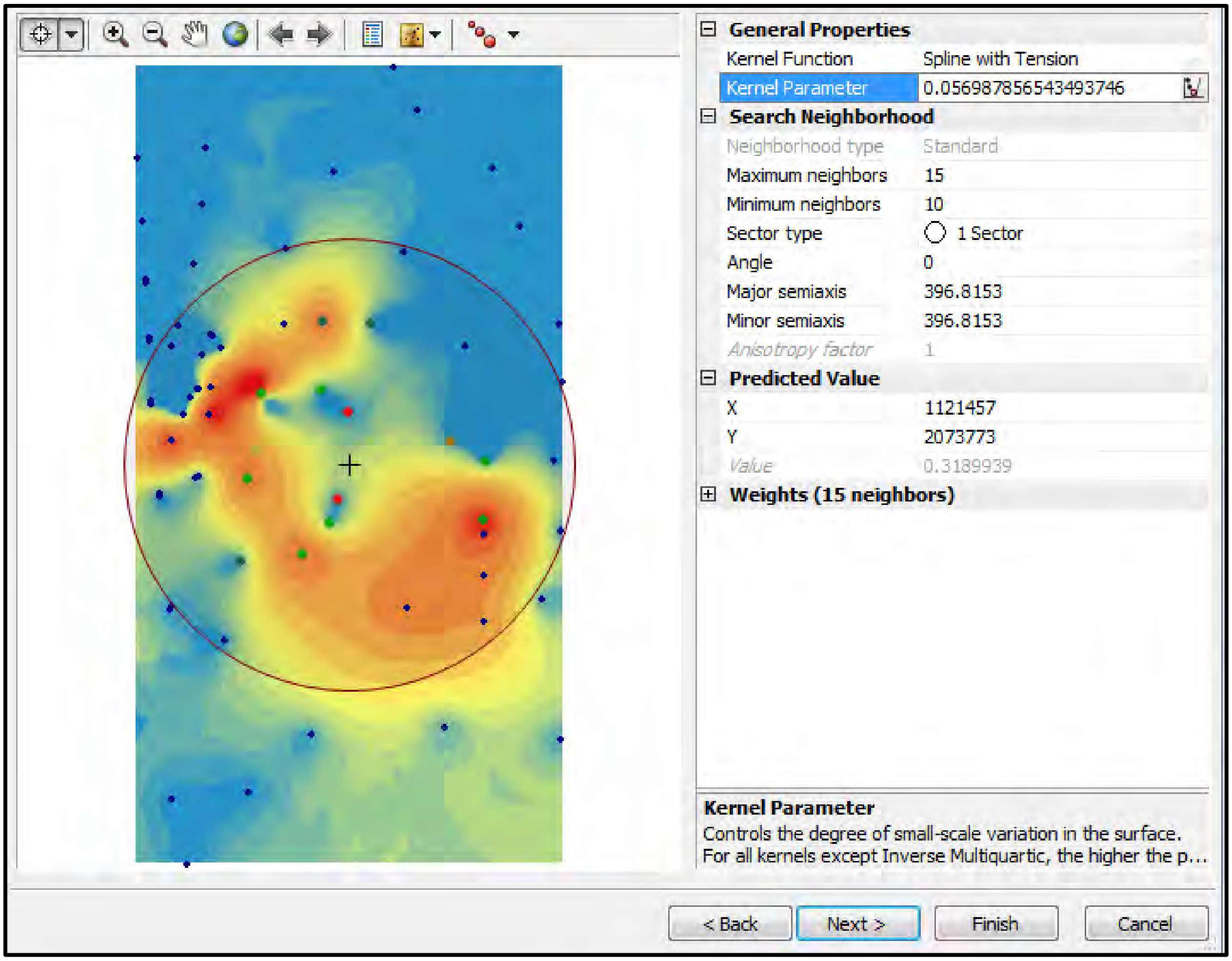
The areas and volumes of DNAPL presented in this subsection were based the thickness of DNAPL observed during groundwater sampling activities and should be considered approximations for planning level purposes. Depending on the selected remedy, pre-design investigations may be beneficial to further refine the areas and volumes of DNAPL prior to final design and subsequent implementation of remedial measures.

Table 1 - Summary of DNAPL Thickness Input for Volume Calculation Model

Well Name	Average DNAPL Thickness March 2013 - March 2014 (ft)	Average Elevation of Top DNAPL March 2013 - March 2014 (NAVD88)	Elevation of Top Clay Layer (NAVD88)	Included in DNAPL Volume Calculation
AKZO-MW01D	3.1	576.23	574.12	Yes
AKZO-MW02D	-	-	572.58	Yes
AKZO-MW03D	-	-	572.20	Yes
AKZO-MW04D	-	-	568.74	Yes
AKZO-MW05D	2.99	574.34	571.47	Yes
AKZO-MW06D	-	-	570.93	Yes
AKZO-MW07D	-	-	575.09	Yes
AKZO-MW08D	-	-	575.88	Yes
AKZO-MW09D	1.12	574.29	575.20	No - DNAPL Elevation Does Not Exceed Top of Clay Elevation
AKZO-MW09S	0.46	576.33	575.17	Yes
AKZO-MW10	-	-	579.00	Yes
AKZO-MW18	0.06	572.07	573.36	No - DNAPL Elevation Does Not Exceed Top of Clay Elevation
COW-MW01D	-	-	579.00	Yes
COW-MW02D	-	-	575.79	Yes
COW-MW03D	-	-	575.16	Yes
NSGSP-MW01	-	-	573.84	Yes
NSGSP-MW02A	-	-	573.00	No - Thicknesses Measurement is inconsistent with Adjacent Well RW-1
NSGSP-MW03	-	-	573.00	Yes
NSGSP-MW04	2	576.21	574.46	Yes
NSGSP-MW23	-	-	577.00	Yes
NSGSP-MW24	-	-	577.00	Yes
NSGSP-MW25	-	-	577.00	Yes
NSGSP-MW26	-	-	575.36	Yes
NSGSP-MW27	-	-	577.09	Yes
NSGSP-MW27D	-	-	577.08	Yes
NSGSP-MW28	-	-	577.20	Yes
NSGSP-MW28D	-	-	577.19	Yes
NSGSP-MW29	-	-	577.39	Yes
NSGSP-MW29D	-	-	577.39	Yes
NSGSP-MW30	0.02	573.3	575.18	No - DNAPL Elevation Does Not Exceed Top of Clay Elevation
NSGSP-MW31	-	-	573.78	Yes
NSGSP-MW32	-	-	577.53	Yes
NSGSP-MW32D	-	-	577.37	Yes
NSGSP-MW33	-	-	577.55	Yes
NSGSP-MW33D	-	-	577.53	Yes
NSGSP-MW34	-	-	575.89	Yes
NSGSP-MW34D	-	-	575.94	Yes
NSGSP-MW35	-	-	575.51	No - Thicknesses Measurement is inconsistent with Adjacent Well NSGSP-MW35D
NSGSP-MW35D	4.36	577.53	575.43	Yes

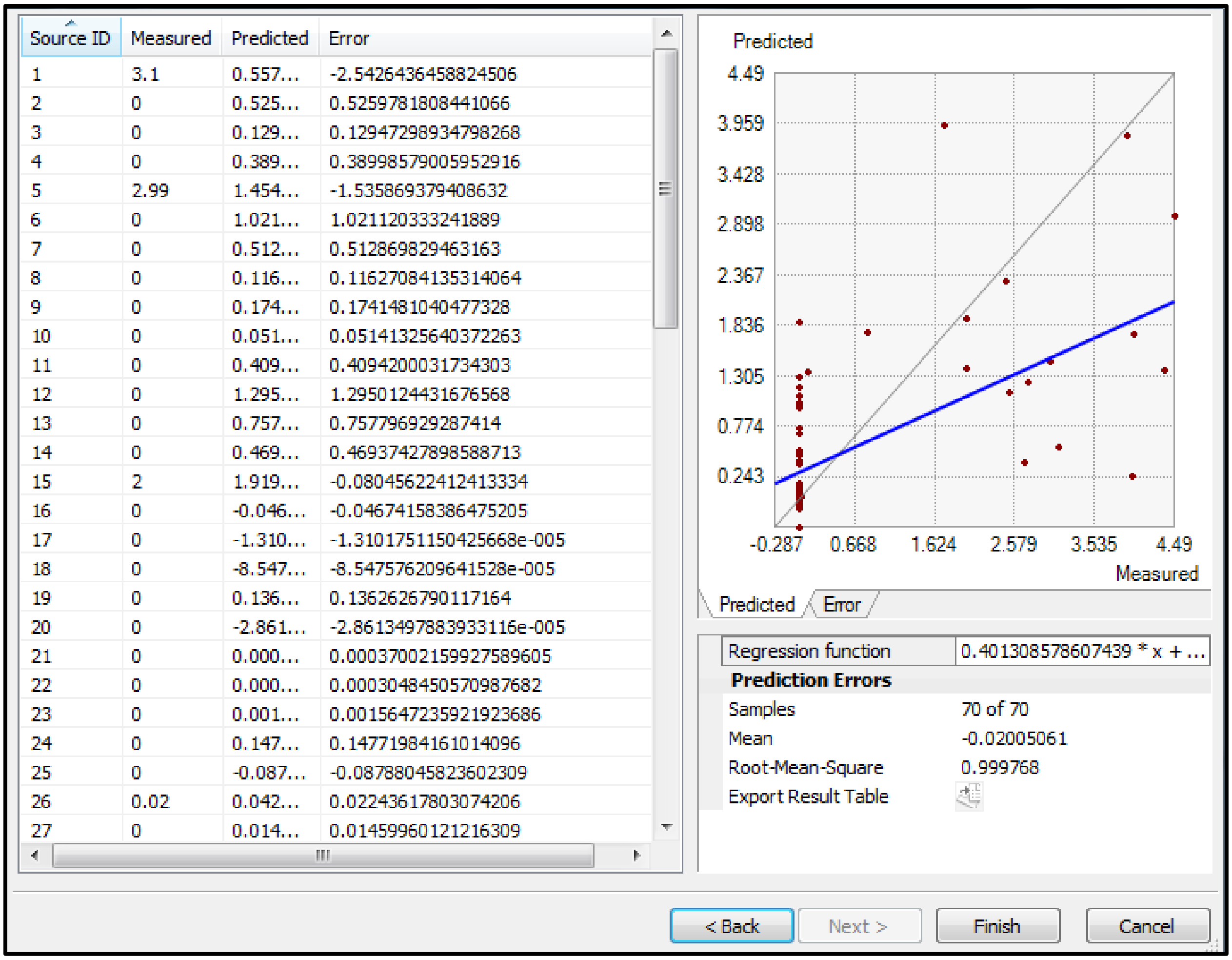
Table 1 - Summary of DNAPL Thickness Input for Volume Calculation Model

Well Name	Average DNAPL Thickness March 2013 - March 2014 (ft)	Average Elevation of Top DNAPL March 2013 - March 2014 (NAVD88)	Elevation of Top Clay Layer (NAVD88)	Included in DNAPL Volume Calculation
NSGSP-MW36	2.5	577.05	575.27	Yes
NSGSP-MW37	-	-	575.73	Yes
NSGSP-MW37D	-	-	575.80	Yes
NSGSP-MW38	-	-	576.05	Yes
NSGSP-MW39	-	-	576.35	Yes
NSGSP-MW40	3.98	580.2	576.93	Yes
NSGSP-MW40D	1.1	575.46	576.85	No - DNAPL Elevation Does Not Exceed Top of Clay Elevation
NSGSP-MW41	-	-	574.63	Yes
NSGSP-MW41D	-	-	574.47	Yes
NSGSP-MW43	-	-	574.40	Yes
NSGSP-MW51	-	-	576.95	Yes
SPPA-MW10D	-	-	566.18	Yes
SPPA-MW11	-	-	566.00	Yes
SPPA-MW12	-	-	566.19	Yes
SPPA-MW13	-	-	566.00	Yes
SPPA-MW14	-	-	566.00	Yes
SPPA-MW15	-	-	567.24	Yes
SPPA-MW16	-	-	568.31	Yes
SPPA-MW17	-	-	567.47	Yes
SPPA-MW18	-	-	568.08	Yes
SPPA-MW19	-	-	568.56	Yes
SPPA-MW21	-	-	569.70	Yes
SPPA-MW22	-	-	569.07	Yes
SPPA-MW4	-	-	572.63	Yes
SPPA-MW44	-	-	568.01	Yes
SPPA-MW45D	4.49	570.96	567.51	Yes
SPPA-MW46	-	-	571.63	Yes
SPPA-MW47D	4	575.81	573.69	Yes
SPPA-MW48	2	570.43	567.38	Yes
SPPA-MW5	0.1	573.09	572.91	Yes
SPPA-MW52	2.73	576.48	574.77	Yes
SPPA-MW52D	-	-	574.69	Yes
SPPA-MW8	-	-	565.41	Yes
RW1	0.81	-	-	Yes
RW7	3.91	-	-	Yes
RW8	2.69	-	-	Yes
RW10	2.46	-	-	Yes
RW11	1.74	-	-	Yes



Attachment 1 – ESRI ArcMap GIS Geostatistical Analyst Extension

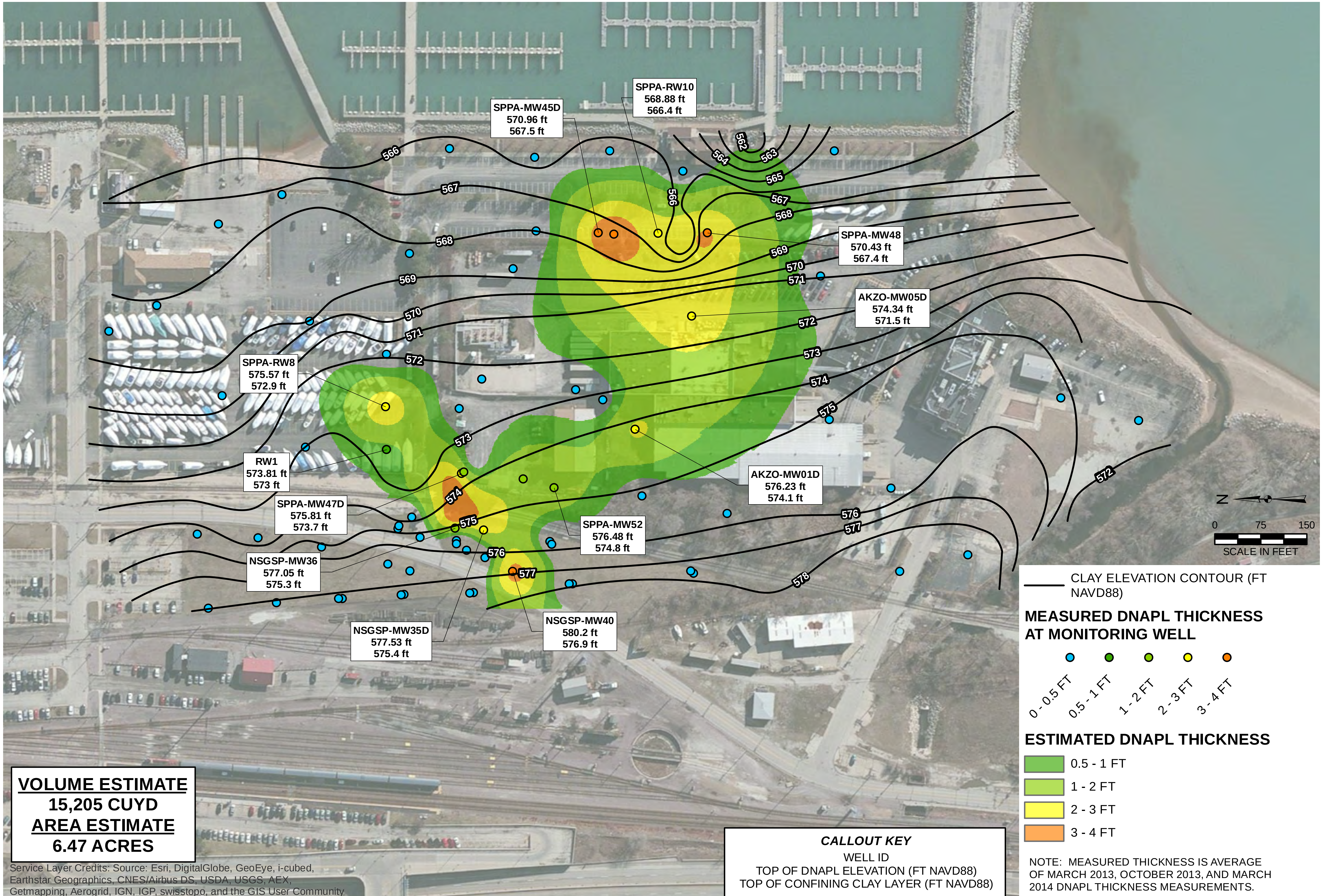
General Properties of Volume Model



Source ID	Measured	Predicted	Error
1	3.1	0.557...	-2.5426436458824506
2	0	0.525...	0.525978180844l066
3	0	0.129...	0.12947298934798268
4	0	0.389...	0.38998579005952916
5	2.99	1.454...	-1.535869379408632
6	0	1.021...	1.021120333241889
7	0	0.512...	0.51286982946316З
8	0	0.116...	0.11627084135314064
9	0	0.174...	0.174148104047 7328
10	0	0.051...	0.05141325640372263
11	0	0.409...	0.4094200031734303
12	0	1.295...	1.2950124431676568
13	0	0.757...	0.757796929287414
14	0	0.469...	0.46937427898588713
15	2	1.919...	-0.08045622412413334
16	0	-0.046...	-0.04674158386475205
17	0	-1.310...	-1.3101751150425668e-005
18	0	-8.547...	-8.547576209641528e-005
19	0	0.136...	0.1362626790117164
20	0	-2.861...	-2.8613497883933116e-005
21	0	0.000...	0.00037002159927589605
22	0	0.000...	0.0003048450570987682
23	0	0.001...	0.0015647235921923686
24	0	0.147...	0.14771984161014096
25	0	-0.087...	-0.08788045823602309
26	0.02	0.042...	0.02243617803074206
27	0	0.014...	0.01459960121216309

Attachment 2 – ESRI ArcMap GIS Geostatistical Analyst Extension

Summary of Prediction Errors



DRAWN BY/DATE:
MDM 9/24/2014
REVIEWED BY/DATE:
MDB 9/24/2014
APPROVED BY/DATE:
JMN 9/24/14

ESTIMATED EXTENT OF DNAPL CONTAMINATION

FOCUSED FEASABILITY STUDY
FORMER SOUTH PLANT MGP
NORTH SHORE GAS COMPANY
WAUKEGAN, ILLINOIS

DRAFT

PROJECT NO: 1983

FIGURE NO: C-1 1

NATURAL RESOURCE TECHNOLOGY

APPENDIX C2

ALTERNATIVE D4 – HORIZONTAL WELL DNAPL RECOVERY CALCULATIONS

Problem Statement:

Determine the approximate time required to recover 95% of the mobile DNAPL at the site using a horizontal well DNAPL recovery system.

To the best of the authors' knowledge, there is no established method developed to estimate the volume of DNAPL recovered by a horizontal well DNAPL recovery system. Due to the lack of an established method, the authors selected a volumetric flow rate equation which reflects Darcy's flow applied to oil flow in a water wetted matrix from [1, Eq. 1]. Site-specific variables in this equation were correlated to actual field recovery information by comparing the initial flow rate of the Darcy equation [1, Eq. 1] to the flow rate of existing horizontal well DNAPL recovery system.

References:

[1] Sale, T., Applegate, D. 1997. *Mobile NAPL Recovery: Conceptual, Field, and Mathematical Considerations*. Groundwater, Vol. 35. No. 3.

[2] NRT. 2013. *Former Waukegan South Plant MGP Remedial Investigation Report, Revision 1*. October 31, 2013.

Known:

Thickness of DNAPL and the associated volume of DNAPL recovery was extracted from the RI Report [2] and tabulated in Attachment 1. The thickness and volume of DNAPL extracted from each recovery well was averaged for the recovery activities conducted between 2013 and 2014 and are presented in the following table.

Recovery Well	Average DNAPL Thickness between 2013 - 2014 (ft)	Average DNAPL Extraction Volume between 2013 - 2014 (gal/month)	DNAPL Volume Recovered per Thickness of DNAPL (gal/ft/month)
RW1	2.04	5.13	2.51
RW7	3.92	5.85	1.49
RW8	2.73	4.39	1.61
RW10	2.58	5.78	2.24
RW11	1.69	3.07	1.81
		Average	1.93

Assumptions:

The existing vertical recovery wells are only able to recover the saturated thickness of DNAPL in contact with the 6-inch diameter vertical well screen. Conceptually, a site-specific DNAPL recovery rate per foot of well screen exposed to DNAPL can be estimated by dividing average DNAPL extraction volume by the average thickness of DNAPL. Potential inaccuracies of this approach are reduced by averaging the DNAPL recovery rate per foot data from all five DNAPL recovery wells.

Calculations:

Step 1 – Develop a Correlation to Existing Site-Specific Recovery Flow Rates

The initial monthly DNAPL recovery rate can be estimated by extrapolating the average DNAPL volume recovered per thickness of DNAPL from the vertical well recovery system across the entire length of the proposed horizontal well system included in Alternative D4. Monthly DNAPL recovery can be estimated by the following equation:

$$Q_{o\text{-monthly}} = w_o \times q_o$$

Where,

$Q_{o\text{-monthly}}$	= Monthly DNAPL recovery rate
w_o	= Length of DNAPL recovery wells
q_o	= Average DNAPL volume per thickness of DNAPL (gal/ft) from existing vertical recovery well system

$$Q_{o\text{-monthly}} = 2190 \text{ ft} \times 1.93 \text{ gal/ft/month}$$

$$Q_{o\text{-monthly}} = 4{,}227 \text{ gallons per monthly extraction event}$$

This monthly flow rate, $Q_{o\text{-monthly}}$, is based on current conditions and does not account for declining rate of recovery as the DNAPL height decreases over time. $Q_{o\text{-monthly}}$ will be used as the initial flow rate in Step 2, which allows for correlating the site-specific oil conductivity variable to the average DNAPL recovery rate measured for the existing vertical well system.

Step 2 – Darcy's Flow Applied to Oil Recovery Reflecting Reduction of DNAPL Thickness Over Time

See attached calculations for estimate of time to recover a given percentage or volume of mobile oil, considering a declining rate of recovery as the oil height decreases over time.

$$t(r) = -\ln(1-r)\left(\frac{V_{max}}{K_o k_{ro} h_o w_o i_o}\right)$$

Where,

t(r)	= time to recover a given fraction of the mobile oil
r	= fraction of the recovered mobile oil

The results of this calculation indicate the following:

t(10%) = 1.1 years

t(50%) = 7.2 years

t(95%) = 31.1 years

Summary and Conclusions:

Feasibility level design calculations indicate that it will take approximately 31 years to recover 95 percent of the estimated mobile DNAPL volume using the horizontal well recovery system described in the Feasibility Study report.

Horizontal Well Oil Recovery

Equations

$Q_o = K_o k_{ro} h_o w_o i_o$ volumetric flow rate of oil along a flow path [1, Eq. 1]

where,

$h_o := 2.4ft$ average initial oil height of the oil flow path between March 2013 and March 2014 (Focused Feasibility, Figure 8)

$w_o := 2190ft$ width of the oil flow path (coincident with the length of the drainline)

$i_o := 0.027 \frac{ft}{ft}$ gradient driving oil flow; a function of capillary and water pressure gradients. For this approximation, it is assumed to equal the gradient between the confining layer monitoring wells: AKZO-MW05D and SPPA-MW48.

$K_o = \frac{k \rho_o g}{\mu_o} = \frac{K_w \mu_w \rho_o}{\mu_o \rho_w}$ oil conductivity; analogous to hydraulic conductivity

where,

$g = 32.174 \frac{ft}{s^2}$ gravity constant

$K_w := 4 \times 10^{-3} \frac{cm}{s}$ $K_w = 11.339 \frac{ft}{day}$ groundwater hydraulic conductivity (horizontally)

$\mu_w := 2.73 \times 10^{-5} \frac{lbf\, s}{ft^2}$ absolute water viscosity at 50°F [2]

$\nu_o := 98.35 cSt$ where $cSt \equiv 10^{-2} stokes$

$\nu_o = 1.059 \times 10^{-3} \frac{ft^2}{s}$ kinematic viscosity of oil at 50°F, see attached reference [3]

$\rho_w := 1.917 \frac{slug}{ft^3}$ density of water at 50°F [2]

$SG_o := 1.07$ specific gravity of oil at 50°F [3]

$\rho_o := SG_o \rho_w$ $\rho_o = 2.051 \frac{slug}{ft^3}$ density of oil at 50°F, see attached reference [3]

$\mu_o := \nu_o \rho_o$ $\mu_o = 2.171 \times 10^{-3} \frac{lbf\, s}{ft^2}$ absolute oil viscosity at 50°F

$K_o := \frac{K_w \mu_w \rho_o}{\mu_o \rho_w}$ $\quad K_o = 5.381 \times 10^{-5} \frac{cm}{s}$ $\quad K_o = 0.153 \frac{ft}{day}$

k_{ro} relative permeability to oil in the oil flow path. Ranges from less than one to zero, depending on oil saturation.

Considering site-specific data collected from the existing vertical extraction wells [2], the relative permeability to oil in the flow path can be correlated as follows:

$q_o := 1.93 \frac{gal}{ft\,mo}$ $\quad q_o = 8.477 \times 10^{-3} \frac{ft^3}{ft\,day}$ flow rate of oil per vertical pipe length per unit time (see "Known" section of Summary Sheet)

$k_{ro} := \frac{q_o}{K_o h_o i_o}$ $\quad k_{ro} = 0.858$

Solution

$V_{max} := 527000gal$ $\quad V_{max} = 70450\,ft^3$ volume of recoverable oil (see Appendix C1 for volume estimate)

$$Q_o = K_o k_{ro} h_o w_o i_o = \frac{d}{dt} V_o$$

where,

$$h_o(t) = h_o(0)\left(1 - \frac{V(t)}{V_{max}}\right)$$

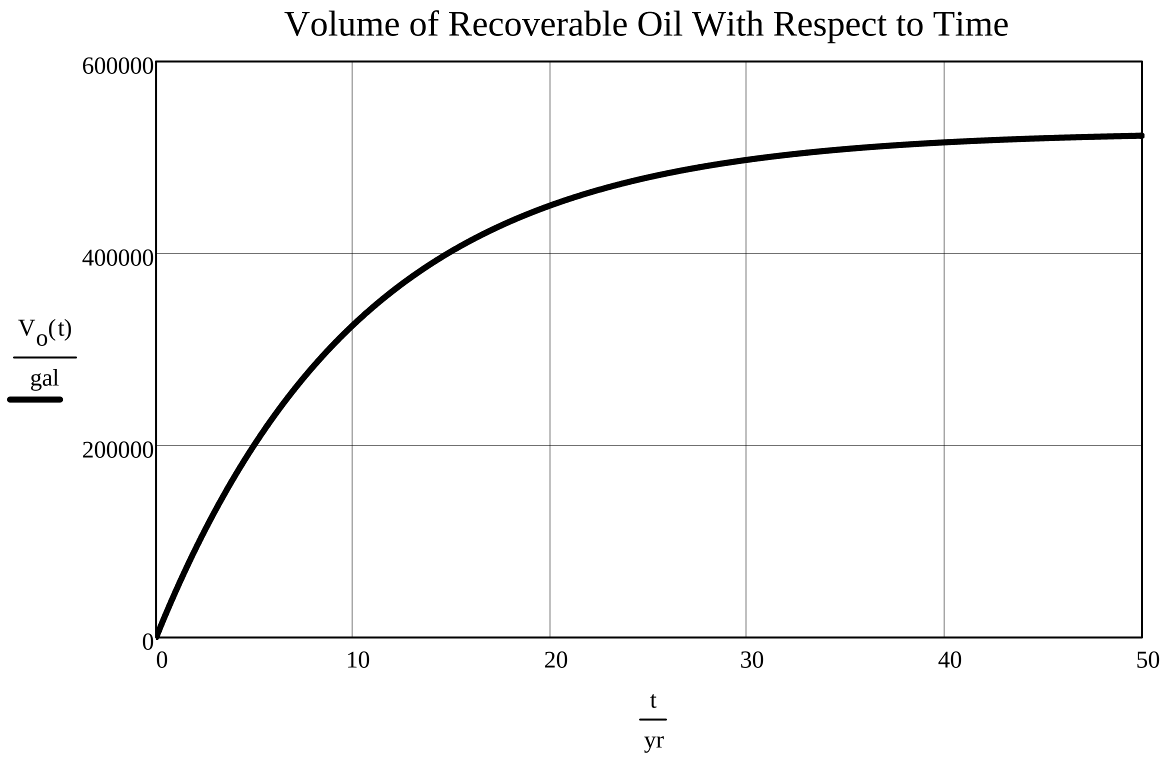
$$\frac{d}{dt} V_o = K_o k_{ro} h_o(0)\left(1 - \frac{V(t)}{V_{max}}\right) w_o i_o$$

$$\int \frac{dV_o}{1 - \frac{V(t)}{V_{max}}} = K_o k_{ro} h_o(0) w_o i_o\, dt$$

$$V_o(t) := V_{max} - V_{max} \exp\left[-\left(\frac{K_o k_{ro} h_o w_o i_o}{V_{max}}\right) t\right]$$ volume of recoverable oil with respect to time

$$Q_o(t) := K_o k_{ro} h_o w_o i_o \exp\left[-\left(\frac{K_o k_{ro} h_o w_o i_o}{V_{max}}\right) t\right]$$ flow rate of recoverable oil with respect to time

$t := 0\text{day}, 10\text{day} .. 50\text{yr}$ time distribution of interest



Time to recover 95% of the mobile oil

$$t(r) := -\ln(1 - r)\left(\frac{V_{max}}{K_o\, k_{ro}\, h_o\, w_o\, i_o}\right) \qquad t(95\%) = 11369\,\text{day} \qquad t(95\%) = 31.1\,\text{yr}$$

Percent recovery with respect to time, volume, and flow rate is summarized as follows:

$r := 0, 10\% .. 90\%$

$r =$ (%)	$t(r) =$ (yr)	$V_o(t(r)) =$ (gal)	$Q_o(t(r)) =$ (gpm)	$Q_o(t(r)) =$ ($\frac{gal}{yr}$)
0	0.0	0	0.096	50720
10	1.1	52700	0.087	45648
20	2.3	105400	0.077	40576
30	3.7	158100	0.068	35504
40	5.3	210800	0.058	30432
50	7.2	263500	0.048	25360
60	9.5	316200	0.039	20288
70	12.5	368900	0.029	15216
80	16.7	421600	0.019	10144
90	23.9	474300	$9.644 \cdot 10^{-3}$	5072

APPENDIX C3

ALTERNATIVE D5 - PHYSICALLY ENHANCED DNAPL RECOVERY CALCULATIONS

Problem Statement:

Optimize the recovery of mobile nonaqueous phase liquids (NAPL), referred to as "oil recovery," using flow path management or waterflooding. Efficient oil recovery can be achieved by optimizing conditions within the oil flow path. The waterflood oil recovery technique considers utilizing dual recovery and parallel delivery drainlines for recovery of DNAPL. The system is modeled using a first-order analytical solution for DNAPL flow to a drainline to support the selected oil recovery system configuration.

References:

[1] Sale, T., Applegate, D. 1997. *Mobile NAPL Recovery: Conceptual, Field, and Mathematical Considerations*. Groundwater, Vol. 35. No. 3.
[2] White, F.M. 2003. Fluid Mechanics, Fifth Edition. McGraw-Hill. New York, NY.
[3] Burns & McDonnell. 2008. *North Shore South Plant Former MGP Site Specific Work Plan, Revision 1, Appendix C2.* September 12, 2008.
[4] NRT. 2013. *Former Waukegan South Plant MGP Remedial Investigation Report, Revision 1*. October 31, 2013.

Known:

Site-specific parameters known based on investigative data or other supporting calculations include:

- Maximum recoverable oil, V_{max}, determined in Focused Feasibility Study, Appendix C1 is approximately 527,000 gallons.
- Absolute water viscosity, $\mu_w = 2.73\times10^{-5}$ lbf·s/ft^2 [2].
- The average kinematic viscosity of oil at 50°F is 98.35 cSt and the average specific gravity of oil, SG_o, is approximately 1.07, reference attached [3].
- Average initial oil height of the oil flow path, h_o, is approximately 2.4 feet as determined from data collected between March 2013 and March 2014 (Focused Feasibility, Figure 8).
- Water head, H_w, is approximately 8 feet based on average groundwater conditions within the remediation area (Focused Feasibility Study, Figures 5 and 6).
- The width of the water flow path, w_w, is assumed to be consistent with the length of the horizontal remediation wells. The average length of the horizontal remediation wells is approximately 330 feet; therefore, the total length of the flow path is approximately 1,320 feet (Focused Feasibility Study, Figure 13).
- The hydraulic conductivity of water through the soil is approximately 4×10^{-3} cm/s [4].

Assumptions:

Assumptions for designing a feasibility level waterflood system include:

- Water flood/flow path was considered to be the water head above the oil flow path.
- Following the observations of field data by Sale and Applegate [1], the ratio of path permeabilities was assumed to be 4.

If implemented, the system-specific performance parameters can be used to refine these assumptions.

Calculations:

Determination of drainline spacing based on the above known and assumed parameters was made using the following the equations developed by Sale and Applegate [1]:

$$V_o(t) = V_{max} - V_{max}\exp\left[-\left(\frac{k_{op}\,k_{ro}\,\mu_w\,h_o\,Q_w}{k_{wp}\,k_{rw}\,\mu_o\,h_w\,V_{max}}\right)t\right]$$

Where,

- $V_o(t)$ = volume of recoverable oil with respect to time
- V_{max} = maximum recoverable oil
- k_{ro} = relative permeability to oil in the oil flow path. Ranges from less than one to zero, depending on oil saturation.
- k_{op} = permeability of the oil flow path
- k_{rw} = relative permeability to water (water flow path)
- k_{wp} = permeability in the water flow path
- μ_w = absolute water viscosity
- h_o = initial oil height of the oil flow path
- Q_w = water pumping rate (combined water production rate from the upper and lower recovery drainlines)
- μ_o = absolute oil viscosity
- h_w = height of water flood/flow path

$$t(r) = -\ln(1-r)\left(\frac{k_{wp}\,k_{rw}\,\mu_o\,h_w\,V_{max}}{k_{op}\,k_{rw}\,\mu_w\,h_o\,Q_w}\right)$$

Where,

- $t(r)$ = time to recover a given fraction of the mobile oil
- r = fraction of the recovered mobile oil

Summary and Conclusions:

The feasibility level design shows that a total flow rate of 23.2 gpm from the horizontal extraction wells with a combined length of 1320 feet, spaced an average of approximately 155 feet apart will remove 95 percent of the estimated 527,000 gallons of recoverable DNAPL within approximately six years. Therefore, the four dual-drainlines (water and oil extraction) will have an average estimated flow rate of 5.8 gpm. Likewise, each oil recovery drainline is anticipated to produce an average of 0.025 gpm of recoverable DNAPL.

Dual Drainline Waterflood Oil Recovery

Equations

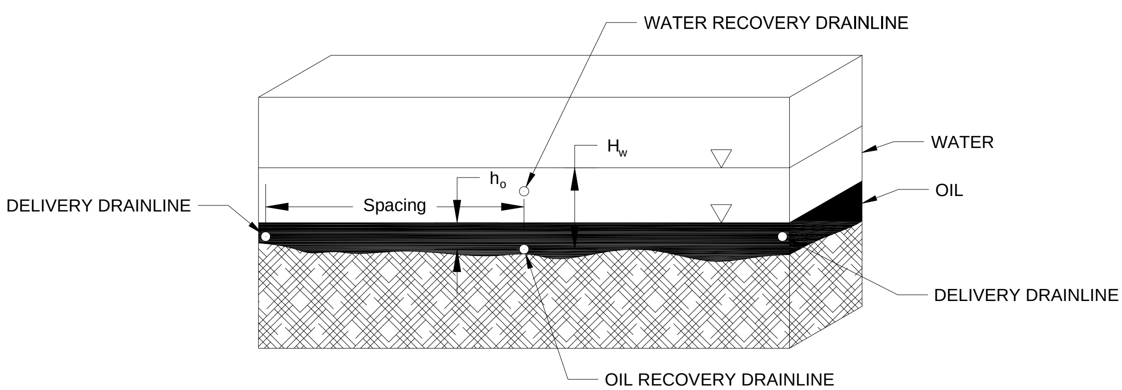
Volume of recoverable oil with respect to time:

$$V_o(t) = V_{max} - V_{max} \exp\left[-\left(\frac{k_{op}\, k_{ro}\, \mu_w\, h_o\, Q_w}{k_{wp}\, k_{rw}\, \mu_o\, h_w\, V_{max}}\right) t\right]$$ [1, Eq. 14]

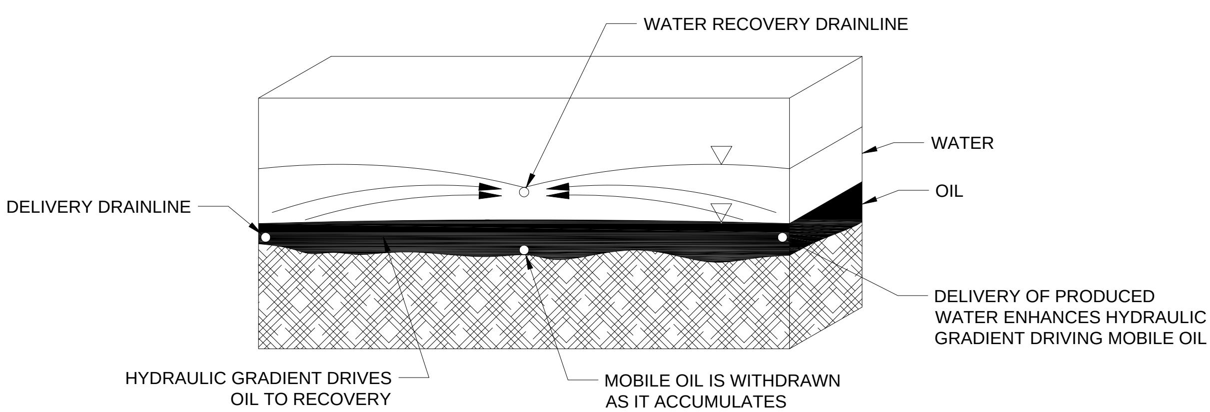
Time to recover a given fraction of the mobile oil:

$$t(r) = -\ln(1 - r)\left(\frac{k_{wp}\, k_{rw}\, \mu_o\, h_w\, V_{max}}{k_{op}\, k_{rw}\, \mu_w\, h_o\, Q_w}\right)$$ [1, Eq. 16]

Sketch



STATIC CONDITIONS



DUAL PUMPING WITH WATER DELIVERY

Site Specific Parameters

$V_{max} := 527000gal$ maximum recoverable oil (see Appendix C1 for volume estimate)

$\mu_w := 2.73 \times 10^{-5} \frac{lbf\ s}{ft^2}$ absolute water viscosity at 50°F [2]

$\nu_o := 98.35cSt$

$\nu_o = 1.059 \times 10^{-3} \frac{ft^2}{s}$ kinematic viscosity of oil at 50°F, see attached reference [3]

$\rho_w := 1.917 \frac{slug}{ft^3}$ density of water at 50°F [2]

$SG_o := 1.07$ specific gravity of oil at 50°F [3]

$\rho_o := SG_o \rho_w \qquad \rho_o = 2.051 \frac{slug}{ft^3}$ density of oil at 50°F, see attached reference [3]

$\mu_o := \nu_o \rho_o \qquad \mu_o = 2.171 \times 10^{-3} \frac{lbf\ s}{ft^2}$ absolute oil viscosity at 50°F

$h_o := 2.4ft$ average initial oil height of the oil flow path between March 2013 and March 2014 (Focused Feasibility, Figure 8)

$Q_w := 23.2gpm$ total water pumping rate from the four horizontal extraction wells (combined water production rate from the upper and lower recovery drainlines). See Focused Feasibility, Figure 13.

$H_w := 8ft$ water head

$h_w := H_w - h_o \qquad h_w = 5.6\,ft$ height of water flood/flow path

$\frac{k_{ro} k_{op}}{k_{rw} k_{wp}}$ or $k_{ratio} := 4$ ratio of flow path permeabilities [1]

where,

k_{ro} relative permeability to oil in the oil flow path. Ranges from less than one to zero, depending on oil saturation.

k_{op} permeability of the oil flow path

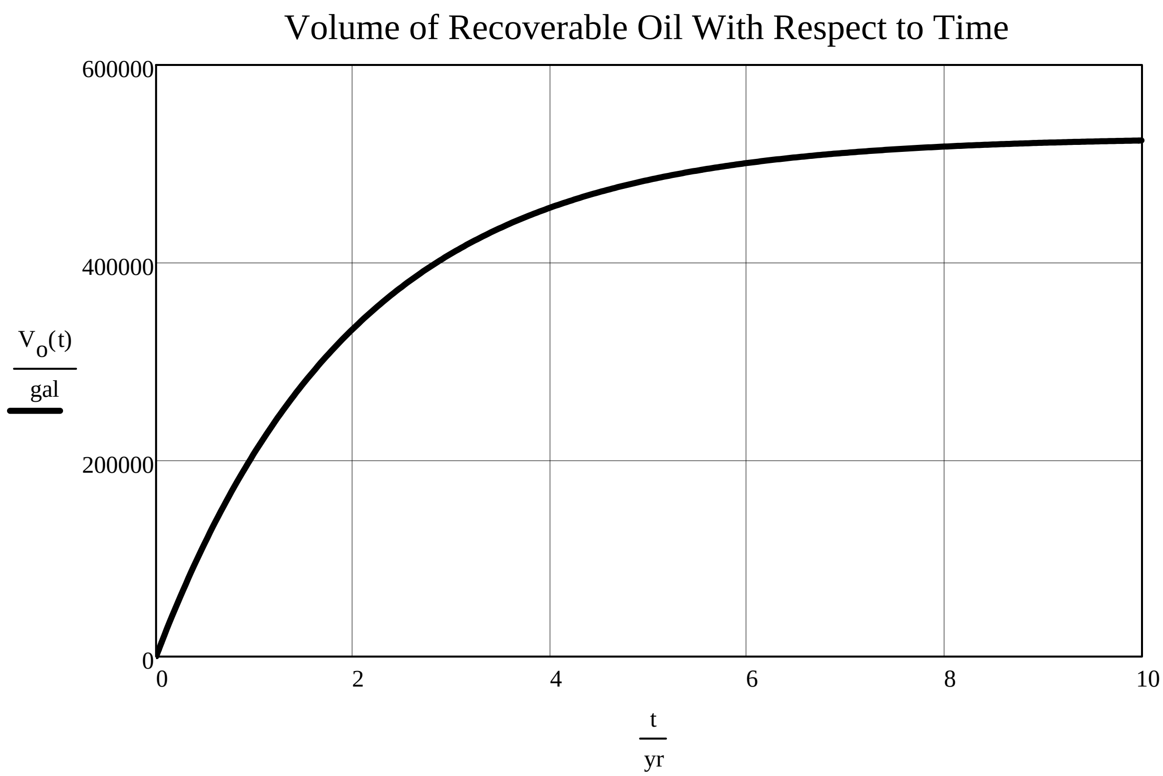
k_{rw} relative permeability to water (water flow path)

k_{wp} permeability in the water flow path

Solution

$t := 0\text{day}, 10\text{day} .. 3650\text{day}$ time distribution of interest

$$V_o(t) := V_{max} - V_{max}\exp\left[-\left(\frac{k_{ratio}\,\mu_w\,h_o\,Q_w}{\mu_o\,h_w\,V_{max}}\right)t\right]$$ [1, Eq. 14]



$$t(r) := -\ln(1-r)\left(\frac{\mu_o\,h_w\,V_{max}}{k_{ratio}\,\mu_w\,h_o\,Q_w}\right)$$ [1, Eq. 16]

$t(95\%) = 2 \times 10^3\,\text{day}$

$t(95\%) = 6.0\,\text{yr}$

Optimization of Drainline Spacing

Plot the time to recover 95% of the oil with respect to the drainline spacing to determine the appropriate remediation system configuration.

Recall the following, previously defined, site-specific parameters:

$V_{max} = 527000\,\text{gal}$ maximum recoverable oil

$\mu_o = 2.171 \times 10^{-3}\,\frac{\text{lbf s}}{\text{ft}^2}$ oil viscosity

$\mu_w = 2.73 \times 10^{-5}\,\frac{\text{lbf s}}{\text{ft}^2}$ water viscosity

$h_w = 5.6\,\mathrm{ft}$ height of water flood

$H_w = 8\,\mathrm{ft}$ water head

$h_o = 2.4\,\mathrm{ft}$ initial oil height of the oil flow path or continuous oil phase

$k_{ratio} = 4$ ratio of flow path permeabilities

Additional site-specific parameters:

$Spacing := 25\mathrm{ft}, 30\mathrm{ft} .. 300\mathrm{ft}$ range for drainline spacing

$w_w := 1320\mathrm{ft}$ width of the water flow path (coincident with the length of recovery drainline)

$K_w := 4 \times 10^{-3} \frac{\mathrm{cm}}{\mathrm{s}}$ $K_w = 11.339 \frac{\mathrm{ft}}{\mathrm{day}}$ water hydraulic conductivity [4]

Determine the water pumping rate (combined water production rate from the upper and lower recovery drainlines)

$$Q'_w = \frac{k_{wp} k_{rw} \rho_w g}{\mu_w} h_w w_w \left(\frac{d}{dx} H_w\right)$$ [1, Eq. 19]

where,

$$\frac{d}{dx} H_w = \frac{H_w}{Spacing}$$

$$\frac{k_{wp} k_{rw} \rho_w g}{\mu_w} = K_w$$ water hydraulic conductivity

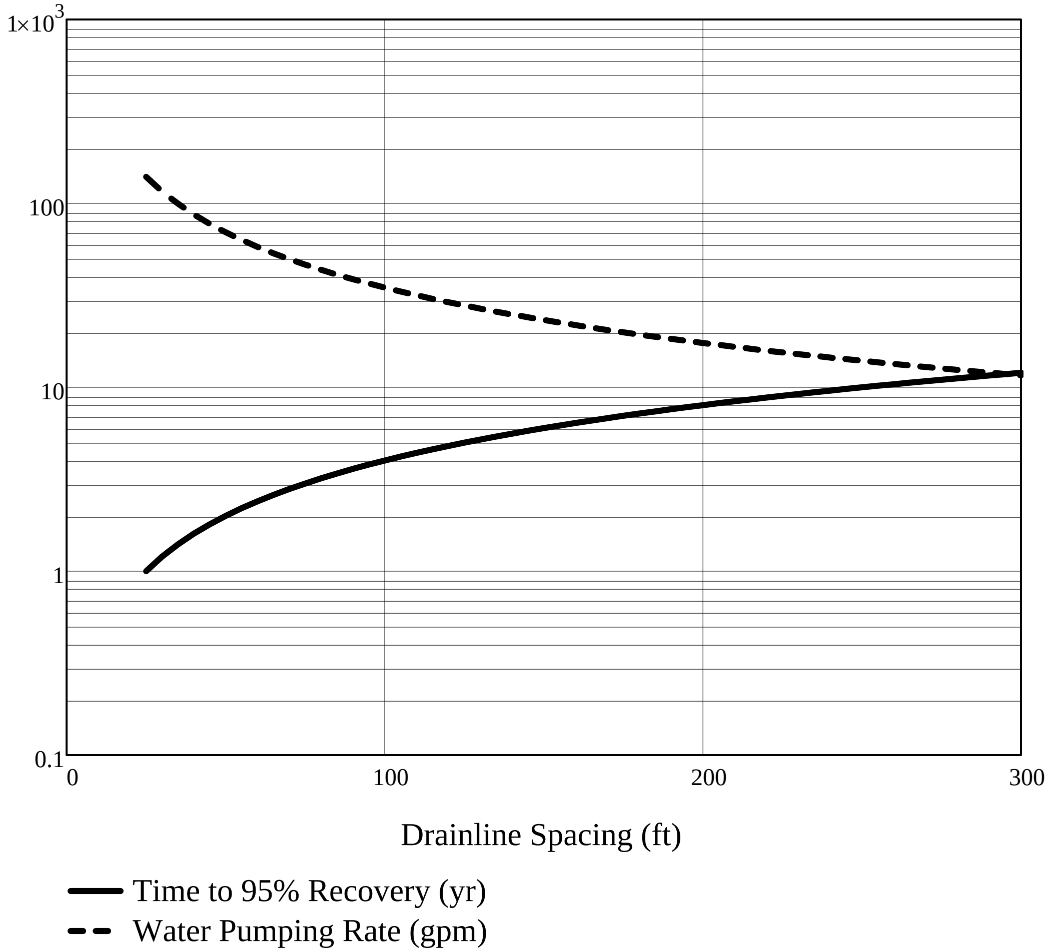
Therefore, the water pumping rate can be expressed as a function of drainline spacing:

$$Q'_w(Spacing) := K_w h_w w_w \frac{H_w}{Spacing}$$

Substituting in water pumping rate as a function of drainline spacing into Eq. 16 [1], the time to recover 95% of the mobile oil can be expressed as a function of drainline spacing:

$$t_{95}(Spacing) := -\ln(1 - 95\%)\left(\frac{\mu_o h_w V_{max}}{k_{ratio} \mu_w h_o Q'_w(Spacing)}\right)$$

The time and water pumping rate with respect to 95% recovery of the mobile oil with respect to drainline spacing is graphically presented below:



Select results for time and pumping rate to recover 95% of the mobile oil for specific drainline spacing:

$s := 25ft, 50ft .. 200ft$

$s =$ (ft)	$t_{95}(s) =$ (yr)	$Q'_w(s) =$ (gpm)
25	1.0	139.3
50	2.0	69.7
75	3.0	46.4
100	4.0	34.8
125	5.0	27.9
150	6.0	23.2
175	7.0	19.9
200	8.0	17.4

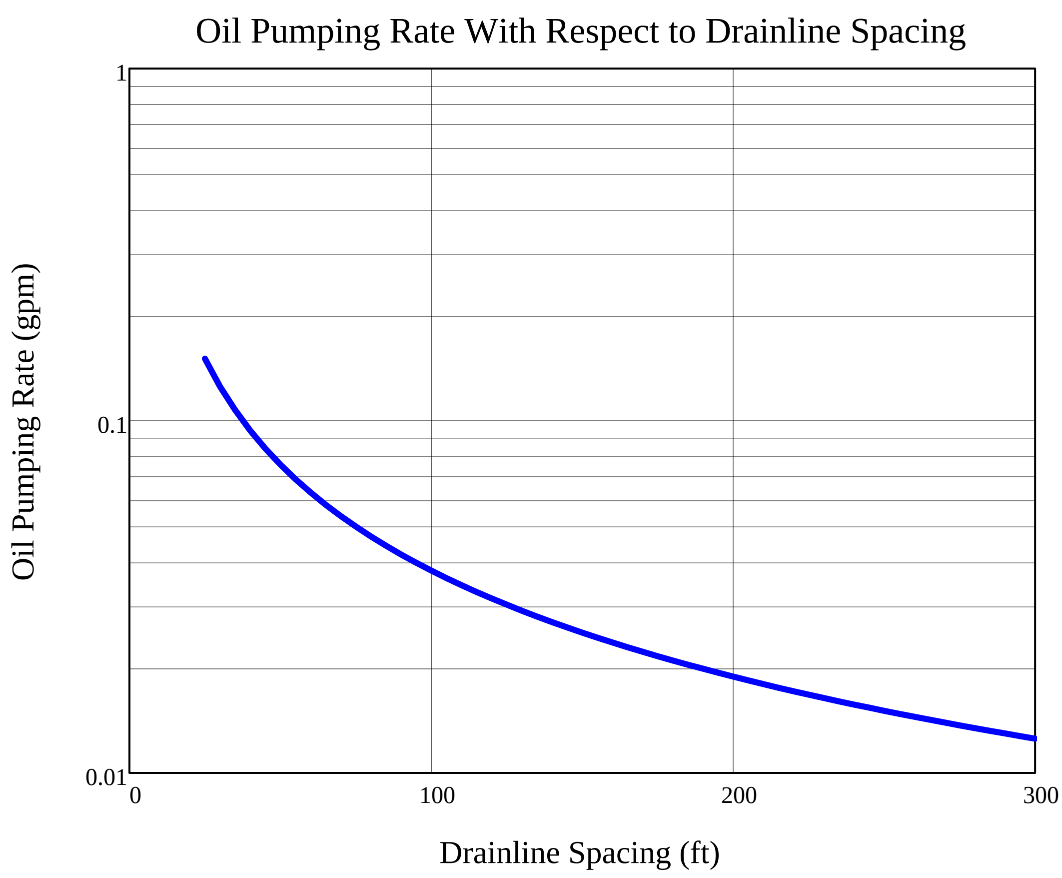
The oil recovery rate is expressed as

$$Q_o = \frac{k_{op}\,k_{ro}\,\mu_w\,h_o\,Q_w}{k_{wp}\,k_{ro}\,\mu_o\,h_w}\,\exp\left[-\left(\frac{k_{op}\,k_{ro}\,\mu_w\,h_o\,Q_w}{k_{wp}\,k_{rw}\,\mu_o\,h_w\,V_{max}}\right)t\right] \qquad [1, Eq. 15]$$

where,

$\frac{k_{ro}\,k_{op}}{k_{rw}\,k_{wp}}$ or $k_{ratio} = 4$ ratio of flow path permeabilities

therefore, $$Q_o(\text{Spacing}) := \frac{k_{ratio}\,\mu_w\,h_o\,Q'_w(\text{Spacing})}{\mu_o\,h_w}\,\exp\left[-\left(\frac{k_{ratio}\,\mu_w\,h_o\,Q'_w(\text{Spacing})}{\mu_o\,h_w\,V_{max}}\right)t_{95}(\text{Spacing})\right]$$



$Q_o(150\text{ft}) = 0.025\ \text{gpm}$ total average oil recovery rate

$\frac{Q_o(150\text{ft})}{4} = 6.256 \times 10^{-3}\ \text{gpm}$ average oil recovery rate per drainline