Imagine the result

Remedial Alternatives Evaluation

Aberdeen Former Manufactured Gas Plant

CERCLIS ID #SDD981553829

April 2010

ARCADIS

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List of Acronyms

AGEISS	AGEISS Environmental, Inc.
amsl	above mean sea level
ARAR	Applicable or Relevant and Appropriate Requirement
ARCADIS	ARCADIS U.S., Inc.
Barr	Barr Engineering Company
bgs	below ground surface
BMP	Best Management Practices
BNSF	Burlington Northern Santa Fe
BTEX	benzene, toluene, ethylbenzene, xylenes
BTU	British Thermal Unit
C°	degrees Celsius
CFR	Code of Federal Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Recovery Act
C&NW	Chicago and Northwestern Railroad
COC	Constituents of Concern
CSM	Conceptual Site Model
DM&E	Dakota, Minnesota, and Eastern

DNAPL	dense non-aqueous phase liquid
DRO	diesel range organics
E&E	Ecology & Environment, Inc.
ELM	ELM Consulting, LLC
F°	degrees Fahrenheit
FRTR	Federal Remediation Technology Roundtable
FS	Feasibility Study
GRAs	General Response Actions
HHRAs	Human Health Risk Assessments
IRAs	Interim Remedial Actions
LTTD	Low Temperature Thermal Desorption
ug/L	micrograms per liter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MGP	manufactured gas plant
MNA	Monitored natural attenuation
NAPL	non-aqueous phase liquid
NCP	National Contingency Plan
NE	Nebraska
NPDES	National Pollution Discharge Elimination System

NWE	NorthWestern Energy
NWPSC	NorthWestern Public Service Company
OSHA	Occupational Health and Safety Administration
O&M	Operations and Maintenance
PAHs	polycyclic aromatic hydrocarbons
POTW	Publicly Owned Treatment Works
PPE	Personal Protective Equipment
PRPs	Potential Responsible Parties
RAE	Remedial Alternatives Evaluation
RAOs	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
RR ROWs	Railroad Right of Ways
SD	South Dakota
SDDGFP	South Dakota Department of Game, Fish, and Parks
SD DENR	South Dakota Department of Environmental and Natural Resources
SD DWNR	South Dakota Department of Water and Natural Resources
SVOCs	semi volatile organic compounds
TarGOST®	Tar-specific Green Optical Screening Tool
TBC	To Be Considered

TCLP	Toxicity Characteristic Leaching Procedure
TPH	total petroleum hydrocarbons
TSCA	Toxic Substances Control Act
URS	URS Consultants, Inc. or URS Operating Services, Inc.
USEPA	United States Environmental Protection Agency
VOCs	volatile organic compounds

Licensed Professional Engineer Affirmation

I attest that this document – **NorthWestern Energy Remedial Alternatives Evaluation** for the **Aberdeen, SD Former MGP Site** was prepared under my direction or reviewed by me, and to the best of my knowledge and belief, the work described in the report has been designed or completed in accordance with the Administrative Rules and Codified Laws of South Dakota, and generally accepted engineering practices, and the information presented is accurate and complete.

Engineer Name: Thomas J. Fischer

Company: ARCADIS

Phone: 312.425.4110

Date of Preparation of Report: April 27, 2010

Professional Engineer's Stamp:

REGISTERED PROFESSIONAL ENGINEER
THOMAS J.
FISCHER
REG. NO. 7978
03-31-2011
EXPIRES
SOUTH DAKOTA

Signature: ____________________

Date: 04-27-2010

Executive Summary

This Remedial Alternatives Evaluation (RAE) documents the evaluation of potential remedial alternatives to manage the environmental impacts associated with the historical operation of NorthWestern Energy's former manufactured gas plant (MGP) in Aberdeen, South Dakota (Site). Through identifying and screening remedial technologies and process options, potential remedial technologies are considered for the Site that are consistent with applicable laws, appropriate and relevant regulations, and provisions within guidance documents. This process builds upon the previous investigations and remedial efforts to further mitigate and manage the remaining environmental risks associated with the historical MGP operations. While this remedial alternative analysis follows the general framework of the USEPA RI/FS Guidance, it is intended to screen only those remedial technologies and process options that are feasible to address the constituents and media of interest identified at the Site that are associated with former MGP operations. Based on this screening process, a remedial alternative is proposed which comprehensively addresses potential human health exposure associated with the Site.

The operation of the MGP started in 1888, which was only seven years after the incorporation of the town of Aberdeen, then part of the Dakota Territory, and one year before South Dakota was admitted as a State to the Union. Reportedly, the town was incorporated to celebrate the first train to ever arrive to the area. To provide some historical context, the Battle of Wounded Knee in southwestern South Dakota was fought two years after initiation of plant operations. The MGP operated until 1948 when natural gas was introduced, supplanting the need for MGP operations. During this period, gas was produced using water gas processes. This involved gas production by heating coal or coke feedstock in a generator-superheater, gas purification, and storage for distribution. Wastes and residuals from the gas manufacturing process typically included tar, ash, clinkers, and spent oxides.

Multiple phases of environmental characterization of the Site since 1980 have determined that coal tar, in the form of non-aqueous phase liquid (NAPL), is present in subsurface soils and groundwater, and has migrated beyond the Site boundary and beneath a number of permanent physical obstacles including railroads, buildings, and water storage structures. NWE has implemented a number of interim remedial actions (IRAs) to address issues associated with NAPL migrating into municipal storm and sanitary sewers, and sediments in Moccasin Creek that were impacted by discharges during historical MGP operation.

The baseline evaluation of human health exposure suggests that control of NAPL and prevention of NAPL's impact on groundwater be the focal considerations in adopting a comprehensive remedial alternative. In addition to controlling the source of impact (NAPL), NWE will continue to perform site-specific vapor intrusion assessments, as needed, for properties where occupied structures are present. Costs associated with vapor intrusion assessments are not included in the scope of this document.

Following a technology screening process, three remedial alternatives are presented for consideration. Alternative 1 consists of applying institutional controls for designated properties, long-term groundwater monitoring, continued operation of the existing wastewater treatment system, and on-going site maintenance consistent with current maintenance practices. Alternative 2 builds upon Alternative 1 by including these same provisions, with the addition of a passive NAPL recovery network consisting of trenches and wells. Alternative 3 includes all provisions of Alternatives 1 and 2 with the addition of targeted excavation of shallow source areas, treatment, and off-site disposal.

The safety of the local residents and public associated with any remedial alternative is paramount to NWE. As such, this technology screening and evaluation places a strong emphasis on the short-term risk of exposure by potential receptors, including these local residents, against the long-term risk reduction for each potential remedial alternative. After consideration of the ten criteria set forth, a remedial alternative is proposed consisting of environmental land use restrictions, continued operation and maintenance of the existing wastewater treatment system and site maintenance, passive free product collection and beneficial use/disposal, and long-term groundwater monitoring (Alternative 2). The cost estimate for this remedial alternative is $13,960,000 (cost estimates range from $3,210,000 to $27,100,000 for Alternatives 1 and 3, respectively).

1. Introduction

ARCADIS U.S., Inc. (ARCADIS) has prepared this Remedial Alternatives Evaluation (RAE) on behalf of NorthWestern Energy (NWE) for the Aberdeen Former Manufactured Gas Plant (MGP) Site ("Site"). This Site, assigned CERCLIS ID# SDD981553829, is not currently under a formal regulatory program; however, the South Dakota Department of Environment and Natural Resources (SD DENR) has issued correspondence to NWE (SD DENR, 2004) detailing known environmental issues associated with historical site operations, and has directed NWE to meet specific requirements to address these issues. Since 2004, NWE has completed several phases of characterization and interim remedial actions (IRAs) under the supervision of SD DENR in fulfillment of these directives.

This RAE follows the general frameworks of the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (RI/FS Guidance; United States Environmental Protection Agency (USEPA), 1988) and the *Handbook for Investigation and Corrective Action Requirements for Discharges from Storage Tanks, Piping Systems, and Other Releases* (SD DENR, 2003) with some variations based on the issues and challenges associated with this specific site.

1.1 Purpose and Intent

This RAE documents the evaluation of potential remedial alternatives to manage the environmental impact associated with the historical MGP operations conducted at the Site. Through identifying and screening remedial technologies and process options, potential remedial alternatives were developed for the Site in consideration of site-specific conditions and are consistent with applicable laws, appropriate and relevant regulations, and applicable guidance documents. Based on this screening process, a comprehensive remedial alternative is proposed that builds upon the previous investigation and remedial efforts to further mitigate and manage the remaining environmental risks associated with historical MGP operations, thereby addressing actual issues present at the Site or reasonable hypothetical issues that may develop.

1.2 Document Organization

This RAE is organized into the following sections:

Section		Contents
1.	Introduction	Provides an introduction to the RAE, describes Site background and summarizes past Site activities
2.	Conceptual Site Model	Provides an overview of the Conceptual Site Model
3.	RAE Approach	States the RAE objectives and describes the remedial alternatives evaluation approach
4.	Development of General Response Actions	Presents the preliminary goals of remediation and develops possible General Response Actions for achieving the goals
5.	Preliminary Technology Screening	Evaluates and screens technologies and process options that are applicable to the Site by medium of interest
6.	Potential Remedial Alternatives	Develops and evaluates potential remedial alternatives based on the retained technologies and process options
7.	Proposed Remedial Alternative	Presents the proposed remedial alternative that is most appropriate for the Site
8.	References	Provides a list of references cited in this RAE

1.3 Site Background

The potential remedial alternatives were developed based on currently available site-specific data and background information, including:

- general Site information (location and physical setting)
- Aberdeen Former MGP history
- previous Site investigations
- previous IRAs
- Site geology and hydrogeology

- nature and extent of environmental impacts

This evaluation benefits from a substantial degree of characterization and IRAs that have been performed to date. This repository of information provided the basis from which to evaluate potential remedial alternatives leading to the development of an appropriate and comprehensive remedial approach.

1.3.1 Site Location and Physical Setting

The Site is located in the southwest quarter (SW1/4) of the northwest quarter (NW1/4) of Section 18, Township 123 North, and Range 63 West in the City of Aberdeen, Brown County, South Dakota (Figure 1). The Site is triangular in shape, encompassing approximately six acres of land roughly extending from 1st Avenue NE to 2nd Avenue NE east of Jackson Street and west of the Burlington Northern Santa Fe (BNSF) railroad right-of-way (RR ROW) (Figure 2). The comparably small footprint and the triangular configuration of the Site present implementation limitations for some remedial technology options. To the north and west, the Site is bordered by the City of Aberdeen properties featuring a five-million gallon concrete water storage tank (north of Site), and a bike path and a three-million gallon concrete water storage tank (west of Site). A bike path is located on the former Dakota, Minnesota, and Eastern (DM&E) RR ROW along the west property line. To the southeast of the Site is an active BNSF RR ROW, and a BNSF RR main line ROW also runs east-west immediately south of the Site.

The areas surrounding and near the Site are a mixture of industrial, commercial, and residential properties (Figure 2). Several residential areas lie to the west, northwest, north, northeast, and southeast of the Site, while commercial properties exist in other areas to the southeast, south, and southwest. Figure 2 depicts the general uses of the properties surrounding the Site. It should be noted that nearby residents are located within about 220 yards from the Site boundary, which was considered during the evaluation of short-term impacts (e.g., fugitive emissions) associated with the implementation of potential alternatives.

The ground surface at the Site is relatively flat with an elevation of approximately 1,300 feet above mean sea level (amsl). In general, the surface drainage pattern at the Site slopes gently to the southeast towards Moccasin Creek, which flows from north to south and is located approximately ¾ mile east of the Site. The creek serves as the main drainage feature in the Aberdeen area with an approximate elevation of 1,290 feet amsl at the Milwaukee Avenue storm sewer outfall.

At the present time, NWE operates an electrical substation at the northeastern corner of the property, which constitutes a surface obstruction to certain remedial alternatives, and a small shed associated with former gas regulating operations is present by the southeast property boundary. Site access is controlled by a perimeter chain-link fence maintained by NWE. The vast majority of the property ground is sparsely vegetated or gravel-covered and maintained by routine grass mowing by NWE. In addition to the RR ROWs, various above ground and below ground utilities are present on and around the Site (Figure 3).

The 2008 census recorded the population of Aberdeen to be 24,460.

1.3.2 Aberdeen Former MGP History Summary

The Aberdeen former MGP operated from 1888 until 1948 when natural gas was introduced supplanting the need for MGP operations. During this period, gas was produced using water gas processes. The water gas process typically involved gas production by heating coal or coke feedstock in a generator-superheater, gas purification, and storage for distribution. Wastes and residuals from the gas manufacturing process typically included tar, ash, clinkers, and spent oxides.

Major historical features of former Aberdeen MGP were located primarily on the southern part of the Site, including three gas storage structures (gasometers #1, #2, and #3), a generator room, a purifier room, a meter room, and several other plant rooms and structures (Figure 3). It was reported that the former MGP operation by-product was attempted to be sold to the public as a disinfectant and preservative (AGEISS, 1995). Cooling water used in association with the former MGP operations was reportedly discharged directly through what is now a municipal storm sewer. Aerial photos appear to show that the northern portion of the Site was used for treating and/or storing utility poles at least since the 1950's through the late 1980's. Railroad tie-dipping operations have also been reported to have taken place on-site (AGEISS, 1995). In 1948, the Site was retrofitted for use as a propane-air peak-shaving facility and was operated through approximately 1997, when the propane tanks were sold, other remaining on-site structures were razed, and the property grounds were revegetated. General industrial use and maintenance of this property, as well as continued operation of a wastewater treatment plant (constructed as an IRA, as further discussed in Section 1.3.4), is anticipated into the foreseeable future.

1.3.3 Previous Site Investigations

During installation of a new segment of sanitary sewer in 1980, City of Aberdeen workers encountered Non-Aqueous Phase Liquid (NAPL) having apparent "creosote-like" characteristics which flowed into the open excavation just north of the Site on 3rd Avenue NE. Subsequently, NAPL was periodically observed within certain sanitary sewer manholes, monitoring wells, and in the wastewater influent entering the City of Aberdeen Publicly Owned Treatment Works (POTW), located approximately four miles south of the Site. A 1941 report documents the release of MGP-related wastes to Moccasin Creek via the storm sewer, and in mid 1990, City workers also encountered coal tar-like materials in Moccasin Creek when dredging sediments between the Milwaukee Avenue and 6th Avenue bridges.

Several phased investigations have been conducted at the Site and surrounding areas to identify and characterize environmental impacts that are associated with the Aberdeen former MGP operations and, in aggregate, result in over twenty years of investigation and IRAs. These previous investigations and regulatory activities were reported previously and are briefly described below:

March 1988 – The SD DENR, formerly the South Dakota Department of Water and Natural Resources (SD DWNR), prepared a Preliminary Assessment Report for the United States Environmental Protection Agency (USEPA) in response to the NAPL found in City of Aberdeen's sewer system that was believed to be associated with the Site. The report found that while the drinking water source was not at risk, exposure potential to private water wells and surface water might exist through migration pathways such as groundwater and subsurface utilities. As a result, a formal, high priority site inspection was recommended.

December 1988 to March 1989 – Ecology & Environment, Inc. (E&E), retained by the USEPA, completed a site investigation including soil and groundwater sampling at the Site and sediment sampling at Moccasin Creek. Volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) were detected in soil, groundwater, and sediment samples. However, the study did not suggest a strong correlation between the findings at the Site and that in the Moccasin Creek. E&E also reported:

- No VOCs or PAHs were detected in the upgradient groundwater sampled from a private well (irrigation well) located two blocks northwest of the Site;

- The highest PAH concentrations in soil were found in the location of the former tie-dipping pit that was identified by a geophysical conductivity survey;
- Surface water sampling results demonstrated that surface water in Moccasin Creek was not impacted;
- Surface soil sampling indicated elevated PAH concentrations on Site and on some areas of the bike path west of the Site; and
- A municipal drinking water sample was collected from a municipal water booster station downgradient of the Site and was found to be free of site-related potential constituents of concern (COCs).

1991 – E&E completed a Preliminary Pathway Analysis and Preliminary Assessment Questionnaire and identified needs for further evaluation in areas of waste quantity assessment and exposure and migration pathway evaluation.

April 1992 – USEPA conducted a National Pollutant Discharge Elimination System (NPDES) audit of the Aberdeen Publicly Owned Treatment Works (POTW). NAPL and/or odor were observed in sanitary sewer manholes on 3^{rd} Avenue and the lift station located at Dakota Street and 1^{st} Avenue NE.

September 1992 – E&E reported sampling of soil and groundwater near the former location of the reported tie-dipping pit area. Samples were also collected from a sanitary sewer manhole and near the storm water outfall at Moccasin Creek. All samples were found to exhibit similar characteristics to samples collected at the Site.

December 1993 – URS Operating Services, Inc. (URS) collected additional surface water and sediment samples near the storm water and POTW outfalls along Moccasin Creek. Elevated concentrations of VOCs and PAHs were found at the outfalls. However, no elevated COCs were identified in ten surface water samples.

December 1995 – AGEISS Environmental Inc., retained by the USEPA, performed a search for potential responsible parties (PRPs) and identified potential impact source areas including an MGP waste area on the southern portion of the Site and a creosote tie-dipping pit on the northern portion of the Site.

November 1999 – Barr Engineering Company (Barr), on behalf of NWE, performed a site characterization consisting of nine soil borings and four piezometers for a risk-based Tier 1 site evaluation. This Tier 1 evaluation concluded that PAH concentrations in subsurface soil and groundwater exceeded Tier 1 action levels and recommended conducting a Tier 2 evaluation to delineate the site impact, evaluate potential exposure pathways, and evaluate the fate and transport of potential COCs.

May 2002 – SD DENR directed NWPSC to conduct a site investigation.

June – November 2002 – Barr completed a supplemental investigation consisting of six soil borings/wells to study the potential source area on the NWPSC property. Sampling results were reported in an Analytical Results Report in November 2002. Elevated PAHs and TPH-diesel range organics (DRO) were identified in soil and groundwater.

August 2002 – URS (contracted by USEPA) collected additional soil and groundwater samples at the Site and sediment and surface water samples at Moccasin Creek, and identified impacts in soil, groundwater near the Site, and surface water at Moccasin Creek.

December 2003 – ELM Consulting (ELM), retained by NWE, conducted groundwater sampling as part of the periodic groundwater monitoring program. Eight monitoring wells were sampled on or near the Site. Detections of benzene, toluene, ethylbenzene, and xylenes (BTEX) and semivolatile organic compounds (SVOCs) were prevalent in most on-site wells, while metals were not present above SD standards. A very low potentiometric gradient was also measured during this event. Results were reported in a February 12, 2004 letter to SD DENR.

June 2004 – ELM submitted a Draft Work Plan for Phase I of Tier 2 Assessment to SD DENR and received approval from SD DENR in July 2004. The objectives of this Phase I of Tier 2 Assessment proposed additional investigation activities including geophysical investigation, soil sampling to correlate with the geophysical investigation, focused sediment investigation near the Moccasin Creek outfall area, groundwater monitoring, and assessment of current conditions of sanitary sewer and storm sewer as well as evaluation of operational equipment associated with municipal water storage tanks and sewer works.

July 2004 – ELM conducted a geophysical investigation using electrical resistivity techniques to identify potential migration pathways to off-site utilities and receptors. The geophysical investigation data were evaluated with soil investigation data performed under a separate mobilization.

October 2004 – ELM performed supplemental investigation to delineate the extent of the NAPL source area.

November 2004 – ELM performed sediment and surface water sampling near the storm water outfall at Moccasin Creek, and began the semi-annual groundwater monitoring program as described in the June 2004 Work Plan.

February - July 2006 – ENTRIX, retained by NWE, collected soil gas samples at an off-site property, Golden Park Apartment Building located northeast of the Site, following the determination that NAPL was present in the subsurface near this location. Winter and summer sampling events were performed, and comparison of COC concentrations to USEPA screening levels indicated that the indoor air inhalation pathway was not complete.

November 2006 – ENTRIX conducted a comprehensive biological characterization of sediment of Moccasin Creek. A sediment quality triad approach was applied to develop an appropriate risk-based cleanup goal for remediation of creek sediments that were impacted by former MGP operations. A cleanup goal of 200 mg/kg total PAHs was proposed in an April 2007 Remedial Objectives Report, and was subsequently approved by SD DENR.

July 2008 – ARCADIS, retained by NWE, conducted a trial excavation to evaluate potential COC off-gas emissions associated with excavation activities and to help determine the need for engineering controls that would be protective of local residents and on-site workers.

July 2009 – ARCADIS submitted a Work Plan for Phase 2 of Tier 2 Assessment – Additional Site Characterization and Remedial Pre-Design Testing to SD DENR. To facilitate a risk-based remedial alternative evaluation, the pre-design study included testing of site-specific NAPL properties, and bench-scale treatability studies of design parameters related to the thermal treatment of impacted site materials as well as stabilization and solidification applications.

August - November 2009 – ARCADIS performed the Phase 2 of Tier 2 assessment to further characterize soil geology and NAPL impact using Tar-specific Green Screening Tool (TarGOST®), and to characterize site hydrogeology by installing groundwater monitoring wells and conduct aquifer testing and sampling. A Tier 2 Report summarizing these results along with a comprehensive database of historical soil and groundwater data was submitted to SD DENR in December 2009.

1.3.4 Previous Interim Remedial Actions

As noted, concurrent with the site characterization activities, several IRAs have been implemented on- and off-site to mitigate risk and interrupt exposure pathways that were associated with the former MGP operations. These IRAs have systematically addressed multiple potential exposure routes by eliminating or significantly reducing the MGP related risks. Collectively, these efforts have led to the current site conditions, upon which the remaining risks are primarily concentrated on the six-acre NWE property and are controlled (fenced) from public access. These previous IRAs and regulatory activities are briefly described below:

Prior to 1989 – Since the observation of NAPL in sanitary sewer manhole and the POTW influent in 1980, the City of Aberdeen began to monitor the NAPL and sealed one sanitary sewer manhole near the Site using pipe joint compound which appeared to reduce the frequency of “creosote episodes” observed at the POTW.

April 1993 – A sanitary sewer line along 3rd Avenue NE (north of the Site) was cleaned, pressure tested, and tele-inspected by the City. Visual NAPL was not observed during this effort, and the inspection documented that the sewer line appeared to be intact. However, subsequently NAPL was observed in three manholes located on 3rd Avenue between Congress and Boyd Streets in May 1994.

July 2006 – NWE constructed a wastewater treatment system near the municipal water booster station immediately west of the Site, and began re-routing the NAPL and impacted groundwater from the booster station sump for on-site treatment via bag filtration and carbon adsorption with discharge to the municipal sanitary sewer. This system eliminated the discharge of NAPL and impacted groundwater into the storm sewer collection system that outfalls at Moccasin Creek. Details of this task were summarized in the Interim Remedial Action Completion Report submitted to SD DENR in January 2009.

November 2006 to July 2007 – ARCADIS, on behalf of NorthWestern Energy, completed remedial design and procurement to support a sediment excavation-oriented remedial action for a 2,000-foot linear reach of Moccasin Creek extending both upstream and downstream of the outfall extending from near the Site. A Remedial Action Plan was submitted to SD DENR documenting the design and required permitting (ARCADIS, 2007).

August to December 2007 - A sediment remedial action was performed at Moccasin Creek and consisted of removing a total of 12,000 tons of MGP-impacted sediment (i.e., sediment with total PAH concentration greater than 200 mg/kg) for off-site disposal at the Brown County Landfill. A Remedial Action Completion Report was submitted to the SD DENR in February 2008. The SD DENR issued a No Further Action Letter for the remediated Moccasin Creek area on March 28, 2008.

August 2008 – ARCADIS, on behalf of NorthWestern Energy, implemented a sewer rehabilitation program to isolate and prevent NAPL and impacted groundwater from infiltrating the 3rd Avenue / Boyd Street sanitary sewer pipeline and manholes. Details of this task were summarized in the Interim Remedial Action Completion Report submitted to SD DENR in January 2009.

1.3.5 Site Geology and Hydrogeology

1.3.5.1 Regional and Local Geology

Glacial drift deposits are approximately 150-200 feet thick at and near the Site, and consist of deltaic sediments, lacustrine sediments, and glacial till (Koch et al, 1976). Up to 35 feet of deltaic sediments deposited by the Foot Creek Delta are present directly under the Site. These sediments are reported to be primarily sandy silt near the edge of the ancient delta, becoming more gravel-rich near the center, and serve as a shallow groundwater-bearing zone near the Site.

Glacial till deposits are present beneath the sediments of the Foot Creek Aquifer, beginning approximately 30 feet below ground surface (bgs) in most areas. The till is generally composed of a medium- to dark-gray colored mixture of clay, silt, sand and gravel. It has extremely low hydraulic conductivity and is generally regarded as a confining layer. Consolidated deposits are present beneath the glacial drift in Brown County, including up to 320 feet of Pierre Shale, the uppermost bedrock formation near Aberdeen (Leap, 1986). The shale is thought of as impermeable, and is believed to rest conformably on the Niobrara Marl, a chalk deposit between 50 to 175 feet thick. Due to challenges experienced on multiple occasions while advancing soil borings into the till horizon, the exact thickness of glacial drift, and associated depth to bedrock, has not been determined at the Site.

Although there are three major aquifers in the glacial sediments of Brown County, none of them are mapped as being present beneath the Site (Koch et al, 1976). Three bedrock aquifers are also used as sources of water in Brown County; however, the depth to the uppermost of these aquifers is approximately 850 feet (Koch et al, 1976). The City of Aberdeen obtains its drinking water from the Elm River and nearby gravel pits located approximately six miles northeast and upgradient of the Site.

1.3.5.2 Site Stratigraphic Units

Site hydrostratigraphic units comprise geologic units of similar hydrogeologic properties (e.g., hydraulic conductivity); therefore, several geologic units can be grouped together as one hydrostratigraphic unit. The use of hydrostratigraphic units aids interpretation and simplifies the discussion of groundwater flow.

There are four principal hydrostratigraphic units beneath the Site (Figure 4):

- Topsoil and Fill (Organic Silt Loam) – varies in thickness, ranging from a thin surficial layer to a thickness of approximately 15 feet from the surface in or near the former gasholders, and is composed primarily of brown to black sand, gravel, cobbles, and silt commingled with wood, bricks, concrete, ash, metal, and other debris.
- Lacustrine (Silty Clay) – up to about twenty feet of dark brown to olive, organic-rich silty clay to clayey silt with traces of fine sand and peat. Discontinuous outwash lenses of up to a few inches thick are often found in this unit. This soil is typically moist with medium plasticity. This deposit directly underlies the topsoil and fill, and occurs throughout the area.
- Deltaic Alluvium (Sand and Gravel) – ranging from about one to four feet thick, this unit, known as the Foot Creek Delta deposit, is a saturated zone composed of poorly sorted olive-brown fine to coarse sand and gravel, with small percentages of silt. The alluvium underlies the lacustrine deposit and rests on glacial till.
- Glacial Till (Silty Clay) – the top of this unit is typically encountered about 25 to 30 ft bgs. This extremely dense deposit consists of gray silty clay to clayey silt, with trace fine sand, pebbles, and gravel. Deeper soil borings advanced at the Site indicate that the till contains intercalated outwash lenses in the form of poorly sorted gravelly sand layers that are nominally two feet or less in thickness. Based on consistent field observations, the glacial till is regarded as a confining layer which prevents the downward migration of NAPL from the overlying deltaic alluvium.

1.3.5.3 Hydrogeologic Setting

Understanding how groundwater moves beneath the Site is important, not only to help understand the fate of impacted groundwater, but also to help assess the mobility of MGP-related NAPL, such as coal tar. Such NAPL is typically only slightly denser than water; the specific gravity of the NAPL found at this Site has been measured to be between 1.034 and 1.105. Movement of NAPL at this density can be greatly influenced by hydraulic gradients. However, the topography of a confining layer on which NAPL resides may cause NAPL to migrate with gravity to lower elevations irrespective of the direction of a hydrologic gradient that may act in another direction.

While limited areas of perched groundwater are at times observed in outwash lenses within the lacustrine deposit, the deeper alluvium deposit represents an invariably saturated geologic horizon. Outwash lenses are present in many, but not all, soil borings completed to date, and the lateral extent of each outwash lens is expected to range only from hundreds to thousands of square feet. Conversely, the alluvium deposit is present throughout the Site and impacts to this stratum represent a primary concern from a migration perspective. The depth to this saturated zone is about 20 to 25 feet across the Site, with a potentiometric surface typically measured around 1290 feet amsl (ten feet bgs). Based on state hydrogeological reports, anecdotal reports, field observations, and measured water levels, the saturated zone has consistently exhibited artesian conditions. Groundwater elevations have routinely been noted to increase within open bore holes approximately ten feet above their confined elevations resulting in a static unconfined groundwater elevation only about ten feet below ground surface. Deeper bedrock aquifers are known to be under artesian conditions as well, and the source of pressure to these aquifers is believed to be associated with recharge from the Black Hills or Rocky Mountains, or leakage from deeper aquifers (Koch et al, 1976). Sanborn maps indicate the presence of an artesian well that was used as a water source for the MGP operations. Additionally, the geochemistry of groundwater sampled from the Foot Creek aquifer indicates a high dissolved salt content and the presence of elevated halogens, such as fluoride ion, which is consistent with a deep bedrock aquifer as opposed to a meteoric (precipitation-derived) source of groundwater. Groundwater from the Foot Creek Aquifer was also previously reported to be highly mineralized with naturally occurring solutes and is not potable (E&E, 1992).

A comparison of soil boring logs from the Site and Moccasin Creek, located ¾-mile east of the Site, indicates that the Foot Creek alluvium elevation is beneath Moccasin Creek by approximately fifteen feet, and appears to be hydraulically isolated from the creek by the overlying lacustrine silty clay. It is not known to which surface drainage, if any, the groundwater in the Foot Creek alluvium discharges.

The presence of artesian conditions at the Site has profound implications for deep excavation-oriented remedial options due to the potential for rapid, uncontrollable, and sustained inflows of highly mineralized groundwater into the excavation. Such an event would constitute a significant groundwater and wastewater management challenge. Moreover, if breached, re-establishing the confining cap to the aquifer could be problematic.

1.3.5.4 Groundwater Occurrence and Flow

As indicated above, groundwater potentiometric depths associated with the Foot Creek alluvium are typically recorded at approximately 10 to 15 feet bgs at the Site. Measured water elevations over several years appear to suggest a dynamic flow regime with directions ranging from west to east, east to west, and often times a “radially-outward” flow direction away from the Site. With generally flat gradients recorded, and an extremely flat local and regional topography, 2009 potentiometric data suggest that recent precipitation events and the operation of groundwater capture and discharge from the booster station sump west of the Site appear to have a noticeable impact on flow directions and gradients (ARCADIS, 2009). The hydraulic conductivities for the Foot Creek alluvium measured during aquifer testing at the Site in 2009 ranged from 0.16 to 10.96 feet per day, which correlates with the fine to coarse alluvium sand present at the Site (Fetter, 2001).

1.3.6 Nature and Extent of Environmental Impacts

The nature and extent of environmental impacts associated with the former MGP have been characterized and summarized below, based on the data collected through the phased investigations and the results of the IRAs. Locations of soil sampling and groundwater monitoring wells are depicted on Figure 5.

1.3.6.1 Soil

The nature and extent of MGP-related soil impacts at the Site have been characterized. It is evident that these impacts stem from the historic release of coal tar NAPL. Potential soil-based COCs associated with former MGP operations have been identified as BTEX and PAHs. However, based on risk-related consideration as further discussed in Section 2, remedial decisions are anticipated to be driven by the NAPL that is present in both shallow and deep soils.

The fate and transport of NAPL in the subsurface are two important aspects in evaluating soil remedial technologies. This evaluation examined those remedial technologies capable of addressing NAPL and its mobility in the subsurface. For purposes of remedial alternative evaluation, soil at the Site is further classified as "shallow soil" from ground surface to 15 ft bgs and "deep soil" with depths greater than 15 ft bgs. The "shallow soil" depth threshold of 15 feet was established by the ability to safely excavate from the surface with a conventional hydraulic excavator without the need to position the hydraulic excavator directly within the excavation. The shallow soil is above the saturated zone (alluvium) and consists primarily of fill materials and former MGP underground structure remnants within the lacustrine silty clay. Deep soil includes multiple general geologic layers: lacustrine soil, alluvium, and glacial till.

As shown in Figure 6, NAPL was observed in shallow soils generally on the southern half of the Site in discrete areas, including within gasometers 1 and 3. NAPL was also found in the shallow soil in an area west of the electrical substation on the northern portion of the Site. In the deep soil (greater than 15 ft bgs), NAPL was observed beneath much of the entire site footprint and the adjacent properties in all directions within an approximate radius of 500 ft from the site property boundaries. It is important to note that the quantity of NAPL present in shallow soil is significantly less than the quantity present in the deep soil. The relationship between the shallow and deep zones containing NAPL is depicted in Figure 6.

1.3.6.2 Groundwater

During initial phases of site investigation, groundwater quality was determined through the course of sampling on-site monitoring wells and various off-site locations consisting of structural sumps for groundwater or wells with undocumented construction details. As of August 2009, a network of discretely-screened perimeter groundwater monitoring wells is now in place, and the nature and extent of groundwater impacts associated with the historical MGP operation at the Site has been significantly improved. Using benzene as an indicator compound (due to its comparatively higher mobility and fate and transport characteristics), the plume of dissolved-phase impacts attenuates within a short distance of areas where NAPL has been observed (or modeled) to be present (Figure 7). This figure presents the modeled NAPL boundary along with a benzene concentration isopleth of five micrograms per liter (the federal maximum contaminant level for benzene in drinking water).

Groundwater quality in the shallow aquifer has been reported to be highly mineralized and not suitable as a potable water source (Koch and Bradford, 1976), and groundwater geochemistry measurements from several on-site wells have also confirmed that the shallow unconsolidated aquifer does in fact exhibit a very high dissolved solids content.

NAPL has been observed in several monitoring wells and soil borings and will continue to act as the main contributing source for dissolved-phase groundwater impacts. Consequently, and based on other risk-related considerations discussed in Section 2, groundwater remediation technologies evaluated in this RAE will focus on source (i.e., NAPL) control.

1.3.6.3 Free Phase NAPL

As described above, NAPL in soil and groundwater was the focus of this RAE in evaluating medium-specific (e.g., soil, groundwater) remedial technologies. For the purpose of screening remedial technologies, the recoverable portion or the free phase NAPL is considered as a "separate" medium in this RAE. Therefore, it should be understood that technologies and process options for remediating soil and groundwater also aid the remediation of NAPL in soil and groundwater.

Analysis of a NAPL sample collected from the Site in August 2009 reported a specific gravity of 1.105 and a viscosity of 431 centipoises at 51 degrees Fahrenheit (^{o}F) or 10.6 degrees Celsius (^{o}C), which represents the average groundwater temperature measured in the field during the August 2009 groundwater sampling event. These properties are consistent with the coal tar properties ranges found at other MGP sites where ARCADIS has provided technical consultation (Table 1). These data suggest that the NAPL at the Site tends to migrate downward as it is denser than water. The topography of a confining layer (such as the glacial till at this Site) on which DNAPL resides will cause DNAPLs to migrate with gravity to lower elevation. Conceptually, this behavior could result in the DNAPL migrating vertically downward until contacting the irregular erosional surface of the glacial till and then migrating laterally along this surface with its movement dictated by the local topography. Lateral migration could cease upon the DNAPL flowing into a confining erosional depression on the glacial till surface. Movement of NAPL at this density (i.e., only slightly denser than water) can also be influenced by hydraulic gradients, but it will flow with a much lower velocity, because the NAPL's viscosity is more than 300 times greater than that of water. However, soluble constituents of NAPL such as BTEX and lighter PAHs, and/or emulsified NAPL when present in groundwater, would have a much higher mobility than that of NAPL. The technologies for free phase NAPL remediation in this document are evaluated for their effectiveness and implementability in mass removal and/or minimizing or constraining the mobility of the free phase NAPL at the Site.

1.3.6.4 Sediment

MGP related sediment impacts in a stretch of Moccasin Creek were characterized and addressed successfully through a sediment removal action in 2007. A No Further Action Letter was issued by the SD DENR following the sediment remediation effort. Therefore, sediment impacts in Moccasin Creek associated with the former MGP operations have been eliminated and were not evaluated further as part of this RAE.

1.3.6.5 Utilities

NAPL was found in the sanitary sewer collection system near the Site, in storm sewers, and in the area of the storm sewer outfall at Moccasin Creek. The risk associated with the NAPL impacts to these sanitary and storm sewer pipes and sediments around the storm sewer outfall in Moccasin Creek have been addressed through IRAs including a sewer rehabilitation program, construction of an on-site wastewater treatment facility, and a sediment remedial action.

Operation and maintenance of the existing NAPL/groundwater collection and treatment system will continue to prevent impacted groundwater from discharging into the storm sewer system. MGP impacts to utilities on and around the Site have been generally mitigated or rendered under control and were not evaluated further as part of this RAE.

1.3.6.6 Soil Vapor

Over the course of several phases of characterization, NAPL has been delineated on- and off-site. Where subsurface NAPL has been determined to be in proximity to an occupied structure, soil gas testing has been performed to determine whether a potentially complete indoor inhalation pathway might exist for residents or workers. A multi-event soil gas survey was performed for the Golden Park Apartments property in 2006, with the finding that no complete exposure pathway was identified (ENTRIX, 2006A and 2006B). Low-level detections of VOCs were reported in shallow soil-gas stations adjacent to the building, while SVOCs were not detected. The VOC concentrations were well below target human health risks established by USEPA. Additionally, the natural shallow geology in the area (lacustrine silty clay) appears to substantially restrict air migration through the subsurface, as evidenced by the difficulty with which soil gas sample collection was accomplished at some locations. A similar survey is ongoing at this time for the Brown County property located south of the Site. As NWE wishes to maintain a proactive approach for assessing potential vapor intrusion for occupied structures on adjacent properties, potential indoor inhalation exposure will continue to be evaluated and addressed, if needed, in parallel and independent of the ongoing remedial management of the Site.

2. Conceptual Site Model and Remedial Action Objectives

This section describes the development of a conceptual site model (CSM) and site-specific remedial action objectives (RAOs).

2.1 Conceptual Site Model

SD DENR (2003) indicates that assessment of a release must provide information on the chemicals of concern and sources of contamination, transport mechanisms, receptors, exposure pathways, and exposure routes. With respect to potential pathways and receptors, the following information is relevant:

- location, depth, and construction of receptors or other potential pathways on the property and immediately adjacent to the property;
- potential receptors on the property and immediately adjacent properties;
- potential pathways that could transport the contaminants of concern from the source to the receptor;
- current and reasonably anticipated future use of the property, ground water, surface water;
- sensitive habitats where the release has occurred and the immediately adjacent properties; and
- potential for complete exposure pathways and impacts to receptors, such as vapor impacts to buildings or utilities and nearby drinking water wells.

According to USEPA, chemical exposure requires a source and mechanism of release, retention or transport medium, a point of exposure, and a route of exposure (USEPA, 1989). The risk of chemical exposure would not exist if one or more of these conditions are absent. For the purpose of this remedial alternative evaluation, a pathway for chemical exposure is defined to be “complete” when it is deemed to satisfy all attributes required for chemical exposure described above.

Only receptors that come into contact with the impacted soil or use impacted soil and groundwater resources can be exposed to site-related COCs. COCs are present primarily at depths beyond which ecological receptors would be exposed. There is no evidence or expectation that sensitive species or habitats are located on the Site or in the path of site materials that are located in the subsurface and/or may be migrating off-site (SDDGFP, 2010). For this reason, human receptors were the focus of the site risk management strategy. Accordingly, risk assessment and any site-specific target remediation goals are developed towards the protection of potential human receptors.

The Site and adjacent properties are located in a populated, developed setting within the City of Aberdeen. The Site property is zoned for Unrestricted Industrial use (I-2) (City of Aberdeen, 2008). No future changes to the zoning or use of the property are anticipated at this time. Adjacent properties are zoned for Industrial, Municipal, and Residential (Low-, Medium-, and High-Density) uses (City of Aberdeen, 2008).

The vast majority of the Site is vegetated vacant land. The buildings and structures associated with the former MGP have been razed, and the Site has been filled as necessary, graded, and revegetated. NWE currently operates the Site as an electric substation and gas regulating station. Currently, there exists one small gas operations shed on-site and workers are not staffed there on a regular basis. To discourage trespassing, the Site is currently surrounded with chain-link fence and barbed wire, and access gates are kept locked. NWE employees and contractors have not reported signs of unauthorized access or vandalism, suggesting that the fencing has provided adequately secure site control. The absence of any reported trespassing reflects the fact that the Site is essentially an open field without any specific objects of interest that might inspire active trespassing to be attempted.

There are no permanent or intermittent surface water bodies at the Site. All surface water runoff is expected to be intercepted by storm sewer inlets and migrate via the sewer directly into Moccasin Creek. Moccasin Creek continues its flow south until reaching its confluence with the James River.

Remaining waste materials associated with the MGP operations are confined to the subsurface. The existence of a surface soil cap that prevents exposure to the wastes at the Site was acknowledged by USEPA (USEPA, 1992); a cap that has been subsequently maintained.

Based on this information, a CSM was developed for this RAE that summarizes the historical source, affected media/secondary sources, transport mechanisms, exposure pathways, exposure routes, and potential receptors. This CSM, presented in Figure 8, reflects current conditions at the Site, i.e., conditions that remain after the completion of plant structure demolition, fill/regrading, and the IRAs discussed in Section 1.3.4. These activities addressed potential exposures to MGP wastes in surface soil, surface water, sediment, and utility structures. The CSM shown in Figure 8 provides the framework for evaluating those current potential exposure pathways that may pose unacceptable human health risks and the subsequent remedial considerations, and these elements are discussed in more detail below.

2.1.1 Historical Source

As presented in Section 1.3, the nature and extent of MGP impacts at the Site and associated fate and transport mechanisms are generally well understood based on the site data collected through several phased investigations and remedial actions. The primary source of environmental impacts at the Site originated from the multi-decade operation of the MGP where gas manufacturing by-products, primarily in the form of coal tar NAPL, were generated. Although the former MGP operations ceased in 1948, the NAPL has migrated into soil, groundwater, and utility structures through natural processes. No visually apparent surficial impact is present at the Site.

The COCs at the Site are typical of MGP residuals and include a mixture of volatile organic constituents VOCs, such as BTEX, and SVOCs including PAHs such as naphthalene and pyrene. The chemical properties of these constituents and the characteristics of the subsurface environment at the Site affect the persistence, transport, and potential for exposure to MGP residuals both on- and off-Site.

Given the presence of NAPL above and below the water table at the Site, groundwater near and downgradient of the NAPL can be expected to contain one or more of the most-soluble components of the NAPL (primarily BTEX and naphthalene). Groundwater near NAPL may also contain less soluble and less mobile compounds (generally higher-molecular-weight PAHs). In addition to the organic compounds discussed above, byproducts from MGPs can contribute inorganics (metals and sometimes cyanide) to groundwater. Elevated metal concentrations have only been observed in the off-site city wells adjacent to the 3rd Avenue sanitary sewer line. The groundwater samples were found to contain little to no cyanide, supporting the model that purifier wastes were not significantly released nor disposed on-site.

2.1.2 Affected Media / Secondary Sources

Sections 1.3.6.1, 1.3.6.2, and 1.3.6.3 identify free-phase NAPL as site-related waste, and subsurface soil and groundwater as environmental media affected by site-related wastes. Based on practical considerations such as limits of hydraulic excavators and presence of artesian conditions in the saturated zone, shallow subsurface soils (less than 15 feet bgs) and deep subsurface soils (more than 15 feet bgs) are considered separately as secondary sources in this CSM. Dissolved COCs in groundwater and NAPL are additional secondary sources.

2.1.3 Transport Mechanisms

Based on current knowledge regarding the distribution and behavior of NAPL and COCs at the Site, the physical transport pathways through which NAPL and COCs may be transported on- and off-site include the following:

- Leaching and ground water transport of dissolved phase COCs;
- Migration of free-phase NAPL; and
- Volatilization and enclosed space accumulation of COCs;

The transport associated with groundwater flow pathways would occur via infiltration/percolation, advective hydrogeologic gradients and/or diffusion through porous media as well as possibly via leaking into on-site utility lines and/or associated backfill.

The free-phase NAPL, while viscous, can flow under the influence of subsurface topography and groundwater movement. The distribution of a dense NAPL such as coal tar will be controlled by its molecular weight composition. Some degree of separation of the coal tar can be expected due to constituents having different molecular weights. Constituents with high molecular weights consisting of multiple benzene rings will tend to not migrate from the point of release; the migration being hampered both by the high viscosity of the coal tar and the low solubility of these constituents. Naphthalene and similar SVOCs will have an intermediate degree of migration. Lighter molecular weight constituents, such as the various VOCs, will tend to separate from the coal tar mass over time and can migrate more readily via groundwater advection and gaseous diffusion. The ongoing separation of relatively lighter molecular weight constituents tends to increase viscosity of the coal tar residual over time.

Transport via volatilization pathways would occur via volatilization of COCs in soil or groundwater into vapor within porous media. The relative concentration and volatility of a given COC influences the likelihood of its volatilization from affected media. Advection and/or diffusion through porous media could cause COCs to be released into outdoor air or to accumulate within enclosed spaces such as buildings located above areas with COCs present in the subsurface.

Because MGP residuals are confined to the subsurface, transport mechanisms that would affect surface soils (e.g., wind erosion, surface water run-off) are not expected to be significant exposure pathways at the Site.

2.1.4 Exposure Pathways and Exposure Routes

Direct contact with or ingestion of impacted soils or water would be possible only in the event that subsurface soils or groundwater were accessed or exposed via trenching, excavation, installation or maintenance of subsurface utilities, or similar invasive activities. In the event that direct contact with subsurface soils or groundwater were to occur, there would be the potential for exposure to COCs via oral (incidental ingestion), dermal, or inhalation routes.

Volatilization of COCs has the potential to affect outdoor and indoor air quality, as COC vapors that migrate out of the subsurface could be released into outdoor air or accumulate within overlying buildings. Under current conditions, these potential exposure pathways are limited because site factors, including the limited natural permeability of the subsurface soils, particularly the lacustrine silty clay, limit the diffusive flux.

Because of natural dispersion processes outdoors (e.g., wind), the potential exposure to COCs in outdoor air would be expected to be insignificant (i.e., at or below current background exposure levels). In contrast, it is possible that individuals could be exposed to chemicals in indoor air that have volatilized from contaminated soils and/or groundwater if they inhabit or use buildings that are constructed over these affected media. However, affected off-site groundwater and/or free-phase NAPL has been confirmed to pose a minimal risk with regard to potential volatilization of chemicals into buildings, as demonstrated by the soil gas characterization work for the Golden Park Apartment building northeast of the Site (ENTRIX, 2006a,b) and other off-site properties (ARCADIS, 2010a,b). This is likely due to the presence of the nominally 15-feet thick lacustrine silty clay stratum between the surface and the saturated zone where groundwater resides. This low-permeability stratum has been observed in all area borings, suggesting that vapor intrusion is unlikely to be a concern within other buildings on or adjacent to the Site below which MGP-related materials may be present. Note, however, that activities that disturb or expose the subsurface could result in enhanced volatilization of COCs presently contained there and could result in exposures that might be significant from a health risk perspective, even in outdoor air.

NAPL and COCs can continue to migrate off-site in the groundwater. Based on the termination of site operations approximately 60 years ago, the extent of NAPL has likely reached a steady state condition and the plume of COCs is not expected to expand appreciably. Groundwater samples obtained from the network of monitoring wells installed in 2009 indicates that COCs are attenuated within 200 feet of the NAPL plume boundary (Figure 7). The City of Aberdeen obtains its municipal water from the Elm River and nearby gravel pits, at least six miles upgradient of the Site. No aquifers used for drinking water are present beneath the Site (E&E, 1992). No known use of shallow groundwater for drinking water has been confirmed within a four mile radius of the Site, and this shallow groundwater is known to be naturally highly mineralized and undrinkable (URS, 2002). The nearest private wells are located ¼ mile southwest and northwest of the Site, and the nearest downgradient wells are three to four miles southeast of the Site (URS, 2002). These private wells are believed to be screened in deeper, more productive water-bearing zones beneath the glacial till. There are no known hydraulic connections between the Foot Creek Aquifer beneath the Site and deeper unconsolidated or consolidated aquifers in Brown County. Therefore, exposure to groundwater, including groundwater ingestion, is not currently viewed as a complete exposure pathway.

2.1.5 Potential Receptors

The CSM identifies nearby residents, on-site construction/utility workers, and off-site indoor workers as potential receptors. Under current conditions and reasonably anticipated future use of the Site and adjacent properties, however, none of these potential receptors is expected to experience significant exposure to NAPL or COCs.

Direct exposure by trespassers to subsurface soil at the Site is minimized by the fact that the Site has controlled access via a chain-link fence and barbed wire. Some nearby residential property and the park may overly regions of the subsurface affected by MGP residuals. Because of the depth at which affected media are located off-site, routine residential activities, e.g., gardening, that involve digging in soil would not be expected to result in direct contact with COCs or to significantly increase the amount of COCs volatilized and released.

NWE employees and contractors only occasionally work on-site, but any such work is typically for short durations. NWE employees do not routinely, if ever, conduct trenching activities on the Site. Accordingly, under current conditions, exposures to NAPL and COCs by workers or trespassers via ingestion, dermal contact, and inhalation are expected to be minimal for all on-site exposure pathways.

While unlikely, the Site could be subjected to redevelopment and/or construction. To the extent that these future activities might involve excavation or trenching, exposure to NAPL and/or COCs in soil and/or groundwater could potentially occur at that time.

Rehabilitation of the 3rd Avenue NE sanitary sewer pipeline and manholes has been completed, which limits the possibility that city workers might come into contact with NAPL or COCs that may have entered the sewer collection system. A bypass of the municipal Booster Station sump discharge to the storm sewer has also eliminated the potential for city workers to encounter site wastes in the storm sewer leading to Moccasin Creek.

Some nearby commercial and industrial property overlies regions of the subsurface affected by NAPL and COCs in groundwater. Because of the depth at which affected media are located off-site, uses of these properties that involve digging in shallow soil would not be expected to result in direct contact with COCs. Indoor workers could potentially be exposed to COCs that volatilize and accumulate in buildings; however, soil gas monitoring conducted to date indicates that this is an incomplete or insignificant pathway (ENTRIX, 2006a,b and ARCADIS, 2010a,b).

2.2 Remedial Action Objectives

To address the potentially complete exposure pathways through remediation, the remedial alternatives need to be developed to meet Remedial Action Objectives (RAOs). According to the RI/FS Guidance (USEPA 1988), RAOs for a site represent medium-specific goals for the protection of human health and the environment. The baseline evaluation of human health exposure described above and in Figure 8 suggests that control of NAPL and prevention of impacted groundwater be the focal considerations in adopting a comprehensive remedial alternative. NWE will also conduct site-specific assessments to address potential vapor intrusion situations where NAPL or significant COC concentrations are documented on properties with occupied structures, and these efforts and costs will be provided for outside of the scope of this document. Therefore, the RAOs for the Site have been developed to address specific media of concern described above and the associated potentially complete exposure pathways. The RAOs are as follows:

- Limit, to the extent practicable, the potential for human exposure to on-site NAPL-containing shallow soil (0 to 15 ft bgs);
- Limit, to the extent practicable, the potential for human exposure to on-site NAPL-containing deep soil (> 15 ft bgs);

- Limit, to the extent practicable, the potential for human exposure to NAPL and COCs beneath and near the Site including in the vicinity of subsurface utilities;
- Limit, to the extent practicable, the further migration of free-phase NAPL on- and off-site;
- Limit, to the extent practicable, the potential for human exposure to groundwater impacted by NAPL beneath and near the Site.

It should be noted that these site-specific RAOs focus on source control (i.e., NAPL) and do not target achievement of any specific numeric federal- or state-specified chemical cleanup levels.

3. Approach for Evaluating Potential Remedial Alternatives

This section describes the approach for developing and evaluating potential remedial alternatives.

The evaluation of the potential alternatives follows the general framework of the RI/FS Guidance (USEPA, 1988) and focuses on those technologies that are appropriate for addressing the MGP impacts identified through the site characterization activities. The potential remedial alternatives are developed to meet the RAOs by addressing one or more of the components of the potentially complete exposure pathways as described in Section 2.

The initial step for evaluating potential remedial alternatives is to develop possible general response actions (GRAs) to address impacted media identified for the Site. It should be noted that the GRAs are developed with the consideration of site conditions and are not meant to be exhaustive and encompassing of all available remedial technologies.

For each GRA, a series of technology types and associated process options were identified. According to the RI/FS Guidance (USEPA, 1988), the term “technology types” refers to general categories of technologies. The term “technology process options” refers to specific processes within each technology type. For example, NAPL recovery could be a technology type, with active and passive recoveries as technology process options. The GRAs and remedial technologies evaluated for the site media are presented in Section 4.

Each identified technology type and process option is then briefly described, and is evaluated against preliminary technology screening criteria (effectiveness, implementability and relative cost) relying on past experience at this and other sites and professional judgment. This approach was used to determine if a particular technology type or process option is applicable given the site-specific conditions for remediation of the impacted media. Based on this screening, remedial technology types and process options were eliminated or retained. The screening of technologies and process options is presented in Section 5.

The retained technology and associated process options are subsequently assembled into potential remedial alternatives for further evaluation in Section 6. Each potential alternative is then evaluated using the following nine criteria identified in the Code of Federal Regulations (CFR) Part 300 National Oil and Hazardous Substances Pollution

Contingency Plan or National Contingency Plan (NCP) and RI/FS Guidance (USEPA, 1988), plus a tenth criterion that ARCADIS has included to incorporate green remediation decision-making:

1. Overall Protection of Human Health and the Environment

2. Compliance with ARARs

3. Long-term Effectiveness and Performance

4. Reduction of Toxicity, Mobility, or Volume through Treatment

5. Short-term Effectiveness

6. Implementability

7. Cost

8. State Acceptance

9. Community Acceptance

10. Green Remediation/Sustainability Considerations

The assembly and evaluation of remedial alternatives is presented in Section 6.

Based on the result of the remedial alternatives evaluation, a remedial alternative is proposed in Section 7 that is most appropriate to achieve the RAOs.

4. Development of Possible General Response Actions

This section describes the development of possible GRAs for each medium of concern to attain the RAOs through addressing the source material associated with the former MGP operations at the Site.

4.1 General

Consistent with the RI/FS Guidance (USEPA, 1988), GRAs are medium-specific and may include various actions, such as institutional controls, containment, treatment, removal or a combination of such actions. The possible GRAs for the Site are developed to address MGP-related sources containing COCs (consisting of BTEX and PAHs) and the associated media including shallow soil (0 to 15 ft bgs), deep soil (greater than 15 ft bgs), free phase NAPL, and groundwater.

4.2 Possible General Remedial Actions

Based on the RAOs identified in Section 2.3, the following possible site-specific GRAs are considered for each medium of concern. A "no further action" GRA has been included and retained through the preliminary screening as required by the USEPA and NCP guidance.

- No further action
- Institutional control
- Monitoring (groundwater medium only)
- *In-situ* containment
- Removal
- *In situ* treatment
- *Ex situ* treatment

4.3 Identification of Remedial Technologies

Remedial technology types that are potentially applicable for addressing the impacted media at the Site were identified through a variety of sources, including vendor information, engineering experience and review of available literature that included the following documents:

- Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA, 1988)
- Technology Screening Guide for Treatment of CERCLA Soils and Sludges (USEPA, 1988)
- Remediation Technologies Screening Matrix and Reference Guide (USEPA and United States Air Force, 2002)
- Management of Manufactured Gas Plant Sites (Gas Research Institute, 1996)
- Federal Remediation Technology Roundtable (FRTR online sources at website address: http://www.frtr.gov/default.htm)

According to the RI/FS Guidance, technology types and process options can be identified by drawing on a variety of sources, including regulatory references and standard engineering texts not specifically directed toward impacted sites (USEPA, 1988). Although each former MGP site offers its own unique site characteristics, the evaluation of remedial technology types and process options that are applicable to MGP-related impacts, or have been implemented at other MGP sites, is well documented. Therefore, this collective knowledge and experience and regulatory acceptance of previous feasibility studies performed on MGP-related sites with similar impacts was used to reduce the universe of potentially applicable remedial technology types and process options for the Site to those with documented success in achieving similar RAOs.

The medium-specific GRAs, technology types, and process options are presented in Table 2 and are described in Section 5 in detail.

5. Technology and Process Option Screening

This section presents a preliminary screening of the technologies and process options to identify those that warrant further evaluation for use at the Site.

5.1 Preliminary Technology Screening

Possible GRAs include general categories of technology types (for example, “containment” is one type of technology), which may include one or more process options that could be applied at the Site (for example, “surface capping” or “vertical impermeable wall”). GRA types, their associated remedial technologies, and process options have been identified for the four media of concern (shallow soil, deep soil, free phase NAPL, and groundwater). In addition, auxiliary technologies and process options that could be applied to manage removed or recovered materials have also been identified (Table 2). The screening process for each medium of interest is described below.

In general, the screening process evaluates each technology type and process option based on technical implementability, effectiveness and relative costs to eliminate those technologies/process options that are not appropriate based on the current understanding of site conditions, the chemical/physical characteristics of the media of concern, or that have not been successfully applied on a full-scale basis at other MGP-impacted sites. This screening is performed by applying general knowledge and experience gained at this and other sites, using information available in the literature and professional judgment.

The following sections describe the identification and the screening process conducted for the technologies and process options to address MGP related impact sources (i.e., NAPL) at the Site, as well as those auxiliary process options for addressing removed or recovered soil, NAPL or groundwater. For those technologies that have multiple process options, a separate subsection is included to present the screening results for the individual process options to identify those that have been retained for further consideration.

Each of these possible GRAs technologies or process options is described briefly below. The highlights of their effectiveness, implementability, and relative costs are presented in Table 2. The preliminary screening results for each of the technology process options are expressed as either “retained “or “not retained.” Those retained technologies or process options are carried over to be assembled into potential remedial alternatives for the Site and are further evaluated in Section 6.

5.1.1 Possible GRAs for Source Material in Shallow Soil (0 to 15 ft bgs)

To address the NAPL in the shallow soil at the Site, the following GRAs are considered, and their associated technologies/process options are screened:

No Further Action - The “no further action” GRA would not include any active or passive remediation in addition to those IRAs that have been implemented and are ongoing at the Site, such as site maintenance and operation of the wastewater treatment system near the municipal Booster Station. It would recognize the changing conditions as natural attenuation of MGP constituents occurs, but would not include any long-term monitoring or controls. Because this option would not be effective in reducing NAPL in shallow soil, it was not retained for further consideration.

Institutional Control - Institutional controls are physical, legal, and/or administrative controls that would be non-intrusive and focus on minimizing potential contact with source material in shallow soil. These controls can be used, alone or in combination, to restrict access to portions of the Site and/or to initiate and maintain appropriate uses that mitigate the potential for future exposure to NAPL during and after remedy implementation. Institutional controls to address soil impacts can include access restrictions (such as fences and signs), construction worker precautions during excavation, and land use restrictions.

Institutional controls can be used at all stages of the remedial process to mitigate the potential for exposure to impacted soil. They are often used in conjunction with other GRAs (e.g., soil removal, containment) both during and following remedy implementation. Institutional controls such as perimeter fencing have been implemented at the Site to control and minimize the exposure potential to soil impacts by potential receptors. Thus, institutional controls have been retained for further consideration.

Containment - This technology type involves the placement of a physical barrier over source material to address potential contact with or the mobility of NAPL in impacted soils (e.g., via infiltration, erosion) without removal or treatment. Two types of containment process options are considered in the preliminary screening process:

Permeable cover involves placing a simple soil cover over the impacted soils to prevent direct contact with and erosion of impacted soils.

Low-permeability engineered barrier involves installation of a relatively low permeable barrier such as pavement over the underlying impacted soils to prevent direct contact with, erosion of, or infiltration of surface water through impacted soils.

The NAPL in shallow soil at the Site is generally concentrated in and around the former MGP structures (e.g., gasometers) and several discrete areas. Overall, the top layer of site soil does not pose human health risk and can act as a permeable soil cover for preventing potential exposure by direct contact. Further, the degree and extent of source material in shallow soil is limited relative to that of source material in deep soil and there is little benefit of constructing a low-permeable barrier when compared to that of the existing permeable soil cover. Therefore, the containment technology and associated process options have not been retained for further consideration.

Removal – This technology type involves removal of source material in shallow soil in targeted areas or contents of former MGP structures and replacement of the removed soil or materials with clean backfill. The removed materials would subsequently undergo on-site *ex situ* treatment, transport, and off-site disposal. This technology can reduce, to some extent, the volume of source material and has been retained for further consideration.

***In situ* Treatment** - This technology type involves altering the characteristics of NAPL-containing shallow soil to address mobility and/or exposure without significant removal. Several types of *in situ* treatment are considered in the preliminary screening process including:

Physical treatment is achieved by mixing an immobilization agent into the soil to reduce the mobility of NAPL in the soil.

Chemical treatment is achieved by introducing chemical agents such as oxidants or surfactants/solvents into the impacted medium to remove or destroy COCs either by injection, physical mixing with a chemical, or placement of a reactive barrier.

Biological treatment is applied by introducing microorganisms and/or nutrients into the impacted medium to increase ongoing biodegradation rates of COCs in soils.

Thermal treatment is accomplished by introducing steam or otherwise raising the temperature of the impacted medium to enhance the mobility and recovery of NAPL and COCs in soil.

Because of the relatively small proportion of source material in shallow soil compared to that in deep soil, the effectiveness of *in situ* physical, chemical, biological, and thermal treatments alone would be limited in addressing the overall source at the Site. In addition, introduction of immobilization agents would increase the waste volume and subsequent material management of associated emissions and overall cost. The success of *in situ* chemical and thermal treatments rely on effective chemical or steam delivery which would be limited due to the fill nature of the shallow soil at the Site consisting of varying amounts of debris and subsurface historical structures or utilities. *In situ* biological treatment is typically more effective for treating low to moderate concentrations of COCs, but not effective for treating NAPL. For these reasons, the *in situ* treatment technology type has not been retained for further consideration.

***Ex situ* Treatment** - This technology type involves treatment of MGP impacted shallow soil after removal to address the mobility and/or potential exposure after the soils are removed from the ground. Several types of *ex-situ* treatment are considered in the primary screening process including:

Physical treatment is achieved by mixing an immobilization agent with the excavated impacted soil to render it such that the mobility potential of NAPL and associated COCs in the soil is reduced. The treated soil is either used as backfill upon approval or disposed off-site. Physical treatment may also include addition of reagents or, for example, drying agents, to meet disposal requirements involving prevention of the release of drainable water during soil handling and transportation.

Chemical treatment is achieved by mixing chemical agents such as oxidants or surfactants/solvents with the excavated impacted soil to remove or destroy COCs by mixing physically with a chemical for on-site reuse or off-site disposal.

Biological treatment is applied by introducing microorganisms and/or nutrients into the impacted soil to enhance ongoing biodegradation rates of COCs in soils. The treated soil is typically transported for off-site disposal.

Thermal treatment is accomplished by introducing steam to or raising the temperature of the impacted medium to enhance the mobility and recovery of NAPL and associated COCs in soil. The treated soil or large portion of it is used as backfill. The remaining treated soil is transported for off-site disposal.

Physical treatment may be applied to render removed source material to a level that is acceptable for reuse or off-site disposal. *Ex situ* chemical, biological, and thermal treatment may be effective in COC concentration reduction; however, their requirements for screening and potential pretreatment of over-size material, physical space demand for equipment setup and operation, minimum volume requirement, achieving regulated stack emissions, ensuring completion of the remedial process during one construction season, and relative high costs pose significant challenges from implementability and cost-effective perspectives at this site. However, some of these technologies such as thermal treatment could be applicable if implemented at an off-site location. The *ex situ* technology type of physical treatment has been retained for further consideration. On-site *ex situ* technology types of chemical, biological, and thermal treatments have not been retained for further consideration.

5.1.2 Possible GRAs for Source Material in Deep Soil (> 15 ft bgs)

To address source or NAPL in the deep soil at the Site, the following GRAs are considered, and their associated technologies are screened:

No Further Action - The "no further action" GRA would not include any active or passive remediation in addition to those measures that have been implemented at the Site. It would recognize the changing conditions as natural attenuation of COCs occurs, but would not include any long-term monitoring or controls. Because this option would not address NAPL in deep soil, it was not retained for further consideration.

Institutional Control - Institutional controls are physical, legal, and/or administrative controls that would be non-intrusive and focus on minimizing potential contact with NAPL-containing soil. These controls can be used, alone or in combination, to restrict access to portions of the Site and/or to initiate and maintain appropriate uses that mitigate the potential for future exposure to NAPL and associated COCs during and after remedy implementation. Institutional controls to address soil impacts can include access restrictions (such as fences and signs), construction worker precaution during excavation, and land use restrictions.

Institutional controls can be used at all stages of the remedial process to mitigate the potential for exposure to impacted soil. They are often used in conjunction with other GRAs (e.g., soil removal, containment) both during and following remedy implementation. Institutional controls such as perimeter fencing have been implemented at the Site to control and minimize the exposure potential to soil impact by receptors. Thus, institutional controls have been retained for further consideration.

Containment - This technology type involves the placement of some type of physical barrier over source material in deep soil to address the mobility without removal or treatment. Two types of containment process options are considered in the preliminary screening process including:

<u>Permeable cover</u> involves placing a simple soil cover over the existing soils,

Low-permeability engineered barrier involves installation of a relatively low permeable barrier such as pavement over the underlying impacted soils to prevent direct contact and minimize downward transport of COCs in soil through infiltration.

Overall, the top layer of site soil does not pose a human health risk and can act as a soil cover for preventing potential exposure to the deep soil by direct contact; therefore, this technology has not been retained for further consideration.

Removal – This technology type involves removal of NAPL-containing deep soil and replacement of the removed soil or materials with clean backfill. The removed materials subsequently undergo transport and off-site disposal or *ex situ* treatment.

As noted above, the Site has a limited footprint constrained by its triangular shape and the presence of many utilities and permanent structures (water storage tanks, electrical substation, and two active rail lines) that are sensitive to ground instability.

These factors combine to constrain the safe and efficient implementation of a deep and large scale excavation. The cost, logistical challenges, vibration, and noise disturbance for perimeter sheet piling (estimated to be approximately 3,000 linear feet that would be installed to a 90 foot depth) would be significant. Without sheet piling, the required sloping of the highwalls would require a large footprint of NAPL and source material to remain in place. As discussed in Section 1, the potential for encountering artesian flow conditions at the Site is another complicating and possibly deciding factor against attempting to implement a deep excavation-oriented approach, as artesian pressured water inflows into the excavation could lead to highwall instability. The presence of obstructing surface obstacles also prevents the complete removal of NAPL and source material in deep soil even under the most aggressive excavation approach possible. For these various reasons, this technology has not been retained for further consideration.

***In situ* Treatment** - This technology type involves altering the characteristics of impacted soil to address the mobility and/or exposure without significant removal. Several types of *in-situ* treatment are considered in the preliminary screening process including:

Physical treatment is performed by mixing an immobilization agent into the soil to reduce the mobility potential of COCs in the soil.

Chemical treatment is accomplished by introducing chemical agents such as oxidants or surfactants/solvents into the impacted medium to remove or destroy COCs either by injection, mixing physically with a chemical, or placement of a reactive barrier, Biological treatment is performed by introducing microorganisms and/or nutrients into the impacted medium to increase ongoing biodegradation rates of COCs in soils, and

Thermal treatment involves introducing steam or otherwise raising the temperature of the impacted medium to enhance the mobility and recovery of NAPL and COCs in soil.

Because NAPL-containing deep soil is present beneath the entire Site and extends off-site (Figure 6), the implementability of *in situ* physical, chemical, biological, and thermal treatments would be limited by physical access both on-site and off-site. In addition, the use of immobilization agents would greatly increase the waste volume and subsequent material management of associated emissions and overall costs. The success of *in situ* chemical and thermal treatments rely on effective chemical or steam delivery which would be limited by the subsurface conditions. *In situ* biological treatment is typically not effective for treating NAPL. Lack of specialized equipment availability, significant time and reagent requirements, and impacts to local hydrology are other likely limitations. For these reasons, the *in situ* treatment technology type has not been retained for further consideration.

***Ex situ* Treatment** - This technology type involves treatment of excavated MGP impacted soil to address the mobility and/or exposure after the soils are removed from the ground. Due to the potential challenges at the Site associated with massive deep soil excavation discussed previously, ex situ treatment following deep soil excavation is not recommended for the Site. Therefore, the *ex situ* treatment coupled with removal is not considered for deep soil and this technology type has not been retained for further consideration.

5.1.3 Possible GRAs for Free Phase NAPL

To address free phase NAPL in the soil or groundwater at the Site, the following GRAs are considered, and their associated technologies are screened:

No Further Action - The "no further action" GRA would not include any active or passive remediation in addition to those measures that have been implemented at the Site. Because a no further action approach would not address NAPL at the Site, it was not retained for further consideration.

Institutional Control - Institutional controls are physical, legal, and/or administrative controls that would be non-intrusive and focus on minimizing potential contact with NAPL. These controls can be used, alone or in combination, to restrict access to portions of the Site and/or to initiate and maintain appropriate uses that mitigate the potential for future exposure to NAPL during and after remedy implementation. Institutional controls to address NAPL impact can include access restrictions (such as fences and signs), land use restrictions, and groundwater ordinances.

Institutional controls can be used at all stages of the remedial process to mitigate the potential for exposure to NAPL. They are often used in conjunction with other GRAs (e.g., soil removal, containment) both during and following remedy implementation. Institutional controls such as perimeter fence have been implemented at the Site to control and minimize the exposure potential to soil impact by receptors. Thus, institutional controls have been retained for further consideration.

Containment - This technology type involves the placement of some type of vertical physical barrier to address the mobility and/or exposure to NAPL with or without hydraulic controls. Two types of technologies are considered in the preliminary screening process including:

Permeable barrier involves installation of a vertical barrier at strategic locations and depths using permeable material without hydraulic control to reduce the lateral movement of NAPL while allowing natural groundwater to flow through.

Low-permeability barrier involves installing a vertical barrier at strategic locations and depths using low-permeability material to retard the movement of NAPL with hydraulic control coupled with the removal of free phase NAPL and limited amount of impacted groundwater.

Because NAPL has migrated off-site, this technology would not be effective for containing the portion of NAPL that is already present beyond the property boundaries. This technology has not been retained for the secondary process option screening.

Removal (NAPL Recovery) – This technology type involves physically removing free phase NAPL through passive means (bailing or manual pumping) or active means to remove or recover NAPL.

Passive NAPL Recovery is achieved by removing free phase NAPL manually in batch modes using a pump or a bailer from one or more collection points (collection galleries). The recovered NAPL subsequently undergoes transport and off-site disposal or beneficial use.

Active NAPL Recovery is achieved by extracting free phase NAPL with groundwater continuously through a pump-and-treat approach. The removed NAPL and groundwater subsequently undergoes separation using an on-site facility. NAPL is then transported for off-site disposal or beneficial use. Groundwater is treated and discharged to the POTW, storm sewer, or an infiltration gallery/injection well(s).

The passive NAPL recovery technology process option has been retained for further consideration. The active NAPL recovery technology process option has not been retained for further consideration due to its long-term operation and maintenance requirements, relative high cost, and high energy consumption.

***In situ* Treatment** - This technology type involves altering the characteristics of NAPL to address the mobility and/or exposure without removal. Because the majority of NAPL is present in deep soil, the evaluation discussion (Section 5.1.2) for this technology type in deep soil also applies to managing the free phase NAPL. In addition, an Electrical Resistive Heating technology option was also evaluated. With this technology, NAPL/groundwater is extracted by introducing steam or otherwise raising the temperature of the NAPL-containing subsurface. The application of this technology at the Site brings logistical challenges and considerations including geohydrological considerations, safety considerations, space requirements, energy consumption, and long-term operation, maintenance, and recovered material management issues. For the reasons discussed above and previously in Section 5.1.2, the *in situ* treatment technology type has not been retained.

***Ex situ* Treatment** - This technology type involves treatment of NAPL to address the mobility and/or exposure after the NAPL is recovered from the ground. The recovered NAPL is anticipated to be disposed of or beneficially used if possible, and no NAPL treatment is anticipated to be necessary prior to its off-site disposition. Therefore, this technology type has not been retained.

5.1.4 Possible GRAs for Groundwater

To address NAPL-containing groundwater at the Site, the following GRAs are considered, and their associated technologies are screened:

No Further Action - The “no further action” GRA would not include any active or passive remediation in addition to those measures that have been implemented at the Site. It would recognize the changing conditions as natural attenuation of COCs occurs in groundwater, but would not include any long-term monitoring or controls. Because no further action would not address NAPL-containing groundwater, it was not retained for further consideration.

Institutional Control - Institutional controls are physical, legal, and/or administrative controls that would be non-intrusive and focus on minimizing potential contact with

COCs. These controls can be used, alone or in combination, to restrict the use of groundwater beneath the Site and surrounding areas for potable purposes such as imposing a groundwater use ordinance. Institutional controls are retained for further consideration.

Monitoring - Long-term groundwater monitoring involves periodic measurements of water elevations and sampling of COCs. As long as NAPL remains in the subsurface, it will serve as a constant source for dissolved-phase groundwater impacts. For this reason and the fact that it is not practicable to completely remove all NAPL from the Site, impacted groundwater will remain at the Site. However, the Site's operational history is such that dissolved-phase groundwater impacts have likely been present for over 100 years, and are expected to be at or near a steady-state condition. Groundwater analytical and potentiometric data from off-site monitoring wells (outside of the zone of NAPL) installed in 2009 confirm the presence of several off-site locations where concentrations of COCs were below laboratory reporting limits of one microgram per liter (µg/L). This suggests that the dissolved-phase groundwater plume appears to be stable in several of these outlying areas. Long-term groundwater monitoring will serve to monitor plume stability and any changing groundwater flow conditions, and has been retained for further consideration.

Containment - This technology type involves the placement of some type of vertical physical barrier to address the mobility and/or exposure to impacted groundwater with or without hydraulic controls. Because the plume of impacted groundwater is stable and has migrated off-site, the implementability and effectiveness of this technology type is limited. For this reason, this technology type has not been retained for further consideration.

Removal (Pump-and-Treat) – This technology type involves physically removing NAPL-containing groundwater through active means to remove or recover NAPL and groundwater. The recovered NAPL subsequently undergoes separation, transport and off-site disposal or recycling while the groundwater is treated and discharged to the POTW, storm sewer, or infiltration/injection into the subsurface. NAPL and source material will form a large source of COCs to the groundwater for a prolonged period of time. Pump and treat approaches have been shown to be unable to achieve groundwater clean-up standards in the presence of NAPL and therefore this technology has not been retained for further consideration due to its long-term operation and maintenance requirements, relative high cost, and high energy consumption.

***In situ* Treatment** - This technology type involves altering the characteristics of NAPL in groundwater to address the mobility and/or exposure without removal. Because the majority of the NAPL is present in deep saturated soil, the evaluation discussion for this technology for deep soil (Section 5.1.2) and NAPL (Section 5.1.3) also applies to managing the NAPL-containing groundwater. For the same reasons, the *in situ* treatment technology type has not been retained for remediating groundwater.

***Ex situ* Treatment** - This technology type involves treatment of impacted groundwater to address the mobility and/or exposure after the groundwater is extracted from the ground.

These process options rely on the groundwater removal technology which was not retained; therefore, the *ex situ* treatment technology type has not been retained for further consideration.

5.1.5 Other Technologies for Managing Removed or Recovered Materials

Should the site remedy involve the removal of MGP-impacted materials (e.g., excavation), the removed material (i.e., soil, free phase NAPL or groundwater) will likely require processing and handling for proper treatment and disposal. The following technologies in addition to those GRAs discussed above are considered and screened for managing removed or recovered materials:

Solids Dewatering – Solids dewatering would likely be needed to remove excess water from removed saturated soils to facilitate their handling, treatment, and disposal. Dewatering is typically performed using some combination of mechanical and/or gravity-assisted techniques, which are briefly described below:

- <u>Mechanical dewatering</u> is accomplished by blending wet soil with bulking agents such as fly ash, quicklime (calcium oxide), or wheat straw, which is locally available and was successfully employed during the Moccasin Creek IRA.
- <u>Gravity dewatering</u> typically involves allowing the removed wet soil to settle and consolidate on a lined, bermed pad or other device to allow liquids to decant and be collected.

Mechanical and gravity dewatering techniques have been successfully applied at a number of sites. Both solid dewatering technology process options have been retained for further consideration.

Stormwater Management – Stormwater would likely need to be managed in the vicinity of where NAPL-containing soils are being removed or treated. Stormwater management is typically performed using a combination of diversion techniques and collection with treatment, as briefly described below:

- Collection with treatment involves capturing stormwater that has potentially contacted MGP-impacted soil using a combination of collection devices and water treatment. These process options are usually required during construction activities to prevent the mobilization of COCs from impacted source material.
- Diversion involves directing stormwater away from impacted source material that has been removed for processing and disposal to prevent the stormwater from becoming impacted. Examples of diversion techniques include straw bale dikes, silt fencing, etc.

Stormwater collection, treatment and diversion techniques have been successfully applied at a number of sites, and have been retained for further consideration.

Process Water Management – The processing of removed groundwater or wet soil may require additional treatment to achieve a water composition compatible with discharge to the local POTW or to a nearby surface water body such as Moccasin Creek.

Water treatment processes may be required for the control of particulate or soluble constituents, or both. Particulate constituents are typically removed by gravity settling and multimedia (sand and anthracite) filtration. Chemical treatments (coagulants and/or flocculants) may be added before settling and filtration to enhance the removal of solids. These chemical treatments may also remove some dissolved constituents by adsorption (e.g., granular activated carbon). This technology type has been retained for further consideration.

Oversize Material and Debris – With any excavation–oriented approach, oversize material consisting of rocks and cobbles (greater than three inches in diameter) and debris in the form of pipes, wires, and concrete blocks will likely be removed and require special handling in preparation for disposal. NAPL-coated material within this waste category will be mixed with a solid amendment such as Portland cement to form a protective coating on the surface of this material, thereby facilitating safe handling and disposal.

Transportation – Transportation would be required to move excavated soil or other materials from the areas of the Site to a nearby processing facility. This pre-processing transport will likely take the form of on-site trucking or the use of a front end loader.

Processing may involve water removal and addition of solidification or stabilization amendments to the removed soil, oversize material and debris. These processed solids would then be transported to a final disposal location. The selected forms and routes of transportation will depend on the waste type, disposal site location, existing transport routes, and economic factors. Although this transportation component will have implications to the community in terms of additional traffic and noise impacts, it has been retained.

Off-site Disposal – Permitted off-site facilities may be used for disposing of soil or NAPL removed from the Site in conjunction with removal or containment activities. Pre-disposal material rendering (e.g., solidification) may be necessary. Off-site disposal is one of the most commonly used methods for final disposition of removed soil from remediation projects throughout the United States. Whereas MGP wastes are exempt from the Toxicity Characteristic Leaching Procedure (TCLP) test to determination as to its classification as a hazardous waste, it is not exempt from other Resource Conservation and Recovery Act (RCRA) criteria as to its classification as a hazardous waste and other waste acceptance criteria applicable to a specific landfill. The local Brown County landfill, which was the repository used for excavated sediments from Moccasin Creek, is the preferred landfill due to its proximity to the Site. For purposes of this evaluation, it is assumed that Brown County Landfill will be able to accept MGP-related waste at its facility under the nonhazardous designation granted by SD DENR (SD DENR, 2009); however, the inability of the landfill to accept excavated material would have significant cost, schedule and implementability implications to excavation-based remedial options. Thus, off-site disposal has been retained for further consideration.

Beneficial Use – The beneficial use option would involve treating the removed material and then using it in beneficial ways, such as cover material for solid waste landfills, burning for energy recovery, or converting it into useable products such as cement, light-weight aggregate, or asphalts. For the beneficial use option to be effective, the removed material would likely require additional treatment to meet beneficial use standards. The type and level of treatment necessary would depend on the future beneficial use of the material.

NAPL may be recovered, separated, and used as a potential fuel source (for example, at industrial kilns). It should be noted that there may be very limited application of this technology type for the recovered NAPL. The implementability for NAPL use or recycling would be further evaluated in the remedial design phase as appropriate.

Beneficial use has tentatively been retained for further consideration.

5.2 Summary of Retained Technologies and Process Options

The following technology types and process options were carried forward to be assembled into potential remediation alternatives for the Site:

Source in Shallow Soil (0 to 15 ft bgs)

- Institutional Controls
  - Physical and legal land use restrictions to the Site and nearby areas and specific depths below ground surface
- Removal
  - Targeted source removal - excavation of contents of former MGP structures such as gasometers and limited Site areas with backfilling using clean or approved materials. This process option is likely to be used in conjunction with stormwater management and waste treatment using an industry standard bulking agent.

Source in Deep Soil (> 15 ft bgs)

- Institutional Controls
  - Physical and legal land use restrictions to Site and nearby areas and specific depths below ground surface

Free Phase NAPL

- Institutional Controls
  - Physical and legal land use restrictions to the Site and nearby areas and specific depths below ground surface
- Recovery
  - Passive NAPL recovery and off-site disposal or recycling of NAPL

NAPL-Containing Groundwater

- Institutional Controls
  - o Physical access restrictions coupled with groundwater use restrictions such as groundwater use ordinance
- Monitoring
  - o Long-term groundwater monitoring

6. Evaluation of Potential Remedial Alternatives

This section describes the potential remedial alternatives for the Site and evaluates alternatives using the ten criteria established in Section 3.

6.1 Potential Remedial Alternatives

The retained technologies and process options have been assembled into three potential site-wide remedial alternatives as presented in Table 3 and described below.

6.1.1 Alternative 1 Institutional Control with Long-Term Groundwater Monitoring

Under this alternative, no active remediation would be conducted aside from operation of the existing wastewater treatment system. Institutional controls would be established and maintained to mitigate the potential for uncontrolled exposure to NAPL and NAPL-containing media at designated properties (Figure 9-1). The specific institutional controls to be established and maintained will be determined in cooperation with SD DENR and affected property owners, but are anticipated to include the following components:

- Land use restrictions to ensure that the Site is used only for commercial or light industrial purposes in the future;
- Land use restrictions on a case by case basis for nearby affected properties ensuring industrial, commercial, or “restricted residential” land uses where, for example, construction of basements would be prevented or construction of deep foundations would require worker protection;
- Groundwater use restrictions that prohibit the installation and use of potable water supply wells at the Site and off-site areas with known groundwater impacts;

- Preparation of a site-specific Health and Safety Plan and a Site Management Plan that would be mandated for use by anyone conducting intrusive subsurface work (e.g., excavation, drilling, utility line maintenance/repair, etc.) at the Site or off-site areas with known NAPL-impacted soil or groundwater; and
- Maintenance (and repair as necessary) of the existing chain-link fence that surrounds the Site to control entry of unauthorized personnel to the Site

Although exposure to impacted groundwater would be controlled by the institutional controls, as a proactive measure this alternative also includes long-term groundwater monitoring at selected monitoring wells to confirm the continued stability of the groundwater plume. The scope of the long-term monitoring program would be determined in cooperation with the SD DENR, but for the purposes of this RAE, it is assumed that sampling would be conducted at 16 existing wells and up to six new wells, and that samples will be analyzed for BTEX and PAHs. It is assumed that sampling would be conducted annually for a period of 30 years. The actual monitoring duration may be less depending on program end-point goals defined in the monitoring plan.

6.1.2 Alternative 2 Institutional Control with Passive NAPL Recovery and Long-Term Groundwater Monitoring

This alternative would involve establishing/maintaining institutional controls and long-term groundwater monitoring, as discussed for Alternative 1 in Section 6.1.1. In addition, this alternative would include passive recovery of NAPL from the subsurface via trenches and/or wells. The term “passive” is used to describe the NAPL removal due to the fact that no active pumping would be conducted to induce NAPL movement into the collection trenches/wells; rather, the approach would rely on natural movement of NAPL to reach the collection trenches/wells followed by gravity separation within the trench and its associated collection sumps. In addition to mitigating potential exposure to NAPL and NAPL-containing media through institutional controls, removal of NAPL from the subsurface via trenches/wells would reduce the overall quantity of NAPL present at the Site and minimize the potential for off-site NAPL migration.

For the purposes of this RAE, it is assumed that eight NAPL collection trenches and three NAPL collection wells would be constructed at the Site to provide mechanisms for passively collecting and removing NAPL from the subsurface. The assumed locations of the trenches and wells are shown on Figure 9-2, along with a cross-section of the assumed trench configuration. The trench and well locations are based on the current distribution of NAPL in the subsurface, targeting the most highly NAPL-impacted areas and would be refined during design if this alternative is selected.

As indicated on Figure 9-2, the trenches would be approximately 35 feet deep, constructed of permeable material intercepting the deltaic alluvium, which is the primary NAPL-impacted stratigraphic unit of concern at the Site, and "keyed" into the underlying glacial till unit. The conceptual trench configurations are nominally 1.5 feet wide, and range from approximately 150 to 800 feet in length for a total length of approximately 3,000 feet. It is assumed that the trenches would be installed using "one-pass" trenching equipment, which will excavate the trench, install a perforated collection pipe in the bottom, install a vertical standpipe at one end, and backfill the trench with permeable backfill material all in one pass of the trenching equipment.

It is assumed that the trench spoils would be transported directly to Brown County Landfill. If necessary, excessively saturated soils would first be transported to a temporary lined on-site staging area where excess water would be removed from the soils via gravity dewatering or blending in a bulking agent such as wheat straw. The dewatered soils would then be loaded onto trucks and transported to the Brown County Landfill for stabilization and disposal. Any water recovered from on-site dewatering would be containerized for subsequent characterization and off-site disposal or discharge to the local POTW (pre-treatment may be required prior to discharge). It is assumed that the soils would be (a) physically stabilized with fly ash, quicklime, or Portland cement or (b) treated through low-temperature thermal desorption (LTTD) at the Brown County Landfill prior to disposal as non-hazardous waste. The implementability of stabilization and LTTD treatment technology would be determined during the remedial design phase. Potential emissions of odor, fugitive gas and dust associated with remedial actions occurring at the Site or landfill would be monitored so that abatement actions can be applied in a timely manner, thus ensuring safety of the workers and general public.

Following trench construction, NAPL that is present or migrating in the subsurface would enter the trench, and due to the NAPL density and hydraulic conductivity difference between the trench backfill and surrounding natural soils, settle through the permeable backfill to the bottom of the trench where it would enter a perforated collection pipe and be transported to a sump at one end of the trench (the bottom of the trench will be sloped to one or more sumps). A vertical standpipe, installed as part of the one-pass trench installation process, would provide a means of accessing the sump from the ground surface. Collected NAPL would be periodically removed from the sump using a pump. Manual sump monitoring and product recovery would be performed immediately following construction, with the addition of automated pumps to be installed at appropriate sump locations depending on the results of initial monitoring. It is assumed that NAPL recovered via the trenches and wells would be transported to a centrally located container, and then periodically sent off-site for disposal or beneficial use (e.g., fuel source for an industrial kiln).

For the purposes of this RAE, it is assumed that NAPL collection would be performed for a period of 15 years. The actual NAPL collection duration may be more or less depending on program end-point goals defined in the remedial design phase.

6.1.3 Alternative 3 Targeted Source Removal and Stabilization/Disposal with Institutional Control, Passive NAPL Recovery, and Long-Term Groundwater Monitoring

This alternative would involve establishing/maintaining institutional controls and long-term groundwater monitoring, as discussed for Alternative 1 in Section 6.1.1, and passive recovery of NAPL from the subsurface via trenches and/or wells, as discussed for Alternative 2 in Section 6.1.2. In addition, this alternative includes excavation and off-site disposal of shallow soils from targeted areas of the Site. In addition to mitigating potential exposure to NAPL and NAPL-containing media through institutional controls, the shallow soil removal combined with passive NAPL collection via trenches and wells would reduce the overall quantity of NAPL present at the Site and minimize the potential for off-site NAPL migration.

The assumed lateral excavation limits associated with this alternative are shown on Figure 9-3. The excavation limits are based on the current distribution of NAPL in shallow soils, targeting the most highly NAPL-impacted areas, and would be refined during design if this alternative is selected. Within these limits it is assumed that soils would be excavated to a depth of approximately 15 feet bgs, resulting in a total bank soil excavation volume of approximately 28,300 cubic yards.

It is assumed that the soil removal will be conducted using standard excavation equipment (e.g., excavators, loaders, etc.). Due to the anticipated excavation depths (15 feet bgs), the vertical sidewalls will require stabilization during excavation. It is assumed that, where possible, sidewall stabilization would be achieved using sloping techniques. However, in certain areas (e.g., along property lines or rail road tracks), alternative sidewall stabilization techniques (e.g., slide rail system) would be used.

It is assumed that the excavated soils would be handled similarly to trench spoils as discussed in Alternative 2, as would the associated water handling, air monitoring, and related work elements. Following removal of the impacted soils, clean backfill materials would be placed and compacted, and the ground surface would be restored to pre-excavation conditions (e.g., gravel or grass) and grades.

6.2 Evaluation of Potential Remedial Alternatives

In this section, the potential remedial alternatives described in Section 6.1 are compared against the nine NCP criteria: 1) overall protection of human health and the environment; 2) compliance with Applicable or Relevant and Appropriate Requirements

(ARARs); 3) long-term effectiveness and permanence; 4) reduction of toxicity, mobility, and volume; 5) short-term effectiveness; 6) implementability; 7) cost; 8) State (support Agency) acceptance; and 9) community acceptance. In addition, the remedial alternatives are evaluated using the current USEPA green remediation guidelines.

The purpose of this evaluation is to identify the relative advantages and disadvantages of the various alternatives, and thereby support the selection of a preferred alternative. The alternatives are assessed based on how each rates relative to the ten evaluation criteria **and** relative to the other alternatives being considered.

To aid in assessing the relative performance and to summarize the results of the comparative evaluation, this RAE incorporates a qualitative rating system. For each of the ten evaluation criteria, each alternative is assigned a rating ranging from “Low” to “High”, with “Low” representing the low end of the performance scale and “High” representing the high end of the performance scale. The ratings are intended to reflect the relative comparisons among the alternatives considered, as well as the extent to which an alternative satisfies each criterion. The ratings are presented in Table 4 and are supported by the criterion-specific considerations presented below.

6.2.1 Overall Protection of Human Health and the Environment

This criterion provides an overall assessment of each alternative for its ability to protect human health and the environment. This assessment draws on the analysis of other criteria evaluated for the developed alternatives (specifically short- and long-term effectiveness and compliance with ARARs), and also included such analysis factors as: compliance with RAOs; the degree to which current risks would be reduced; and the manner in which each source of impacts would be eliminated, reduced, or controlled.

The existing chain link fence, which would be maintained under all three alternatives, combined with institutional controls for the Site and affected nearby properties that would be established and maintained under all three alternatives, will serve to mitigate potential uncontrolled exposures to NAPL and NAPL-containing media. Alternative 2 offers a slight increase in overall and long-term protectiveness, in that it includes removal of NAPL from the subsurface. Along those lines, Alternative 3 offers an even greater increase in overall and long-term protectiveness, in that it includes removal of both NAPL and NAPL-containing soils from the subsurface. Specifically, impacted soils that potential receptors are most likely to be exposed to in the future would be removed under Alternative 3. However, under both Alternatives 2 and 3, the majority of the NAPL and NAPL-containing soils currently present at the Site would not be removed, leaving a vastly larger quantity of source material behind. In addition, there are greater short term risks associated with implementation of Alternatives 2 and 3 (e.g., worker safety, community exposures and/or nuisance issues, etc.), although these risks could be mitigated to some degree through proper planning, design and implementation. All three alternatives would meet the site-specific RAOs and comply with ARARs.

Based on the evaluations discussed above relative to short- and long-term effectiveness, compliance with RAOs, and overall risk reductions, all three alternatives were assigned a rating of "Medium" for the Overall Protection of Human Health and the Environment criterion.

6.2.2 Compliance with ARARs

There are three broad categories of ARARs: chemical-specific, location-specific, and action-specific.

- Chemical-specific ARARs are numerical standards that establish the acceptable amount or concentration of a chemical that may be found in, or discharged to the environment.
- Location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities solely based on their specific locations, such as floodplains, wetlands, historic places, or sensitive ecosystems or habitats.
- Action-specific ARARs are technology-based or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy.

The alternatives are evaluated for their ability to comply with ARARs as well as their ability to attain other "To Be Considered" criteria (TBCs). Possible ARARs and TBCs for the Site are identified based on the current understanding of the site conditions and the potential remedial alternatives developed to address the complete exposure pathways. Table 5 presents the possible federal and state chemical-specific, location-specific, and action-specific ARARs and TBCs associated with the potential remedial alternatives.

Identification of ARARs must be done on a site-specific basis. An alternative that does not comply with an ARAR may have grounds for invoking a waiver, provided protection of human health and the environment is still achieved, as described in CERCLA Section 121(d)(4). An ARAR waiver may be invoked under the following circumstances:

- the selected remedial action is only part of a total remedial action that will attain such an ARAR when completed;
- compliance with such an ARAR will result in greater risk to human health and the environment than alternative options;
- compliance with such an ARAR is technically impracticable from an engineering perspective;
- the selected remedial action will attain a standard of performance that is equivalent to that required under the given ARAR, through use of another method or approach; or
- the requirement is a state requirement that has been inconsistently applied in similar circumstances at other remedial actions within the state.

As noted in Section 2, the site-specific RAOs focus on source control and do not target to achieve any specific numeric federal- or state-specified chemical cleanup levels. Through proper planning, design and implementation, all three of the potential remedial alternatives would be compliant with the ARARs/TBCs listed in Table 5. Alternatives 2 and 3, which involve active remediation activities, would require certain permits prior to implementation, but these permits are readily obtainable. Accordingly, all three alternatives were assigned a rating of “High” for the Compliance with ARARs criterion.

6.2.3 Long-Term Effectiveness and Permanence

The long-term effectiveness of a remedial alternative is evaluated relative to its potential effect on human health and the environment after the remedial alternative is implemented and until the RAOs are met. This criterion considers the effect of the potential remedial action in terms of the risk remaining at the Site after the short-term response objectives have been met. The following factors were assessed during the evaluation of each alternative’s long-term effectiveness:

- potential environmental impacts from untreated waste or treatment residuals remaining at the completion of the remedial alternative;
- the adequacy and reliability of controls (if any) that would be used to manage treatment residuals or remaining untreated waste;
- the magnitude of the risk remaining after the response objectives have been met; and
- the alternative’s ability to meet RAOs established for the media.

All three alternatives would meet the site-specific RAOs by mitigating potential exposures to NAPL and NAPL-containing media. Alternatives 2 and 3 would involve the permanent removal and off-site disposal of some quantity of NAPL and NAPL-containing media compared to Alternative 1. However, under both Alternatives 2 and 3, a significant quantity of NAPL-containing soils currently present at the Site and nearby areas at depths greater than 15 feet (see Figure 6) would remain, and therefore offer medium levels of long-term effectiveness. Alternative 1 doesn't include the removal of any NAPL or NAPL-containing media.

In summary, due to the increased level of long-term effectiveness afforded by Alternatives 2 and 3, these alternatives were assigned a rating of "Medium" for the Long-Term Effectiveness and Permanence criterion. Alternative 1 was assigned a rating of "Low" due a slightly lower level of long-term effectiveness relative to Alternatives 2 and 3.

6.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

This evaluation criterion addresses the degree to which a remedial alternative would permanently reduce the toxicity, mobility or volume of the impacts present in the site media. This criterion addresses the preference for remedial actions that permanently and significantly reduce the toxicity of impacts, irreversibly reduce the mobility of the impacts and/or reduce the total volume of media containing impacts as opposed to relocation of untreated impacted media, for example, to a landfill. The evaluation focused on the following factors:

- the process the remedy would employ and the amount of materials that would be treated;
- the remedy's anticipated ability to reduce the toxicity, mobility or volume of impacts present in site media;
- the nature and quantity of residuals that would remain after treatment;
- the relative amount of MGP-related residuals that would be destroyed, treated or recycled; and
- the degree to which the treatment is irreversible.

Alternative 1, which does not include any active remediation activities, would not result in a reduction of toxicity, mobility or volume of impacted media. Alternatives 2 and 3 would reduce the mobility and volume of NAPL in the subsurface through collection and removal of NAPL via trenches and wells. In addition, Alternative 3 would also reduce the volume of NAPL-containing soil through excavation, treatment, and off-site disposal of NAPL-containing shallow soil. However, even if Alternative 3 were implemented, the vast majority of NAPL-containing soils currently present at the Site (particularly at depths greater than 15 feet) would not be removed, leaving a large quantity of source material behind (Figure 10).

In summary, because Alternative 1 would not result in a reduction of toxicity, mobility or volume of impacted media, it was assigned a rating of "Low" for the Reduction of Toxicity, Mobility, or Volume through Treatment criterion. Alternatives 2 and 3 were assigned a rating of "Medium" because they would include reductions in NAPL and NAPL-containing soil mobility and volume.

6.2.5 Short-Term Effectiveness

The short-term effectiveness of a remedial alternative is evaluated relative to its potential effect on human health and the environment during the construction and implementation phases until the remedial response objectives are met. The evaluation of each alternative with respect to its short-term effectiveness considered the following:

- short-term impacts to the community during implementation;
- potential short-term impacts to workers during implementation and the effectiveness and reliability of protective measures;
- potential short-term environmental impacts and the effectiveness of mitigative measures to be used; and
- time required to achieve the RAOs for protection of health and the environment.

Alternative 1, which does not include any active remediation activities, would result in minimal short-term risks/impacts associated with groundwater monitoring activities; these risks could be mitigated by following established sampling protocols and the use of standard personal protective equipment (PPE) as specified in the site-specific Health and Safety Plan. Both Alternatives 2 and 3, which do include active remedial construction activities, would result in significantly greater short-term risks compared to Alternative 1. Such short-term risks/impacts could potentially include (but are not limited to, the following):

- working with and around construction equipment;
- noise generation from operating construction equipment;

- increased vehicular traffic associated with delivery of equipment and materials, and transportation of excavated materials within the Site and from the Site to the Brown County Landfill, including potential releases of impacted materials during off-site transportation and damage to roadways;
- dust generation during trenching/excavation and backfill activities;
- odor and off-gas emissions generation during trenching/excavation and backfill activities;
- worker exposure to impacted soil and groundwater;
- presence of open excavations to depths of up to 15 feet (specific to Alternative 3 only); and
- risk of erosion and/or flooding of exposed soil areas during the extended timeframe required for soil removal (specific to alternative 3 only).

To the extent possible, the short-term risks/impacts listed above could be minimized by proper planning, design and implementation, including use of proper engineering controls (e.g., dust/vapor suppression measures) and proper health and safety protocols and PPE. The duration of each of these potential short-term risks/impacts would be commensurate with the alternative-specific construction durations.

In summary, Alternative 1 would result in minimal short-term risks/impacts and was therefore assigned a rating of “High” for the Short-Term Effectiveness criterion. Alternative 2 was assigned a rating of “Medium” due to its potential to result in the short-term risks/impacts listed above. Alternative 3 was assigned a rating of “Low” given its increased potential for short-term risks relative to Alternative 2 due to the longer estimated construction duration (26 weeks for Alternative 3 compared to eight weeks for Alternative 2), greater volume of materials being generated, handled and transported off-site, and the presence of open excavations.

6.2.6 Implementability

This evaluation criterion addresses the technical and administrative feasibility of implementing a remedial alternative, including the availability of the various services and materials required. The following analysis factors were considered during the implementability evaluation:

- Technical Feasibility – This refers to the relative ease of implementing or completing the remedial alternative based on site-specific constraints. In addition, the remedial alternative's constructability and operational reliability are considered, as well as reliability of the technology and the ability to monitor the effectiveness of the remedial alternative.

- Administrative Feasibility – This refers to items, such as coordination with other agencies, permitting, and availability of services, equipment and materials, such as treatment, storage and disposal services, as well as required technical specialists and contractor services.

All three of the potential remedial alternatives are both technically and administratively feasible. Institutional controls, which are components of all three remedial alternatives, are commonly used mechanisms to mitigate exposures, and are therefore readily implementable and administratively feasible. Groundwater monitoring, which is also a component of all three remedial alternatives, is readily implementable based on both technical and administrative feasibility. The equipment, materials, trained labor and off-site disposal facilities necessary to install the NAPL collection trenches and wells (Alternatives 2 and 3) and to conduct the soil excavation and backfill (Alternative 3) are readily available. However, the degree of technical complexity/difficulty in conducting excavations to 15 feet bgs and associated excavation support, dust/odor suppression, material handling and backfill operations under Alternative 3 is significantly greater than that of the other two alternatives. The permits, approvals, and/or licenses necessary to implement both Alternatives 2 and 3 are expected to be readily obtainable, and the associated required level of effort is anticipated to be similar for both alternatives.

In summary, Alternative 1 has the fewest number of technical and administrative implementability issues and was therefore assigned a rating of "High" for the Implementability criterion. Alternatives 2 and 3 were assigned ratings of "Medium" due to their increased technical complexity/difficulty relative to Alternative 1.

6.2.7 Cost

This criterion refers to the total cost to implement the remedial alternative on the basis of present worth analysis. Present worth analysis allows remedial actions to be compared based on a single cost representing the amount that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the remedial actions over the planned project life cycle.

The total cost of each alternative represents the sum of the direct capital costs (materials, equipment and labor), indirect capital costs (engineering, licenses or permits and contingency allowances), operation and maintenance (O&M) costs (operating labor, energy, chemicals and sampling and analysis) and future capital costs (when appropriate, when there is a reasonable expectation that a major component will require replacement).

The present worth costs, which were developed to allow the comparison of the remedial alternatives, were estimated with expected accuracies of -30 percent to +50 percent, in accordance with USEPA guidance (USEPA, 1988a). A contingency factor of 25 percent has been included for each alternative to cover unforeseen costs incurred during implementation. Present value costs are calculated for alternatives expected to last more than two years. In accordance with the RI/FS Guidance (USEPA, 1988a), a five percent discount rate (before taxes and after inflation) was used to calculate present worth.

It should be noted that this Site is unique in that the entity responsible for implementing the selected remedial alternative (NWE) is a public utility. As such, some or all of the remediation costs may qualify for allocation amongst South Dakota NWE customers through utility rate increases. Accordingly, cost may be a more important evaluation criterion for this Site, compared to a typical privately funded remediation project.

Preliminary cost estimates were prepared for each of the three potential remedial alternatives in accordance with the procedures outlined above. The costs are summarized in Table 6 and detailed cost estimates are provided in Appendix A. Total estimated costs for the three alternatives are as follows:

- Alternative 1: $3,210,000
- Alternative 2: $13,960,000
- Alternative 3: $27,100,000

As indicated above, estimated costs for Alternative 1 are significantly lower than the estimated costs for Alternative 2, which in turn are significantly lower than the estimated costs of Alternative 3. Accordingly, Alternative 1 was assigned a rating of “High” for the Cost criterion. Alternatives 2 and 3 were assigned ratings of “Medium” and “Low,” respectively.

6.2.8 State Acceptance

The selected remedial alternative will be subject to approval by the SD DENR prior to design and implementation. Regardless of the selected remedy, it is anticipated that

SD DENR's concerns could be addressed through proper design and implementation. Accordingly, State Acceptance is not a differentiating criterion for selection of a remedial alternative, and no ratings have been assigned for any of the potential remedial alternatives for the State Acceptance criterion.

6.2.9 Community Acceptance

The selected remedial alternative will be presented to community and stakeholders for comment prior to design and implementation. This criterion evaluates the anticipated community acceptance of each alternative.

As indicated in Section 6.2.7, cost is an important factor for community acceptance because a significant portion of the remediation costs may be distributed amongst South Dakota NWE customers through utility rate increases. Accordingly, the community is likely to prefer a lower cost alternative over a higher cost alternative, particularly when the specifics of this particular project stand to benefit few people, with costs absorbed by many. Further, because institutional controls will be implemented to protect the community from future exposures to NAPL and NAPL-containing media, without the need for an eight to 26 week construction project that would cause noise, dust, odors, vapors, traffic congestion, the community is likely to prefer Alternative 1 over Alternatives 2 and 3. Regardless of the selected remedy, it is anticipated that community concerns could be addressed to some degree through proper design and implementation.

In summary, due to lower cost, same level of future community exposure protection, and fewer potential construction-related nuisance/health issues, the community is likely to prefer Alternative 1 over Alternative 2 and Alternative 2 over Alternative 3. Therefore, Alternative 1 was assigned a score of “High” for the Community Acceptance criterion, and Alternatives 2 and 3 were assigned scores of “Medium” and “Low,” respectively.

6.2.10 Green Remediation Consideration

During the remedial alternative evaluation, and the subsequent design and implementation of the remedial actions, the best management practices (BMPs) to promote sustainability and green remediation concepts are considered. Consistent with the USEPA guidance *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites* (USEPA, 2008), the green remediation aspects of the specific planned remedial activities include:

- Reduction of energy consumption;
- Reduction of greenhouse gas emission;
- Improving groundwater quality;
- Maximize efficiency;
- Minimize airborne contaminants and particulates emission during construction; and
- Reuse and recycle.

Alternative 1 does not include any active remediation activities, and would therefore consume the lowest amount of energy and cause the smallest amount of greenhouse gas and airborne contaminant/particulate emissions of the three alternatives. Alternative 3 would require the longest construction duration and use the greatest amount of petroleum-powered equipment, and would therefore consume the greatest amount of energy and cause the largest amount of greenhouse gas and airborne contaminant/particulate emissions of the three alternatives. Both Alternatives 2 and 3, which will include collection and removal of NAPL form the subsurface, offer greater improvements in groundwater quality compared to Alternative 1. However, significant improvements in groundwater quality are not likely because significant amounts of source material will remain under all three alternatives, and the shallow groundwater (irrespective of NAPL impacts) is already viewed as being of non-potable quality. As discussed in Section 6.1.2, NAPL removed from the subsurface may be beneficially used as a fuel source for an industrial kiln (which would likely result in additional emissions of airborne contaminants/particulates). Further, it is likely that diesel fuel may need to be added to the collected NAPL in order to increase its potential heat content (its “British Thermal Unit” or “BTU” content) sufficient to be acceptable as an additional fuel source.

In summary, Alternative 1 offers the greatest adherence to green remediation concepts, and is therefore assigned a rating of “High” for the Green Remediation Consideration criterion. Based on energy consumption, emissions and groundwater improvement considerations, Alternatives 2 and 3 were assigned ratings of “Medium” and “Low,” respectively.

6.3 Evaluation Summary

Based on the comparative analysis of potential remedial alternatives described above, Remedial Alternative 2 – Institutional Control with Passive NAPL Recovery and Long-

Term Groundwater Monitoring was selected as the proposed remedial alternative to be implemented at the Site. As described in detail in Section 6.1.2, Alternative 2 includes the following:

- Establishing and maintaining institutional controls to mitigate the potential for uncontrolled exposure to NAPL and NAPL-containing media;
- Conducting long-term groundwater monitoring at selected monitoring wells to confirm the continued stability of the groundwater plume, or to identify unanticipated migration of COCs; and
- Passive recovery of NAPL from the subsurface via installed recovery trenches and wells to reduce the overall quantity of source material (NAPL) present at the Site and minimize the potential for off-site NAPL migration.

Alternative 2 was selected over Alternative 1 because it offered additional protection of human health through removal of source material (NAPL) from the subsurface. Alternative 3 included removal of a greater amount of source material from the subsurface than Alternative 2, but it was not selected because of its significant short-term impacts/risks and costs compared to its overall reduction in risk compared to Alternative 2. Specifically, the excavation associated with Alternative 3 would represent a significant extra cost, as well as potentially significant adverse impacts such as noise, traffic, and fugitive dust and airborne COC impacts to the local community. In addition, because the majority of the source material is located below the designated 15-foot excavation depth (Figure 10), this alternative, with the increased short-term risk associated with the soil removal, would still offer a similar level of reduction in overall protection to human health as that of Alternative 2.

7. Proposed Site Remedial Alternative

Based on the comparative analysis of potential remedial alternatives described in Section 6, Remedial Alternative 2 – Institutional Control with Passive NAPL Recovery and Long-Term Groundwater Monitoring was selected as the proposed remedial alternative to be implemented at the Site. As explained in Section 6.1.2, Alternative 2 includes the following:

- Establishing and maintaining on-site and off-site institutional controls to mitigate the potential for uncontrolled exposure to NAPL and NAPL-containing media;
- Conducting long-term groundwater monitoring at selected monitoring wells to confirm the continued stability of the groundwater plume, or to identify unanticipated migration of COCs; and

- Passive recovery of NAPL from the subsurface via installed trenches and wells to reduce the overall quantity of source material (NAPL) present at the Site and minimize the potential for off-site NAPL migration.

7.1 Establish and Maintain Institutional Controls

Delineation of NAPL and impacted groundwater has served to identify those properties adjacent to the Site for which institutional controls and groundwater use restrictions are appropriate (Figure 9-1). These properties include undeveloped land, municipal/commercial/industrial properties, and residential/institutional properties. Implementation of this task would involve working with land owners to place an administrative land use restriction on each property and record this restriction with the County Recorder. Institutional controls would restrict the use of groundwater and require notification to NWE for any deep excavation on these properties to ensure adequate worker protection.

This task would also include ongoing site maintenance and security, as well as continued operation and maintenance of the existing wastewater treatment system on the City’s Booster Station property west of the Site.

7.2 Conduct Long-Term Groundwater Monitoring

The existing monitoring well network would undergo regular monitoring on an annual basis, or at a frequency acceptable to SD DENR that may be required to demonstrate stability of the NAPL and dissolved-phase groundwater plume. Potentiometric data would be recorded to monitor groundwater flow direction, and groundwater samples would be analyzed for COCs (BTEX and PAHs) to evaluate long-term trends. Up to six additional monitoring wells would be constructed to supplement the 16 existing monitoring wells as part of this program.

7.3 Design, Construction, and Operation of Passive NAPL Collection System

A network of NAPL recovery wells and trenches would be located and constructed as part of this alternative. For recovery trench construction, engineered zones of very high and/or low permeability would be used to intercept and collect NAPL, and prevent or mitigate its migration. Locations where access is limited would be candidates for installation of a recovery well. The proposed operation of the NAPL recovery trenches and wells would be in “passive” mode; that is, removal of NAPL from collection wells and sumps without continuous active pumping, handling, and treatment of large volumes of groundwater. Due to the high cost of operating groundwater extraction and treatment systems and the longevity of NAPL in the subsurface, NAPL containment remedies that do not require groundwater extraction are strongly preferred.

Key design factors for passive NAPL barriers include NAPL distribution and potential mobility, NAPL physical properties (density, viscosity, and interfacial tension), soil properties (hydraulic conductivity, porosity), NAPL-soil interaction characteristics (wetability, displacement pressure), hydraulic gradients, and the hydraulic and physical effects of remedy components (e.g., barrier walls, vertical or horizontal high-permeability zones, passive wells, permeable sorptive/wicking media, etc.). Many of these design factors have been obtained over the course of several phases of characterization at the Site, while other design factors would be determined through pilot testing.

Activities performed during the design process commonly include a combination of the following:

- assessment of NAPL distribution and potential mobility;
- groundwater flow modeling to simulate pre-remedy hydraulic conditions and predict the hydraulic gradient magnitudes and directions following barrier construction – transient simulations are performed for sites with variable hydraulic boundary conditions;
- review of modeled hydraulic gradients within a high-permeability NAPL barrier and/or passive NAPL collection wells;
- comparisons between NAPL density or buoyancy gradients versus vertical hydraulic gradients to assess gravity separation potential;
- calculation of “critical gradients” required to mobilize NAPL around, under, or through the barrier, and comparison to simulated gradients; and
- calculation of NAPL velocities in key areas;

The proposed approach for implementation consists of installing the recovery network in phases to optimize the ongoing positioning and construction of additional collection wells and trenches over two or three construction seasons. Wells are typically constructed as four-inches in diameter or larger, to provide for ample storage capacity of NAPL. Recovery trenches are nominally eighteen inches wide and would extend into the glacial till stratum to act as a sump for NAPL residing on the till surface (or higher elevation). Backfill of higher permeability is used to take advantage of differences in specific gravity between NAPL and groundwater and encourage collection of NAPL within a drain pipe at the bottom of the trench. The drainage pipe flows to sumps that are positioned strategically throughout the trench. Sumps may be constructed as four-inch diameter wells or up to manhole-sized vaults. Installation of the trenches can be performed using manual construction equipment, or a "One-Pass" trenching machine. For conceptual purposes, approximately 3,000 lineal feet of trench is anticipated. Assuming a reasonable rate of 70' per day can be installed, construction associated with this alternative amounts to approximately eight weeks (likely spread over two or three construction seasons).

Once the trench is constructed, manual monitoring of the sump vaults is performed on a regular basis. Accumulated NAPL is measured, recorded, and bailed or pumped into a storage tank for off-site disposal. Depending on the volume of NAPL collected, an automated pump system can be installed in the collection sump. A conceptual passive NAPL recovery network is depicted on Figure 9-2.

The passive NAPL recovery network as presented on Figure 9-2 is conceptual at this time, and would likely be refined during pre-design, pilot testing, and initial operation. The conceptual layout presents trenches and wells based on areas where (a) NAPL collection is likely based on historical field observations, (b) a trench or well would serve as a protective means of ensuring that NAPL would not migrate from an upgradient location beyond this location (for example, towards a residential area). It is quite common that NAPL is not recovered from every collection well or trench sump; however, this observation would serve as empirical documentation that NAPL in any such area is not mobile and this could be confirmed through performance of a location-specific NAPL mobility evaluation. Pilot testing and a phased implementation will be helpful to optimize the design and efficiency of this approach.

7.4 Evaluation of Proposed Alternative to Ten Criteria

The following bullets provide additional rationale for the selection of Alternative 2, based on a comparison to the ten evaluation criteria discussed in Section 6.2:

- Alternative 2 will be protective of human health and the environment by mitigating potential uncontrolled exposures to NAPL and NAPL-containing media through establishing and maintaining institutional controls, monitoring groundwater and by removal and off-site disposal or re-use of source material (NAPL) from the subsurface via trenches and wells (Figure 11).

- Through proper planning, permitting, design and implementation, Alternative 2 would be compliant with the ARARs/TBCs listed in Table 5.
- Alternative 2 would meet the site-specific RAOs and have long-term effectiveness by mitigating potential exposures to NAPL and NAPL-containing media through establishing and maintaining institutional controls and monitoring groundwater. The long-term effectiveness of Alternative 2 is further enhanced through the permanent removal of some NAPL from the subsurface via collection trenches and wells (Figure 9-2).
- Alternative 2 would reduce the mobility and volume of NAPL in the subsurface through collection and removal of NAPL via trenches and wells. Strategic positioning near the municipal water booster station will aid in the removal of localized NAPL, thus improving the long-term operation of the existing wastewater treatment system.
- Short-term human health exposures associated with alternative 2 could be minimized by proper planning, design and implementation, including use of proper engineering controls (e.g., dust/vapor suppression measures) and proper health and safety protocols and PPE. The estimated construction duration and associated duration of short-term risks/impacts associated with Alternative 2 (eight weeks) is less than that of Alternative 3 (26 weeks). In addition, compared to Alternative 3, Alternative 2 has fewer short-term impacts associated with the quantity of materials being generated, handled and transported off-site, the likelihood of odor and/or off-gas generation, and the presence of large, open excavations.
- Alternative 2 is both technically and administratively feasible. Institutional controls and groundwater monitoring are commonly used mechanisms to mitigate exposures, and are therefore readily implementable and administratively feasible. The equipment, materials, trained labor and off-site disposal facilities necessary to install the NAPL collection trenches and wells are readily available. The permits, approvals, and/or licenses necessary to implement Alternatives 2 are expected to be readily obtainable. Alternative 2 has a much lower degree of technical complexity/difficulty compared to Alternative 3.
- Alternative 2 is more cost effective than Alternative 3 in that it achieves site-specific RAOs, and offers similar levels of overall protection of human health and the environment as Alternative 3, but for cost savings of approximately 13 million dollars.
- The selection of Alternative 2 will be subject to approval by the SD DENR, but it is anticipated that it will be an acceptable remedy.

- Alternative 2 would adhere to green remediation concepts in that it would include collection and removal of NAPL form the subsurface, which would result in improvements in groundwater quality, and potentially include beneficial use of NAPL removed from the subsurface.

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Tables

Table 1. NAPL Properties Ranges Found at Aberdeen MGP Site and Other ARCADIS Managed MGP Sites

Evaluation Criteria	Temperature (oC)	Specific Gravity (unitless)	Density (g/cc)	Viscosity (centipoise)	NAPL/Water Interfacial Tension (dynes/cm)
NAPL at Aberdeen Former MGP Site					
Groundwater	10.6	1.006	1.004	1.32	22.68
NAPL	10.6	1.105	1.103	431	
NAPL at Other MGP Sites					
NAPL (range)[1]	7 to 17	--	0.987 to 1.16	13 to 38,000	11 to 28.6
NAPL (average)[2]	7 to 17	--	1.09	225	23.4

Notes:
[1] 29 samples from ARCADIS U.S. Sites; the maximum and minimum values (outliers) were excluded in calculating the averages
[2] Values for 4 of these samples measured at 21•C

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Table 2. Preliminary Screening of Remedial Technologies and Process Options

General Response Action/	Technology Type	Process Option	Description	Effectiveness	Implementability	Relative Cost	Preliminary Screening
1. Source in Shallow Soil (0 to 15 ft bgs)							
Institutional Controls	Institutional Controls	Physical Access Restrictions	Physical constraints, such as fencing and signs, placed around the Site to limit access, thereby limit exposure.	Would reduce potential human exposure to COC in soil by potential receptors. Could be used during implementation of remedial actions and on a longer-term basis. Would require routine monitoring and maintenance.	Technically and administratively implementable. Would require property owner(s) agreement for off-site properties.	Low	Retained.
Containment	Capping	Permeable Cover	Placing a clean cover material (e.g., soil) sufficient to prevent the direct contact with COC in soil. Can be used by itself or after initial removal of impacted soil.	Would reduce the long-term potential exposure to human receptors by providing a clean cover over the impacted soil. Post-construction maintenance and monitoring would be required. Would not be effective in reducing downward migration of NAPL.	Implementable. Capping by itself is readily implementable. Would require access agreements from the property owners if applied off site. Requires long-term maintenance of the cap integrity.	Low	Not Retained. Would function similarly as that of the existing surface soil cover at the Site.
	Engineered Barrier	Low-permeability engineered barrier	Placing a low-permeability barrier (e.g., asphalt pavement) sufficient to reduce the vertical migration of COC in soil to groundwater and prevent direct contact with COC. Can be used by itself or after initial removal of impacted soil.	Would reduce the long-term potential exposure to human receptors by providing an engineered barrier over the impacted soil. Post-construction maintenance and monitoring would be required. Would not be effective in reducing downward migration of NAPL.	Implementable. Engineered barrier is readily implementable. Would require access agreements from the property owners if applied off site. Requires long-term maintenance of the cap integrity.	Low to Medium	Not Retained. Would be effective in source control.
Soil Removal	Removal in Targeted Areas	Excavation and Backfilling	Excavating impacted soil using conventional earthmoving equipment (e.g., excavators), backfilling and compacting excavated areas with clean material, and grading the surface to match existing conditions. Dewatering may be required in some locations.	Removal would reduce the amount of source material present in soil and/or inside historical MGP structures such as gas holders. Would reduce long-term risk of exposure to construction workers. Would need to replace excavated soil. The scope of the removal may range from excavating contents of historical structures such as gas holders and targeted source areas.	Implementable. Equipment, materials, and personnel are readily available. May be difficult to implement in areas with underground utilities and structures, in roadways, and railroad right-of-ways. Would need access permission from property owners for off-site properties.	Medium	Retained.

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1. Source in Shallow Soil (0 to 15 ft bgs) (Continued)							
***In Situ* Treatment**	Physical	Immobilization/ Stabilization	Mixing impacted soils in situ with Portland cement, activated carbon, fly ash, or other stabilization agents to reduce mobility of COC in soil.	Could reduce the mobility of COC in soil, thereby reducing the potential for human exposure. Would require treatability testing to determine site-specific effectiveness.	Technically implementable. May be difficult to apply in certain areas. Would require specialized equipment, materials, and operating personnel; commercial vendors are available. Problems/challenges include volume increase/bulking, requiring subsequent material management/disposal, and freeze/thaw integrity issues. May require that a soil cover be placed over the treated material to sustain vegetation. Would require long-term monitoring and maintenance.	Medium	Not Retained.
	Chemical	Chemical Oxidation	Introducing chemical agents such as oxidants or surfactants/solvents into the impacted medium to remove or destroy potential COC either by injection, mixing physically with a chemical, or placement of a reactive barrier.	Could destroy or reduce the toxicity, mobility, and volume of COC in soil, thereby reducing the potential for human exposure. Would require treatability testing to determine site-specific effectiveness.	Technically implementable. May be difficult to apply in certain areas. Would require specialized equipment, materials, and operating personnel; commercial vendors are available. Problems/challenges include operation safety, effectiveness of reagent delivery system, requiring subsequent material management/disposal, and freeze/thaw integrity issues. Would create short-term emission associated with chemical reactions. Would require multiple treatment cycles, monitoring and maintenance.	Medium to High	Not Retained. Would not be as effective as removal for addressing source in shallow soil.
	Biological	Bioremediation	Introducing biodegradation enhancement agents such as microorganisms and nutrients and/or surfactants into the impacted medium to breakdown or destroy potential COC either by injecting or mixing.	Could reduce the toxicity and mobility of COC in soil, thereby reducing the potential for human exposure. Would require treatability testing to determine site-specific effectiveness.	Technically implementable. May be difficult to apply in certain soil conditions. Would require specialized equipment, materials, and operating personnel; commercial vendors are available. Problems/challenges include the survival and health of microbial community, effectiveness of reagent delivery system, and freeze/thaw integrity issues. Would require long-term monitoring and maintenance.	Low to Medium	Not Retained. Would not be effective for addressing source in soil.
	Thermal	Electric Resistance Heating	Introducing steam to or raising the temperature of the impacted medium to enhance the mobility and recovery of NAPL and COC in soil and groundwater.	Would significantly increase the mobility of COC in soil through engineered recovery (e.g., vacuum extraction) and reduce the amount of COC in soil, thereby reducing the potential for human exposure. Would require treatability testing to determine site-specific effectiveness.	Technically implementable. May be difficult to apply in certain soil types and site areas. Would require specialized equipment, materials, and operating personnel; require significant amount of energy for system operation and maintenance; commercial vendors are available. Would require treatability or pilot studies to evaluate implementability and design criteria. Would require relatively large NAPL/groundwater extraction network and on-site long-term monitoring and maintenance of a NAPL/groundwater recovery and separation, groundwater treatment, and vapor treatment system.	High	Retained.

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General Response Action/	Technology Type	Process Option	Description	Effectiveness	Implementability	Relative Cost	Preliminary Screening
1. Source in Shallow Soil (0 to 15 ft bgs) (Continued)							
Ex Situ Treatment	Physical Treatment Post Removal	Immobilization/ Stabilization	Mixing impacted soils in situ with Portland cement, activated carbon, fly ash, or other stabilization agents to reduce mobility of COC in soil.	Could reduce the mobility of COC in soil, thereby reducing the potential for human exposure. Would require treatability testing to determine site-specific effectiveness.	Technically implementable. May be difficult to apply in certain areas. Would require specialized equipment, materials, and operating personnel; commercial vendors are available. Problems/challenges include volume increase/bulking, requiring subsequent material management/disposal, and freeze/thaw integrity issues. May require that a soil cover be placed over the treated material to sustain vegetation. Would require long-term monitoring and maintenance.	Medium	Not Retained. May be used as material rendering in conjunction with soil removal but not as Site-side remedial technology.
	Chemical Treatment Post Removal	Chemical Treatment	Introducing chemical agents such as solvents into the impacted medium to remove COC either by mixing.	Could destroy or reduce the toxicity and the volume of COC in soil, thereby reducing the potential for human exposure. Would require treatability testing to determine technology effectiveness.	Technically implementable. Would require soil removal and specialized equipment, materials, and operating personnel; commercial vendors are available. Problems/challenges include operation safety and subsequent material management/disposal. Would create short-term emission associated with excavation and chemical usage.	Medium to High	Not Retained. Would require extensive deep soil excavation.
	Biological Treatment Post Removal	Bioremediation	Introducing biodegradation enhancement agents such as microorganisms and nutrients and/or surfactants into the impacted medium to breakdown or destroy potential COC either by mixing.	Could reduce the toxicity and quantity of COC in soil, thereby reducing the potential for human exposure. Would require treatability testing to determine site-specific effectiveness.	Technically implementable, but would not be effective in treating NAPL. Would likely require subsequent treatment prior to disposal or reuse.	Medium	Not Retained. Would not be effective for addressing source in soil.
	Treatment Post Removal	Thermal Desorption	Physically separating COC from the soil by heating soil to volatilize the hydrocarbons. Volatilized COC are then condensed and collected as liquid, captured on activated carbon, or destroyed in an afterburner.	Would reduce potential toxicity, mobility, and volume of COC in the removed soils via treatment and proper management and/or disposal of treatment residuals. Would require appropriate environmental and process controls. Depending on effectiveness, could be evaluated for use in reducing COC concentrations in removed materials to levels that may allow more cost-effective disposal options or possibly reuse as backfill. Treatability studies using soils from the Site may be warranted to evaluate degree of effectiveness and reuse potential of treated solids. Would not require long-term operation and maintenance for the treated area. The effectiveness of this technology is limited by the accessibility of the site area for removal action. Areas within active railroad right-of-way and utility corridor will be difficult.	Potentially implementable. Would require specialized equipment, materials, and operating personnel; commercial vendors are available. May require stabilization and/or dewatering before treatment. Would require sufficient space to conduct the treatment and processing activities. Difficult to implement for impacted soils inaccessible by removal actions. Thermal treatment units at other sites have met with community resistance.	High	Not Retained. Would be significantly limited by the soil removal action and operation accessibility.

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General Response Action/	Technology Type	Process Option	Description	Effectiveness	Implementability	Relative Cost	Preliminary Screening
2. Source in Deep Soil (> 15 ft bgs)							
No Further Action	No Further Action	No Further Action	No remedial measures or monitoring conducted. Would take account of changing conditions through the ongoing natural attenuation of COC in soil.	No monitoring performed to track effectiveness.	Readily implementable.	Low	Not Retained.
Institutional Controls	Institutional Controls	Physical Access Restrictions	Physical constraints, such as fencing and signs, placed around the Site to limit access, thereby limit exposure.	Would reduce potential human exposure to COC in soil by potential receptors. Could be used during implementation of remedial actions and on a longer-term basis. Would require routine monitoring and maintenance.	Technically and administratively implementable. Would require property owner(s) agreement for off-site properties.	Low	Retained.
Containment	Capping	Permeable Cover	Placing a clean cover material (e.g., soil) sufficient to prevent the direct contact with COC in soil. Can be used by itself or after initial removal of impacted soil.	Would reduce the long-term potential exposure to human receptors by providing a clean cover over the impacted soil. Post-construction maintenance and monitoring would be required. Would not be effective in reducing downward migration of NAPL.	Implementable. Capping by itself is readily implementable. Would require access agreements from the property owners if applied off site. Requires long-term maintenance of the cap integrity.	Low	Not Retained. Site surface soil currently does not pose any exposure risk to potential receptors. This option would not be effective in mitigation the source materials present in the saturated zone.
	Engineered Barrier	Low-permeability engineered barrier	Placing a low-permeability barrier (e.g., asphalt pavement) sufficient to reduce the vertical migration of COC in soil to groundwater and prevent direct contact with COC. Can be used by itself or after initial removal of impacted soil.	Would reduce the long-term potential exposure to human receptors by providing an engineered barrier over the impacted soil. Post-construction maintenance and monitoring would be required. Would not be effective in reducing downward migration of NAPL.	Implementable. Engineered barrier is readily implementable. Would require access agreements from the property owners if applied off site. Requires long-term maintenance of the cap integrity.	Low to Medium	Not Retained. Would be effective in source control.
Soil Removal	Removal	Excavation and Backfilling	Excavating impacted soil using conventional earthmoving equipment (e.g., excavators), backfilling and compacting excavated areas with clean material, and grading the surface to match existing conditions. Significant water management would be required.	Removal would reduce the amount of source material present in subsurface soil. Would reduce long-term risk of exposure to construction workers. Would need to replace excavated soil.	Implementable. Equipment, materials, and personnel are readily available. May be difficult to implement in areas with underground utilities and structures, in roadways, and railroad right-of-ways. Would need access permission from property owners for off-site properties.	High	Not Retained. Would not be practical to implement as a site-wide remedial technology due to the significant volume of source in deep soil and the site-specific hydrogeological conditions. Would create significant short-term risk associated with air emission and disturbance to local community.

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General Response Action/	Technology Type	Process Option	Description	Effectiveness	Implementability	Relative Cost	Preliminary Screening
2. Source in Deep Soil (> 15 ft bgs) (Continued)							
***In Situ* Treatment**	Physical	Immobilization/ Stabilization	Mixing impacted soils in situ with Portland cement, activated carbon, fly ash, or other stabilization agents to reduce mobility of COC in soil.	Could reduce the mobility of COC in soil, thereby reducing the potential for human exposure. Would require treatability testing to determine site-specific effectiveness. Problems/challenges include volume increase and freeze/thaw integrity issues. Bulking of treated soils may require off-site disposal of some soils. May require that a soil cover be placed over the treated material to sustain vegetation. Would require long-term monitoring and maintenance.	Technically implementable. Specialized equipment, materials, and operating personnel may be available. May be difficult to apply in certain areas.	Medium	Not Retained. Would require significant waste management and energy consumption.
	Chemical	Chemical Oxidation	Introducing chemical agents such as oxidants or surfactants/solvents into the impacted medium to remove or destroy potential COC either by injection, mixing physically with a chemical, or placement of a reactive barrier.	Could destroy or reduce the toxicity, mobility, and volume of COC in soil, thereby reducing the potential for human exposure. Would require treatability testing to determine site-specific effectiveness.	Technically implementable. May be difficult to apply in certain areas. Would require specialized equipment, materials, and operating personnel; commercial vendors are available. Problems/challenges include operation safety, effectiveness of reagent delivery system, requiring subsequent material management/disposal, and freeze/thaw integrity issues. Would create short-term emission associated with chemical reactions. Would require multiple treatment cycles, monitoring and maintenance.	Medium to High	Not Retained. Would introduce substantial amount of chemicals to subsurface, consume significant energy to deliver reagents, and create short-term risk of chemical exposure.
	Biological	Bioremediation	Introducing biodegradation enhancement agents such as microorganisms and nutrients and/or surfactants into the impacted medium to breakdown or destroy potential COC either by injecting or mixing.	Could reduce the toxicity and mobility of COC in soil, thereby reducing the potential for human exposure. Would require treatability testing to determine site-specific effectiveness.	Technically implementable. May be difficult to apply in certain soil conditions. Would require specialized equipment, materials, and operating personnel; commercial vendors are available. Problems/challenges include the significant presence of free phase NAPL, health of microbial community in subsurface, and effective delivery of enhancement reagents. Would require long-term monitoring and maintenance.	Medium	Not Retained. Would not be effective for addressing NAPL in soil.
	Thermal	Electric Resistance Heating	Introducing steam to or raising the temperature of the impacted medium to enhance the mobility and recovery of NAPL and COC in soil and groundwater.	Would significantly increase the mobility of COC in soil through engineered recovery (e.g., vacuum extraction) and reduce the amount of COC in soil, thereby reducing the potential for human exposure. Would require treatability testing to determine site-specific effectiveness.	Technically implementable. May be difficult to apply in certain soil types and site areas. Would require specialized equipment, materials, and operating personnel; require significant amount of energy for system operation and maintenance; commercial vendors are available. Would require treatability or pilot studies to evaluate implementability and design criteria. Would require relatively large NAPL/groundwater extraction network and on-site long-term monitoring and maintenance of a NAPL/groundwater recovery and separation, groundwater treatment, and vapor treatment system.	High	Not Retained. Would require significant costs and long-term maintenance and operation.
Ex Situ Treatment	Treatment Post Removal	Treatment Post Removal	Treating soil by physical, chemical, biological, or thermal means to reduce the toxicity and volume of COC in soil.	Could reduce the volume of COC in soil, thereby reducing the potential for human exposure. Would require treatability testing to determine site-specific effectiveness.	Technically implementable. Would require deep soil excavation and on-site material management prior to any treatment.	High	Not Retained. Would not be practical to implement as a site-wide remedial technology due to the significant volume of source in deep soil and the site-specific hydrogeological conditions. Would create significant short-term risk associated with air emission and disturbance to local community.

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3. Free Phase NAPL							
No Further Action	No Further Action	No Further Action	No remedial measures or monitoring conducted. Would take account of changing conditions through the ongoing natural attenuation of COC in impacted medium.	No monitoring performed to track effectiveness.	Readily implementable.	Low	Not Retained.
Institutional Controls	Institutional Controls	Physical Access Restrictions	Administrative or institutional controls such as ordinances to restrict the installation of potable wells or require worker precautions when performing excavation or sewer work in the impacted area.	Would reduce, to a limited degree, the potential human exposure by potential receptors (e.g., sewer workers) to NAPL in certain areas. Could be used in conjunction with other remedial options and on a longer-term basis. Would require routine monitoring and maintenance.	Technically and administratively implementable. Would require property owner(s) agreement for off-site properties.	Low	Retained.
Containment	Engineered Barrier	Vertical Permeable Barrier without Hydraulic Control	Installing a permeable barrier (e.g., slurry wall) at strategic depths sufficient to retard the lateral movement of NAPL in subsurface while allow natural groundwater flow. This option would utilize the natural geological characteristics (i.e., the naturally developed bowls on top of the dense silty clay layer) beneath the site to retard NAPL movement.	NAPL has migrated offsite to several adjacent properties, perhaps negating the use of this technique except in combination with other remedial options. In certain areas, could reduce the long-term potential exposure to human receptors by interrupting the movement of the source of impact, i.e., NAPL. Post-construction maintenance and monitoring would be required.	Implementable in some areas. Would require specialized equipment, materials, and operating personnel; commercial vendors are available. May require management of excess volume of wastes associated with the barrier construction. Would not be effective for areas inaccessible for construction such as railroad right-of-ways, utility corridors, or in off-site areas.	Medium	Not Retained. Would not reduce the volume of source.
	Engineered Barrier	Vertical Low-Permeability Barrier with Hydraulic Control	Placing a low-permeability barrier (e.g., slurry wall or reactive wall) sufficient to retard the lateral movement of NAPL and groundwater in subsurface and reduce the mixing of NAPL with groundwater. This option would remove some NAPL as part of the hydraulic control and groundwater recovery.	NAPL has migrated offsite to several adjacent properties, perhaps negating the use of this technique except in combination with other remedial options. In certain areas, could reduce the long-term potential exposure to human receptors by interrupting the movement of the source of impact, i.e., NAPL. Post-construction maintenance and monitoring would be required.	Potentially implementable. Would require specialized equipment, materials, and operating personnel; commercial vendors are available. May require management of excess volume of wastes. Would not be effective for areas inaccessible for construction such as railroad right-of-ways, utility corridors, or off-site areas.	Medium to High	Not Retained. Would not be effective in source reduction.

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3. Free Phase NAPL (Continued)							
Removal	NAPL Recovery	Passive NAPL Recovery and Disposal	Removing NAPL by passive means (collection galleries and manual recovery in a batch mode). Passive NAPL removal would require disposal or recycling of the removed NAPL. May require on-site storage to separate NAPL from groundwater and the treatment and disposal of impacted groundwater.	Removal would reduce the amount of impact source (i.e., NAPL) in subsurface. Would require relatively long-term maintenance of recovery operation and the management and disposal of the recovered materials.	Implementable. Equipment, materials, and personnel are readily available. Difficult to implement in areas with underground utilities and structures, in roadways, and railroad right-of-ways. Would need access permission from property owners for off-site properties.	Low to Medium	Retained.
	NAPL Recovery	Active NAPL Recovery and Disposal	Removing NAPL (with groundwater) by active means (continuous pumping or extraction). Active NAPL removal would require disposal or recycling of the removed NAPL and groundwater. May require on-site facility to separate NAPL from groundwater and the treatment or disposal of impacted groundwater. Active NAPL removal would require on-site NAPL/groundwater separation and groundwater treatment system.	Removal would reduce the amount of impact source (i.e., NAPL) in subsurface. Would have limited impact in reducing off-site source and require long-term maintenance of recovery facilities and on-site groundwater treatment system, and the storage, transport and disposal of the recovered materials.	Implementable. Equipment, materials, and personnel are readily available. Difficult to implement in areas with underground utilities and structures, in roadways, and railroad right-of-ways. Would need access permission from property owners for off-site properties.	Medium to High	Not Retained. Would require long-term operation and maintenance, high costs, and high energy consumption.
***In Situ* Treatment**	Thermal	Electric Resistance Heating	Introducing steam to or raising the temperature of the impacted medium to enhance the mobility and recovery of NAPL and COC in soil and groundwater.	Would significantly increase the mobility of COC in soil through engineered recovery (e.g., vacuum extraction) and reduce the amount of COC in soil, thereby reducing the potential for human exposure. Would require treatability testing to determine site-specific effectiveness.	Technically implementable. May be difficult to apply in certain soil types and site areas. Would require specialized equipment, materials, and operating personnel; require significant amount of energy for system operation and maintenance; commercial vendors are available. Would require treatability or pilot studies to evaluate implementability and design criteria. Would require relatively large NAPL/groundwater extraction network and on-site long-term monitoring and maintenance of a NAPL/groundwater recovery and separation, groundwater treatment, and vapor treatment system.	High	Retained.
Ex Situ Treatment	Treatment Post Removal	Treatment Post NAPL Recovery	Relatively low volume of recoverable NAPL is anticipated. The treatment post NAPL recovery would be limited to the separation of NAPL from groundwater prior to its disposal. No treatment of NAPL is anticipated to be necessary.	Not Applicable	Not Applicable	Not Applicable	Not Retained. Recovered NAPL would be disposed or beneficially used if possible. No treatment of NAPL is anticipated to be necessary.

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4. Groundwater							
No Further Action	No Further Action	No Further Action	No remedial measures or monitoring conducted. Would take account of changing conditions through the ongoing natural attenuation of COC in groundwater.	No monitoring performed to track effectiveness.	Readily implementable.	Low	Not Retained.
Institutional Controls	Institutional Controls	Groundwater Use Restrictions	Administrative or institutional controls such as ordinances to restrict the installation of domestic wells for potable purposes.	Would reduce potential human exposure to COC in groundwater by potential receptors. Could be used on a longer-term basis. Would require routine monitoring and maintenance.	Technically and administratively implementable. Would require property owner(s) agreement for off-site properties.	Low	Retained.
Monitoring	Long-term Groundwater Monitoring	Long-term Groundwater Monitoring	Monitoring of natural physical, chemical, and/or biological processes that are continuing to break down soluble COC in groundwater.	Would utilize natural processes to reduce potential exposure to human receptors to COC in soil over time (e.g., biodegradation and dilution). Monitoring would be performed to track effectiveness and rate of recovery.	Readily implementable and minimally intrusive. Activities would be limited to groundwater sampling from monitoring wells. Materials, personnel, and equipment are readily available. May require access agreement to off-site locations.	Low to Medium	Retained.
Containment	Engineered Barrier	Vertical Low-Permeability Barrier with Hydraulic Control	Placing a low-permeability barrier (e.g., slurry wall or reactive wall) sufficient to retard the lateral movement of NAPL and groundwater in subsurface and reduce the mixing of NAPL with groundwater. This option would remove some NAPL as part of the hydraulic control and groundwater recovery.	Would reduce the source (i.e., NAPL) of groundwater impact. NAPL has migrated offsite to several adjacent properties, perhaps negating the use of this technique except in combination with other remedial options. In certain areas, could reduce the long-term potential exposure to human receptors by interrupting the movement of the source of impact, i.e., NAPL. Post-construction maintenance and monitoring would be required.	Potentially implementable. Would require specialized equipment, materials, and operating personnel; commercial vendors are available. May require management of excess volume of wastes. Would not be effective for areas inaccessible for construction such as railroad right-of-ways, utility corridors, or off-site areas.	Medium to High	Not Retained. This technology would not likely improve the groundwater plume stability due to the significant presence of NAPL on- and off-site.
Removal	Groundwater Removal and Treatment	Pump-and-Treat	Removing impacted groundwater by pumping and treating impacted groundwater. Would require discharge of treated water to a POTW or a surface water body via a permit. Would require the construction of a wastewater treatment plant and long-term monitoring, reporting, and maintenance.	Pump-and-treat would reduce the amount of COC in groundwater to some extent. Would require long-term operation and maintenance of recovery wells, treatment plant, and the discharge of the treated water and spent treatment materials such as granular activated carbon. Would not likely be effective in long-term risk reduction due to the amount of NAPL present at the Site.	Implementable. Equipment, materials, and personnel are readily available. Due to the extent of NAPL present at the Site acting as the source of soluble COC in groundwater, pump-and-treat impacted groundwater would not provide long-term effectiveness.	Medium to High	Not Retained. Would have minimal effect with high energy consumption and long-term operation and maintenance costs.
***In Situ* Treatment**	Thermal	Electric Resistance Heating	Introducing steam to or raising the temperature of the impacted medium to enhance the mobility and recovery of NAPL and COC in soil and groundwater.	Would significantly increase the mobility of COC in groundwater through engineered recovery (e.g., vacuum extraction) and reduce the amount of COC in groundwater, thereby reducing the potential for human exposure. Would require treatability testing to determine site-specific effectiveness.	Technically implementable. May be difficult to apply in certain soil types and site areas. Would require specialized equipment, materials, and operating personnel; require significant amount of energy for system operation and maintenance; commercial vendors are available. Would require treatability or pilot studies to evaluate implementability and design criteria. Would require relatively large NAPL/groundwater extraction network and on-site long-term monitoring and maintenance of a NAPL/groundwater recovery and separation, groundwater treatment, and vapor treatment system.	High	Not Retained.
Ex Situ Treatment	Treatment Post Pump-and-Treat	Treatment Post Pump-and-Treat	Because Pump-and-Treat technology is not retained. Relatively low volume of impacted groundwater is anticipated to be recovered through other processes. The treatment post pump-and-treat would be limited. See Process Water Management under Item 5 for additional information.	See Process Water Management under Item 5 for additional information.	See Process Water Management under Item 5 for additional information.	See Process Water Management under Item 5 for additional information.	Not Retained.

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5. Auxiliary Technology and Options for Managing Removed Material							
Solids Dewatering	Mechanical Dewatering	Blending with Absorbent	Blending wet materials with bulking agents such as fly ash, wheat straw, Quicklime.	Effectiveness to soils with moderate amount of liquid. Would result in increased material volume for disposal or processing.	Implementable. Equipment, materials, and operating personnel are available. May result in temporary emission concerns during the blending action.	Low to Medium	Retained.
	Gravity Dewatering	Stockpile	Material is placed in a stockpile, and free liquids are allowed to drain off and are collected.	Reliable. Effectiveness primarily applies to excavated saturated soils.	Implementable. Equipment, materials, and operating personnel are readily available. Would require adequate space for dewatering structures.	Low	Retained.
Storm water Management	Collection with Treatment	Collection and Treatment	Collect storm water that comes in contact with impacted soil. Collected water would be treated on-site or off-site or directly discharged to a POTW or a surface water body or used as a reagent for treatment of impacted soil.	Reliable. Would not require long-term operations and maintenance.	Implementable. Equipment, materials, and operating personnel are available. Would require adequate space for treatment equipment and permit for processing water.	Medium	Retained; surface impact at site is minimal; would design remedial action to avoid or minimize contact by storm water to impacted material.
	Diversion	Diversion	Divert storm water away from impacted soil. Some pretreatment may be necessary to remove solids.	Reliable. Would not require long-term operations and maintenance.	Implementable. Equipment, materials, and operating personnel are available. Requires adequate space and topography for effective drainage.	Low to Medium	Retained.
Process Water Management	Treatment	On-site Treatment Plant	Process water is pumped to a water treatment plant constructed on-site and treated to meet discharge requirements.	Reliable. Already implemented at the Site during previous and ongoing interim remedial activities. Would be effective for permanent removal of COC from the process water. Would not require long-term operations and maintenance.	Implementable. Equipment, materials, and operating personnel are available. Would require adequate space for treatment equipment.	Medium	Retained.
Oversize Material and Debris	Mechanical	Mechanical Rendering of Oversize Materials	Reducing over oversized materials using conventional mechanical means or debris post removal or rendering removed materials with solid amendments such as Portland cement to meeting disposal requirements.	Reliable. Already implemented in a great number of sites.	Implementable. Would require the acceptance of the disposal facility. May require community acceptance with respect to noise and emission potentials.	Low	Retained.
Transportation	Truck	On-site Transport or Off-site Trucking	Transporting removed soils on site for treatment or to appropriate off-site treatment/disposal facility via truck. May require stabilization or dewatering before transportation.	Reliable.	Implementable; for off-site transport, as long as there is an appropriate number of permitted trucks with the necessary availability and capacity. May require community acceptance for off-site route to disposal facility.	Low	Retained.
Disposal	Off-site Disposal	Off-site Permitted Facility	Transporting excavated soils or NAPL to permitted disposal facility(ies). May require stabilization or dewatering before offsite transport and disposal.	Would be effective for permanent disposition of removed soil from the site, not effective in reducing the amount of COC in the environment. Risks of exposure and transportation accidents increase with significantly increased haul distances of materials. Would have the exposure potential to facility operators/workers to elevated levels of airborne COC from NAPL or NAPL-containing soils during material handling.	Implementable so long as there are appropriate permitted offsite facility (ies) with the necessary availability and capacity, and an adequate means of transport is available.	Medium	Retained.
Beneficial Reuse	Beneficial Reuse	Beneficial Reuse	Using treated material in beneficial ways, such as cover material for solid waste landfills, or converting it into useable products such as cement, lightweight aggregate, or asphalts.	Would be effective for permanent placement of treated soils or reuse of NAPL. Would require further testing for converting into reusable materials. May require regulatory approval and community acceptance for the material reuse.	Potentially implementable, but may require specialized equipment and materials. Operating personnel are likely readily available. Would need to confirm viable cost-effective uses (e.g., potential markets).	Medium	Retained.

Remedial Alternatives Evaluation
Aberdeen Former Manufactured Gas Plant, Aberdeen, SD

Table 3. Development of Remedial Alternatives

Evaluation Criteria	Remedial Alternative Description	Remedial Technologies/ Process Options					Comments
		Source in Shallow Soil 0 to 15 ft bgs	Source in Deep Soil > 15 ft bgs	NAPL (Free Phase)	Groundwater	Management of Removed Materials	
1	Institutional Control with Long-term Groundwater Monitoring	Institutional Control	Institutional Control	Institutional Control	Institutional Control/ Long-term Monitoring	NA	Limits exposure to soil and groundwater impact through access controls (e.g., perimeter fence) and use restrictions (e.g., groundwater use restriction); performs long-term groundwater monitoring
2	Institutional Control with Passive NAPL Recovery and Long-term Groundwater Monitoring	Institutional Control	Institutional Control	Institutional Control/ Passive NAPL Collection (Collection Galleries)	Institutional Control/Long-term Monitoring	NAPL Disposal or Reuse/ Water Management/ Soil Stabilization and Off-site Disposal	Limits exposure to soil and groundwater impact through access controls (e.g., perimeter fence) and use restrictions (e.g., groundwater use restriction); performs long-term groundwater monitoring; provides some retardation of NAPL movement in subsurface through NAPL collection; removes limited volume of NAPL using passive means
3	Targeted Source Removal and Stabilization/Disposal with Institutional Control, Passive NAPL Recovery, and Long-term Groundwater Monitoring	Institutional Control/ Excavation (MGP Structures and limited source areas) and Backfilling	Institutional Control	Institutional Control/ Passive NAPL Collection (Collection Galleries)	Institutional Control/ Long-term Monitoring	NAPL Disposal or Reuse/ Water Management/Soil Stabilization or Treatment and Off-site Disposal or Reuse	Limits exposure to soil and groundwater impact through access controls (e.g., perimeter fence) and use restrictions (e.g., groundwater use restriction); performs long-term groundwater monitoring; provides some retardation of NAPL movement in subsurface through NAPL collection; removes limited volume of NAPL using passive means; provides additional source reduction through excavation; likely requires material rendering or treatment prior to reuse or off-site disposal

Note:

Alternative No. 1 is the baseline alternative and is part of Alternatives 2 and 3. Alternative 1 includes the operation and maintenance of the off-site groundwater treatment system, soil gas monitoring (as needed), and the maintenance of the existing site security perimeter fence.

Remedial Alternatives Evaluation
Aberdeen Former Manufactured Gas Plant, Aberdeen, SD

Table 4. Comprehensive Evaluation of Candidate Remedial Alternatives

Evaluation Criteria	Candidate Remedial Alternatives		
	Alternative 1	Alternative 2	Alternative 3
1. Overall Protection of Human Health and the Environment	Medium	Medium	Medium
2. Compliance with ARARs	High	High	High
3. Long-term Effectiveness and Performance	Low	Medium	Medium
4. Reduction of Toxicity, Mobility, or Volume through Treatment	Low	Medium	Medium
5. Short-term Effectiveness (Impacts)	High	Medium	Low
6. Implementability	High	Medium	Medium
7. Cost	High	Medium	Low
8. State Acceptance	Not Rated	Not Rated	Not Rated
9. Community Acceptance	High	Medium	Low
10. Green Remediation Considerations	High	Medium	Low

Notes:

1. Each alternative was assigned a rating level ranging from Low to High for each criterion, with "Low" representing the low end of the performance scale, and "High" representing the high end of the scale. The rating was intended to reflect the relative comparisons among the alternatives considered, as well as the extent to which an alternative satisfies each criterion.

2. Evaluation criteria are described in Section 6 of the RAE.

3. The rating for Short-term Effectiveness considers the degree and extent of the potential impacts associated with each alternative such as fugitive emission or noise. A "Low" rating suggests a higher potential impact.

4. The rating for State Acceptance was not performed for the screening of remedial alternatives. The selection of any alternative will be subject to the review and approval by the State.

5. Community acceptance is rated based on the potential short-term effects resulted from construction activities and past project experience in the area.

Remedial Alternatives Evaluation
Aberdeen Former Manufactured Gas Plant, Aberdeen, SD

Table 5. Federal and State Potentially Applicable or Relevant and Appropriate Requirements and To Be Considered

Authority	Citation	Requirement Synopsis and Rationale	ARAR Type	Applicability to Aberdeen MGP Site
Federal Potential ARARs and TBCs				
Safe Drinking Water Act of 1974, Amended in 1986 and 1996 42 USC 300g	40 CFR Part 141.60-63 National Primary Drinking Water Regulations	Establish health based standards for public water systems (maximum contaminant levels)	Chemical	Applicable, if groundwater in the area is used for potable purposes. The shallow aquifer beneath the site (Foot Creek Aquifer) is reported to be highly mineralized and unsuitable for potable uses. Elm River, approximately 6 miles northeast of the site, is the drinking water source for the City of Aberdeen.
Safe Drinking Water Act of 1974, Amended in 1986 and 1996 42 USC 300g	40 CFR Part 143.03 National Secondary Drinking Water Standards	Establish aesthetic based standards for public water systems (maximum contaminant levels)	Chemical	Applicable, if groundwater in the area is used for potable purposes. The shallow aquifer beneath the site (Foot Creek Aquifer) is reported to be highly mineralized and unsuitable for potable uses. Elm River, approximately 6 miles northeast of the site, is the drinking water source for the City of Aberdeen.
Safe Drinking Water Act of 1974, Amended in 1986 and 1996 42 USC 300g	40 CFR Part 141.50 Maximum Contaminant Level Goals	Establish drinking water quality goals set at levels of unknown or anticipated adverse health effects, with an adequate margin of safety	Chemical	Applicable, if groundwater in the area is used for potable purposes.
Clean Water Act 33 USC §§ 1251-1387	40 CFR Part 125.1-3 Toxic Pollutant Effluent Standards	Establishes criteria and standards for technology-based requirements in permits under the Clean Water Act	Chemical	Relevant and appropriate; Treatment of excavation water and/or process water will require pre-treatment prior to being discharged to Publicly Owned Treatment Works (POTW) or directly to a surface water body such as Moccasin Creek or for potential reuse.
Resource Conservation and Recovery Act (RCRA) 42 USC §6901 et seq	40 CFR 264.94 and 264.100 Alternate Concentration Limits (ACLs) for Groundwater	Risk assessment may be used to develop risk-based Remediation Goals (RGs) under CERCLA or Target Cleanup Levels (TCLs) (CERCLA Section 121) or Alternate Concentration Limits (ACLs) under RCRA. Risk-based RGs, TCLs, or ACLs should be developed after the baseline risk assessment has been performed incorporating site-specific factors in the calculations (if conditions for ACLs are met at areas of potential applicability).	Chemical	ARAR
Endangered Species Act of 1973, as amended, 16 USC §§ 1531-1544	50 CFR Part 17 Endangered and Threatened Wildlife and Plants 50 CFR Part 402 Interagency Cooperation	Identifies those species of wildlife and plants determined to be endangered or threatened with extinction. Federal agencies are required to verify that any action authorized, funded, or carried out by them is not likely to jeopardize the continued existence of any endangered species or threatened species, or result in the destruction or adverse modification of a critical habitat of such species, unless such agency has been granted an appropriate exemption by the Endangered Species Committee (16 USC § 1536).	Location	ARAR
Migratory Bird Treaty Act 16 USC §§ 703, et seq.	50 CFR Part 10 General Provisions	Establishes a federal responsibility for the protection of the international migratory bird resource and requires continued consultation with the U.S. Fish and Wildlife Service during remedial design and remedial construction to ensure remedial action at the Site does not unnecessarily impact migratory birds.	Location	ARAR
Bald Eagle Protection Act 16 USC §§ 668, et seq.	50 CFR Part 17 Endangered and Threatened Wildlife and Plants	Establishes a federal responsibility for the protection of bold and golden eagles and requires continued consultation with the U.S. Fish and Wildlife Service during remedial design and remedial construction to ensure remedial action at the Site does not unnecessarily impact migratory birds.	Location	ARAR
Natural Resources Conservation Service 7 USC § 4201 et seq.	7 CFR Part 658 Farmland Protection Policy Act of 1981	Regulates the extent to which federal programs contribute to the unnecessary and irreversible conversion of farmland to non-agricultural uses.	Location	ARAR
National Historic Preservation Act 16 USC § 470 et seq.	36 CFR Part 65 Natural Historic Landmarks Program 36 CFR Part 800 Protection of Historic Properties	Remedial actions must take into account effect on properties in or eligible for inclusion on the National Registry of Historic Places.	Location	No know historic properties or landmarks exist on Site or nearby. Becomes ARAR if activities will affect historic properties or landmarks in or near the Site.
Archeological and Historical Preservation Act 16 USC 469 et seq.	40 CFR Part 6.301(c)	Establishes procedures to provide for preservation of historical and archaeological data which might be destroyed through alteration of terrain as a result of a federal construction project for a federal licensed activity or program.	Location	Historic or archaeological value is currently unknown. Applicability will be determined during the remedial design phase.

Remedial Alternatives Evaluation
Aberdeen Former Manufactured Gas Plant, Aberdeen, SD

Table 5. Federal and State Potentially Applicable or Relevant and Appropriate Requirements and To Be Considereds

Authority	Citation	Requirement Synopsis and Rationale	ARAR Type	Applicability to Aberdeen MGP Site
Federal Potentially ARARs and TBCs (Cont'd)				
Native American Graves Protection and Repatriation Act (NAGPR) 25 USC § 3001 et seq.	43 CFR Part 10 Native American Graves Protection and Repatriation Regulations	The NAGPR act requires federal agencies and museums with possession or control over Native American human remains and associated funerary objects to compile an inventory of such items. It requires federal agencies and museums with possession or control over Native American non-associated funerary objects, sacred objects, or objects of cultural patrimony to provide a written summary of such objects. It prescribes when a federal agency or museum must return Native American cultural items.	Location	Applicable, if Native American remains or funerary objects are present at the Site.
Executive Order 11988 on Floodplains Management 42 USC 7401	40 CFR 6.302(b)	Requires federal agencies to evaluate the potential effects of actions they may take in a floodplain to avoid, to the extent possible, the adverse impacts associated with direct and indirect development of a floodplain.	Location	Not applicable; the Site is located outside of the 100-year floodplain.
Clean Air Act 42 USC § 7401 et seq.	40 CFR Part 50 National Primary and Secondary Ambient Air Quality Standards	Establishes ambient air quality standards for protection of public health.	Action	ARAR
Clean Air Act 42 USC § 7401 et seq.	40 CFR Part 52 Approval and Promulgation of Implementation Plans	Establishes filing requirements and standards for constituent emission rates in accordance with National Ambient Air Quality Standards (NAAQS). To be considered for remedial alternatives.	Action	ARAR
Clean Air Act 42 USC § 7401 et seq.	40 CFR Part 61 National Emission Standards for Hazardous Air Pollutants	Establishes regulatory standards for specific air pollutants	Action	ARAR
Resource Conservation and Recovery Act 42 USC §§ 6901-6992k	40 CFR Part 261 Identification and Listing of Hazardous Waste	Defines threshold levels and criteria to determine whether material is hazardous waste.	Action	ARAR
Solid Waste Disposal Act (as amended) 42 USC §§ 6901-6992k	40 CFR Part 262 Standards Applicable to Generators of Hazardous Waste	Includes manifest, record-keeping and other requirements applicable to generators of hazardous waste.	Action	ARAR
Solid Waste Disposal Act (as amended) 42 USC §§ 6901-6992k	40 CFR Part 263 Standards Applicable to Transporters of Hazardous Waste	Sets forth standards for transporters of hazardous wastes, including the receipt of an EPA identification number and manifesting requirements.	Action	ARAR
Solid Waste Disposal Act (as amended) 42 USC §§ 6901-6992k	40 CFR Parts 264 and 265 Standards for Owners and Operators of Hazardous Waste Treatment and Storage Facilities	Includes management standards including record keeping, requirements for particular units such as tanks or containers, and other requirements applicable to owners and operators of hazardous waste treatment, storage and disposal facilities.	Action	ARAR
Solid Waste Disposal Act (as amended) 42 USC §§ 6901-6992k	40 CFR Part 268 Land Disposal Restrictions	Places land disposal restrictions, including treatment standards and related testing, tracking and record keeping requirements on hazardous waste.	Action	ARAR
Clean Water Act 33 USC §§ 1251-1387	40 CFR Part 122.44 (a,e,i) Establishing Limitations, Standards, and Other Permit Conditions	Best available technology and monitoring requirements.	Action	ARAR
Clean Water Act 33 USC §§ 1251-1387	40 CFR Part 125 Criteria and Standards for the National Pollutant Discharge Elimination System	Establishes criteria and standards for imposing technology-based treatment requirements.	Action	ARAR
Clean Water Act 33 USC §§ 1251-1387	40 CFR Part 403 General Pre-Treatment Regulations for Existing and New Sources of Pollution 40 CFR Part 136 Guidelines Establishing Test Procedures for the Analysis of Pollutants	Establishes responsibilities of Federal, State, and local government, industry and the public to implement National Pretreatment Standards to control pollutants which pass through or interfere with treatment processes in Publicly Owned Treatment Works (POTWs). Provides guidelines establishing test procedures for the analysis of pollutants.	Action	ARAR
Transportation of Hazardous Materials 49 USC Subtitle III, Ch. 51, §§ 5101-5127	49 CFR Part 107 Hazardous Materials Program Procedures 49 CFR Part 171 General Information, Regulations and Definitions 49 CFR Part 172 Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, and Training Requirements	Transportation and handling requirements for hazardous materials, including procedures for the packaging, labeling, manifesting and transporting of hazardous materials. This would apply to alternatives where impacted materials that are identified as hazardous wastes are transported from the Site.	Action	ARAR

Remedial Alternatives Evaluation
Aberdeen Former Manufactured Gas Plant, Aberdeen, SD

Table 5. Federal and State Potentially Applicable or Relevant and Appropriate Requirements and To Be Considereds

Authority	Citation	Requirement Synopsis and Rationale	ARAR Type	Applicability to Aberdeen MGP Site
Federal Potentially ARARs and TBCs (Cont'd)				
Energy Policy Act of 2005 42 USC 15801	NA	Promotes energy conservation nationwide	Action	TBC; to be considered during the evaluation of remedial alternatives.
Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites (2008)	United States Environmental Protection Agency Office of Solid Waste and Emergency Response	Describes and promotes innovative cleanup strategies that restore contaminated sites to productive use, reduce associated costs, and promote environmental stewardship.	Action	TBC; to be considered during the evaluation of remedial alternatives
Guidance for Conducting Remedial Investigation and Feasibility Studies Under CERCLA (1988)(Interim Final)	United States Environmental Protection Agency Office of Emergency and Remedial Response	Describes methodologies that Superfund program has established for characterizing the nature and extent of risks posed by uncontrolled hazardous waste sites and for evaluating potential remedial options; sets preferences to those technologies that would destroy COCs or eliminate risk rather than those would transfer risk through physical means such as landfill disposal.	Action	TBC; to be considered during the evaluation of remedial alternatives. Note the Site is not a Superfund site.
State Potentially ARARs and TBCs				
South Dakota Codified Laws 34A-6 Solid Waste Management	74:27:17:01 Minimum Requirements for Collection, Transportation, Storage, and Processing	Establish the minimum requirements for handling solid wastes.	Action	ARAR, if impacted soil and debris from the site are designated non-hazardous wastes.
South Dakota Codified Laws 34A-11-8 Rules Identifying characteristics and listing hazardous wastes	74:28:22:01 Identification and Listing of Hazardous Wastes	Identifies a listing of hazardous waste which includes the Federal listing under 40 CFR Parts 261.1 through 261.41. Impacted soil, sludge, and groundwater to be generated and rendered, as necessary, from the Aberdeen MGP Site has been designated non-hazardous per SD DENR Waste Management Program project memorandum dated July 9, 2009.	Action	ARAR
South Dakota Codified Laws 34A-11-9 Rules governing management of hazardous wastes	74:28:24:01 Standards for Transporters	Establishes standards for transporters of hazardous waste. State adopts 40 CFR Parts 263.10 through 263.31	Action	ARAR
South Dakota Codified Laws 34A-1 Air Pollution Control	74:36:01-18 Air Pollution Control Regulations	Establishes permit requirements for construction, amendment, and operation of air discharge services.	Action	Relevant and appropriate, when ex situ soil treatment technology is considered as part of the remedial alternatives.
South Dakota Codified Laws 34A-2 Water Pollution Control	74:52 Surface Water Discharge Permits	Establish conditions and permit requirements for discharging to surface water	Action	Applicable, when wastewater treatment and discharge of effluent are considered as part of the remedial alternatives.
South Dakota Codified Laws 34A-2 Water Pollution Control	74:53:01 Individual and Small On-site Wastewater Systems 74:53:02 Certification of Installers of Individual and Small On-site Wastewater	Establishes requirements for individual or small on-site wastewater treatment systems.	Action	Applicable, when an on-site wastewater treatment plant is considered as part of the remedial alternatives.
South Dakota Codified Laws 34A-2-11 Water Quality Standards	74:54:01 Groundwater Quality Standards '74:54:04 Standards for groundwater of 10,000 mg/L Total Dissolved Solids concentration or less	Defines ground water classifications by beneficial use and sets chemical standards.	Chemical/ Action	Relevant and appropriate, to the extent that typical MGP constituents include volatile and semi-volatile hydrocarbons such as BTEX and PAHs.
South Dakota Codified Laws 34A-2-2 Water Pollution Control 34A-2-12 Regulated Substance Discharges	74:56:05 Remediation Criteria for Petroleum-contaminated Soils	Establishes requirements for the assessment and remediation of soil impacted with petroleum products.	Chemical/ Action	Relevant and appropriate, to the extent that typical MGP constituents include volatile and semi-volatile hydrocarbons such as BTEX and PAHs.

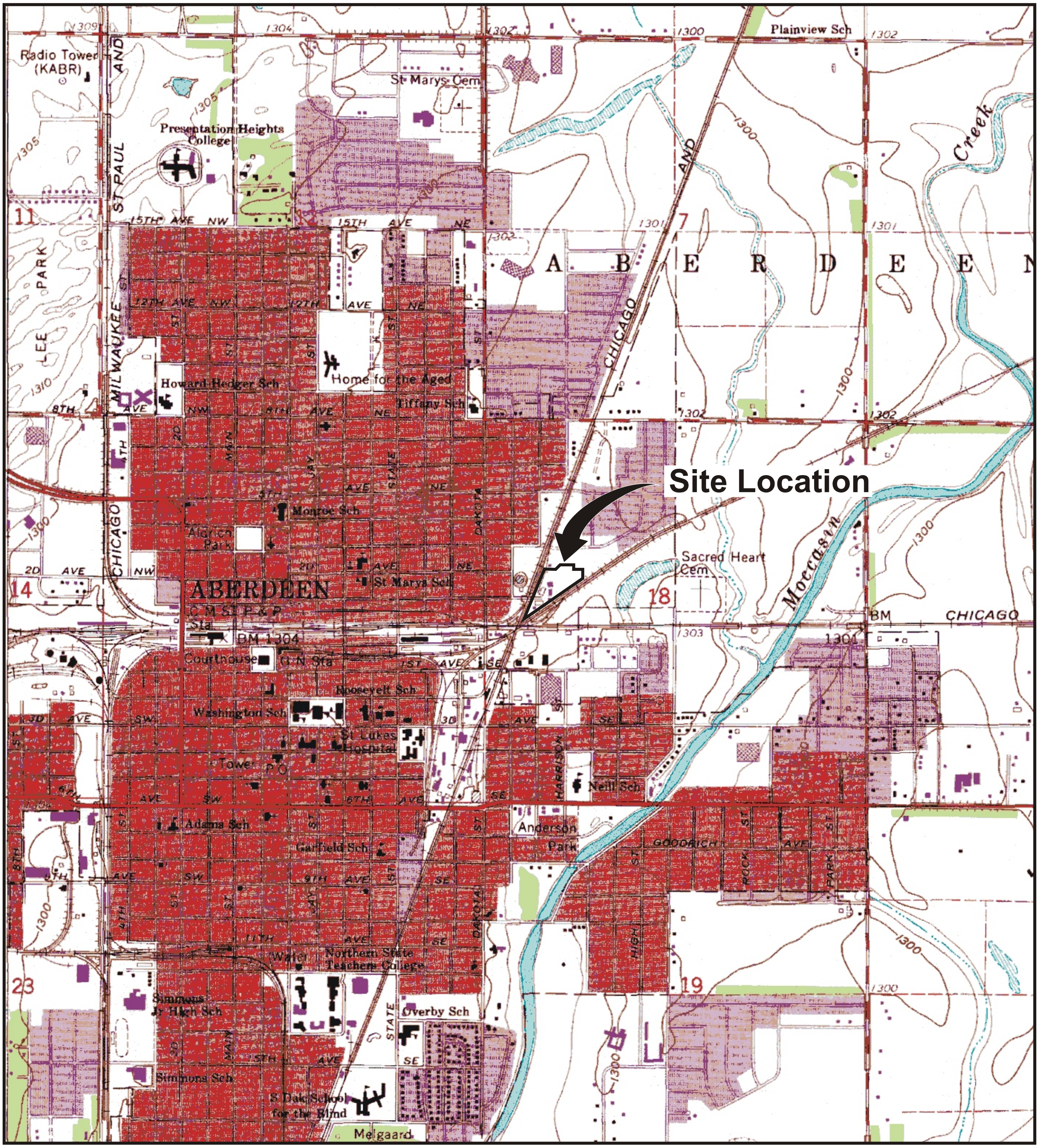
Remedial Alternatives Evaluation
Aberdeen Former Manufactured Gas Plant, Aberdeen, SD

Table 6. Cost Evaluation of Candidate Remedial Alternatives

Evaluation Criteria	Remedial Alternative Description	Remedial Technologies/ Process Options Cost Estimates (Thousand $)					Estimated Cost
		Source in Shallow Soil 0 to 15 ft bgs	Source in Deep Soil > 15 ft bgs	NAPL (Separate Phase)	Groundwater	Management of Removed Materials	
1	Institutional Control with Long-term Groundwater Monitoring	Institutional Control	Institutional Control	Institutional Control	Institutional Control/ Long-term Monitoring	NA	$ 3,210,000
2	Institutional Control with Passive NAPL Recovery and Long-term Groundwater Monitoring	Institutional Control	Institutional Control	Institutional Control/ Passive NAPL Collection (Collection Galleries)	Institutional Control/Long-term Monitoring	NAPL Disposal or Reuse/ Water Management/ Soil Stabilization and Off-site Disposal	$13,960,000
3	Targeted Source Removal and Stabilization/Disposal with Institutional Control, Passive NAPL Recovery, and Long-term Groundwater Monitoring	Institutional Control/ Excavation (MGP Structures and limited source areas) and Backfilling	Institutional Control	Institutional Control/ Passive NAPL Collection (Collection Galleries)	Institutional Control/ Long-term Monitoring	NAPL Disposal or Reuse/ Water Management/Soil Stabilization or Treatment and Off-site Disposal or Reuse	$27,100,000

ARCADIS

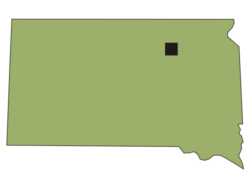
Figures



REFERENCE: BASE MAP USGS 7.5 MIN. QUAD., ABERDEEN EAST, SOUTH DAKOTA, 1960, PHOTOREVISED 1978.

2000' 0 2000'

Approximate Scale: 1" = 2000'



Area Location

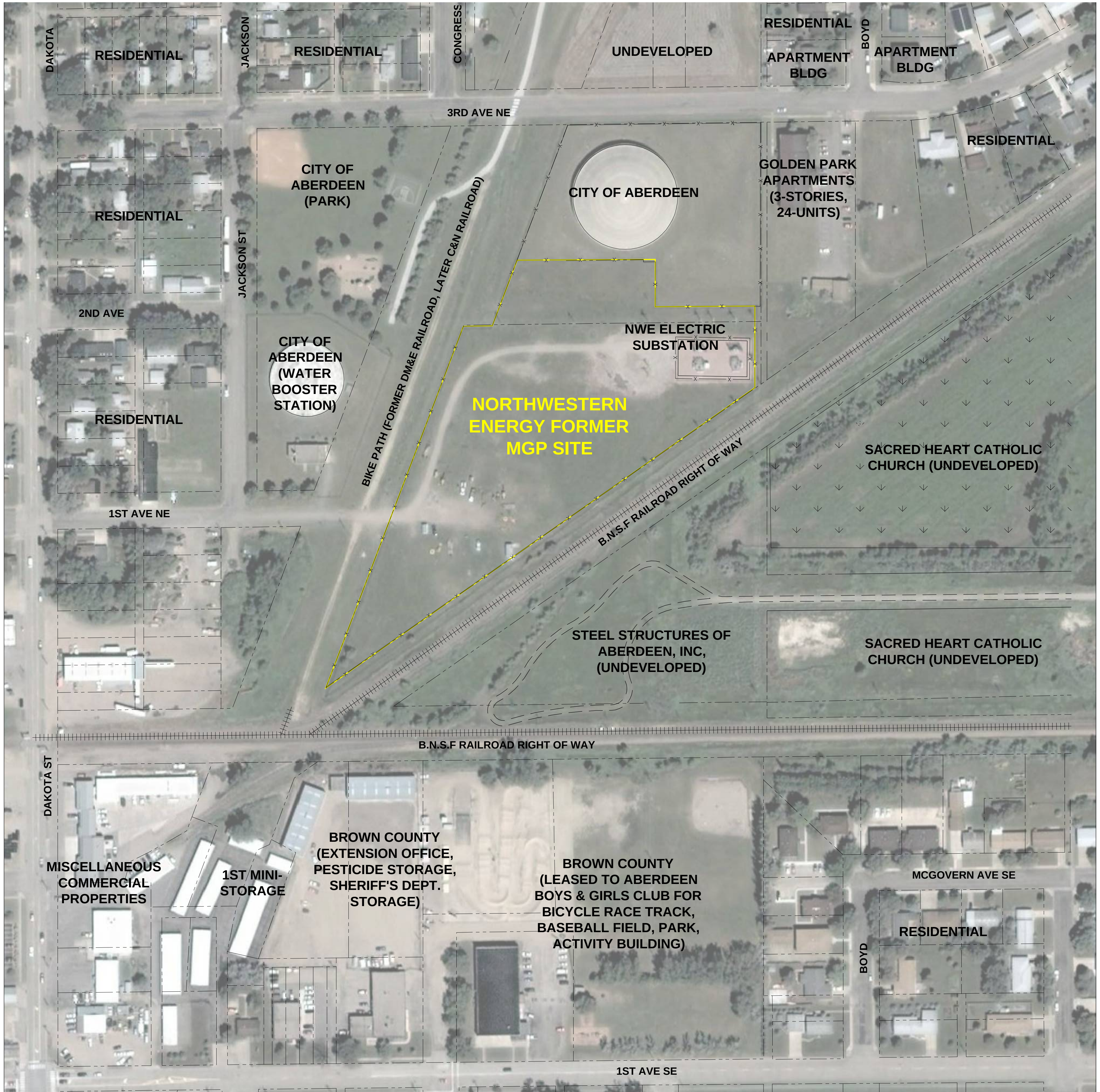
NORTHWESTERN ENERGY
FORMER MANUFACTURED GAS PLANT SITE
ABERDEEN, SOUTH DAKOTA

SITE LOCATION MAP

ARCADIS

FIGURE
1

02/10/09 SYRACUSE, NY-ENV/CAD-DJH
B0014505/0000/04000/CDR/14505N01.CDR



LEGEND:

- PROPERTY BOUNDARY
- FENCE

0 100' 200'
GRAPHIC SCALE

NORTHWESTERN ENERGY
ABERDEEN, SOUTH DAKOTA
FORMER MANUFACTURED GAS PLANT SITE

SITE FEATURES AND SURROUNDING PROPERTY USES

ARCADIS

FIGURE
2

CITY:(Reqd) DIV/GROUP:(Reqd) DB:(Reqd) LD:(Opt) PIC:(Opt) PM:(Reqd) TM:(Opt) LYR:(Opt)ON=*;OFF=*REF*
G:\ENVCAD\SYRACUSE\ACT\B0014505\0000\04200\DWG\14505G02.dwg LAYOUT: 2 SAVED: 3/4/2010 1:34 PM ACADVER: 17.0S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 3/4/2010 1:57 PM BY: KOWALCZYK, STEVE
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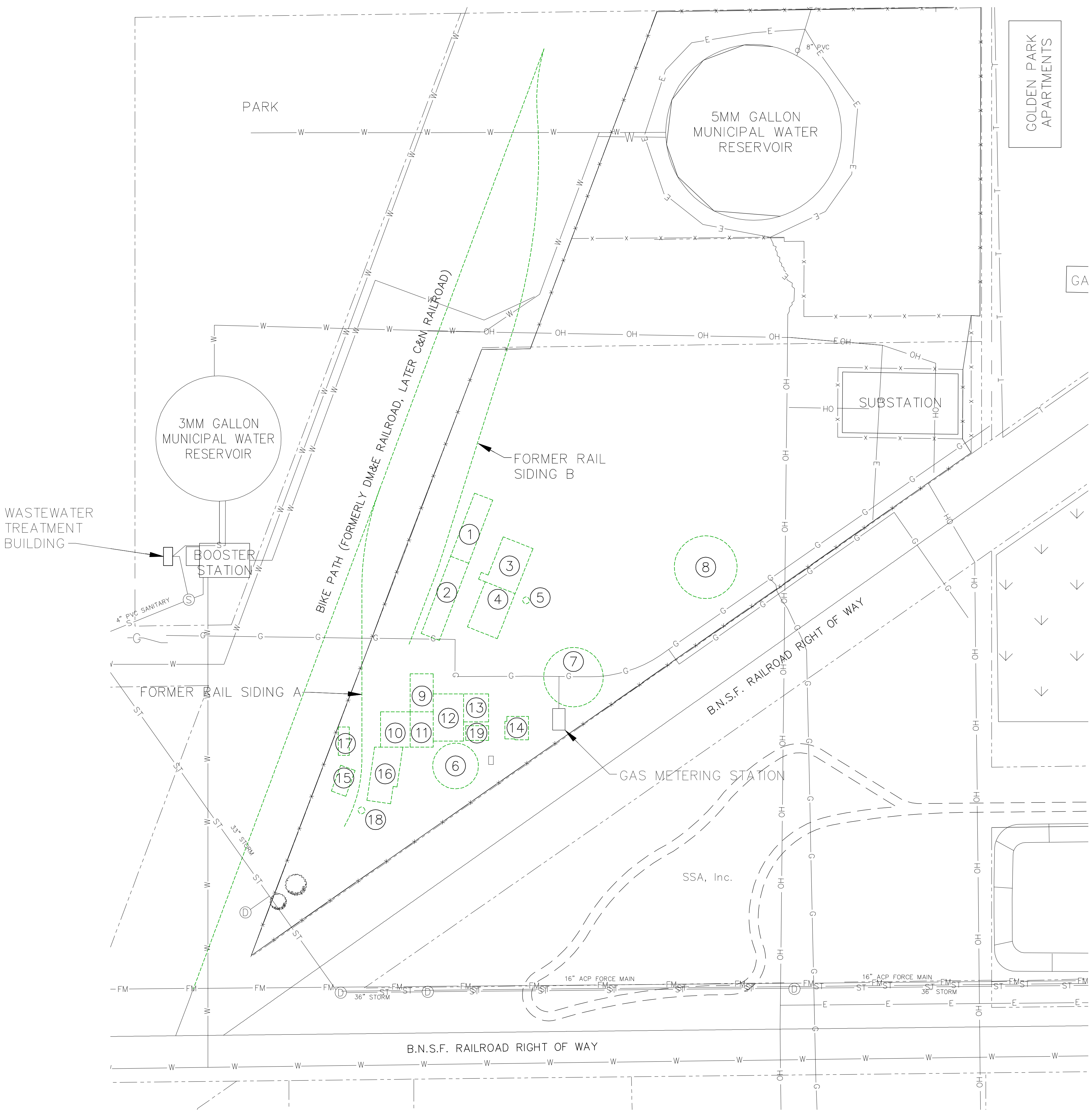
14505X01



MGP BUILDING LEGEND:

1. COAL BINS
2. COKE BINS
3. ENGINE ROOM #2 (POST–1917
4. GENERATOR ROOM #2 (POST–1917)
5. ARTESIAN WELL
6. GASOMETER #1
7. GASOMETER #2
8. GASOMETER #3
9. REPAIR SHOP
10. BOILER ROOM #1 (PRE–1917)
11. GENERATOR ROOM #1 (PRE–1917)
12. PURIFIER ROOM
13. OFFICE
14. STORAGE
15. WATER RESERVOIR
16. COAL SHED (PRE–1917)
17. CRUDE OIL TANK
18. PRODUCTION WELL
19. METER ROOM

LEGEND:

— — —	PROPERTY BOUNDARY
—x—x—	FENCE
++++++	RAILROAD TRACKS
—G—	NATURAL GAS
—OH—	OVERHEAD ELECTRIC
—E—	BURIED ELECTRIC
—T—	QWEST COMMUNICATIONS LINE
—W—	CITY WATER
—FM—	FORCEMAIN
—S—	SANITARY SEWER
—ST—	STORM SEWER
- - - (green)	APPROXIMATE LOCATION OF HISTORICAL STRUCTURES

0 60' 120'
GRAPHIC SCALE

NORTHWESTERN ENERGY
ABERDEEN, SOUTH DAKOTA
FORMER MANUFACTURED GAS PLANT SITE

CURRENT AND HISTORICAL MGP FEATURES

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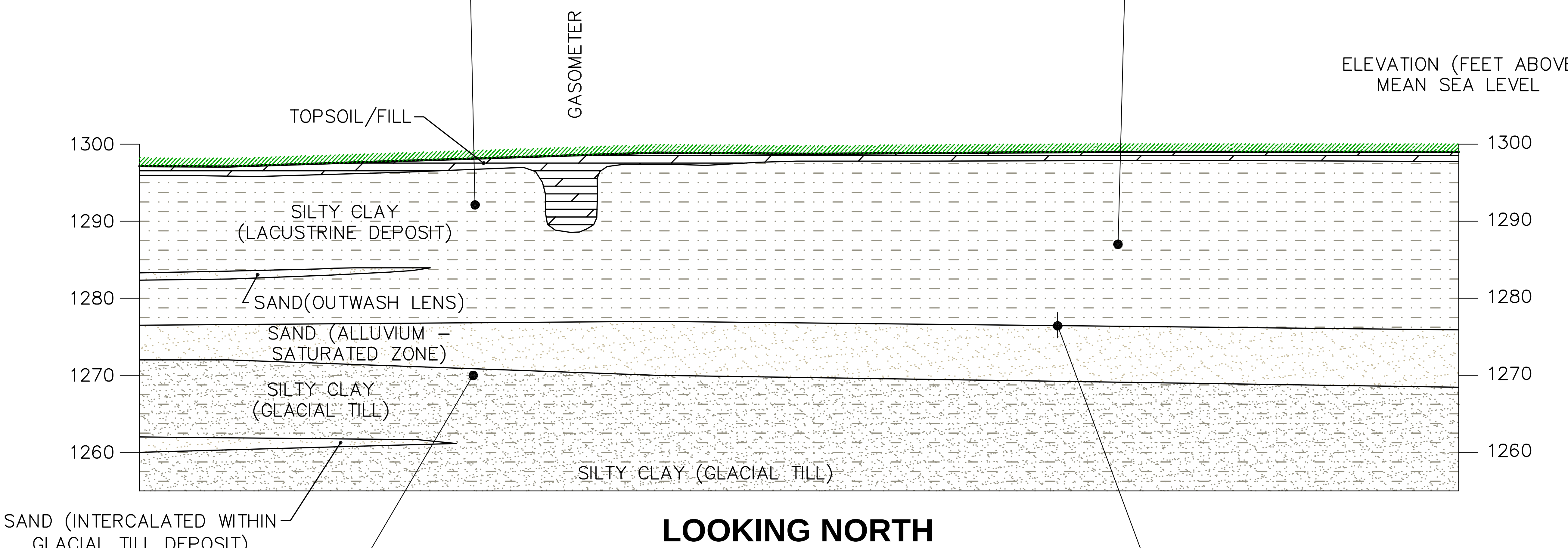
FIGURE
3

Geotechnical Sample BC(5–7)	
Bulk density	1.41 g/cc=88 lb/ft3=2.03 ton/yd3
Fat Clay (CH)	
Moisture Content	38.5%
Liquid Limit	59
Plasticity Index	32
Plastic Limit	27
Specific Gravity	2.743
Porosity	48.6%
Shear Strength	Ranges from 1.0–2.0 tsf

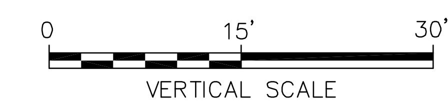
Geotechnical Sample BC(11–13)	
Bulk density	1.30 g/cc=81.2 lb/ft3=1.87 ton/yd3
Lean Clay (CL)	
Moisture Content	41.7%
Liquid Limit	45
Plasticity Index	21
Plastic Limit	24
Specific Gravity	2.752
Porosity	52.8%
Shear Strength	Ranges from 1.0–2.0 tsf



LOOKING NORTH

Geotechnical Sample OSB–35(30–32)	
Bulk density	1.9 g/cc=118.3 lb/ft3=2.73 ton/yd3
Sandy Lean Clay (CL)	
Moisture Content	16%
Liquid Limit	N/A
Plasticity Index	N/A
Plastic Limit	N/A
Specific Gravity	2.740
Porosity	30.8%
Shear Strength	>4.5 tsf

Geotechnical Sample OSB–37(22–23)	
Bulk density	1.7 g/cc=105.4 lb/ft3=2.43 ton/yd3
Lean Clay with Sand (CL)	
Moisture Content	23.3%
Liquid Limit	N/A
Plasticity Index	N/A
Plastic Limit	N/A
Specific Gravity	2.785
Porosity	39.3%
Shear Strength	N/A



NOT TO SCALE HORIZONTALLY

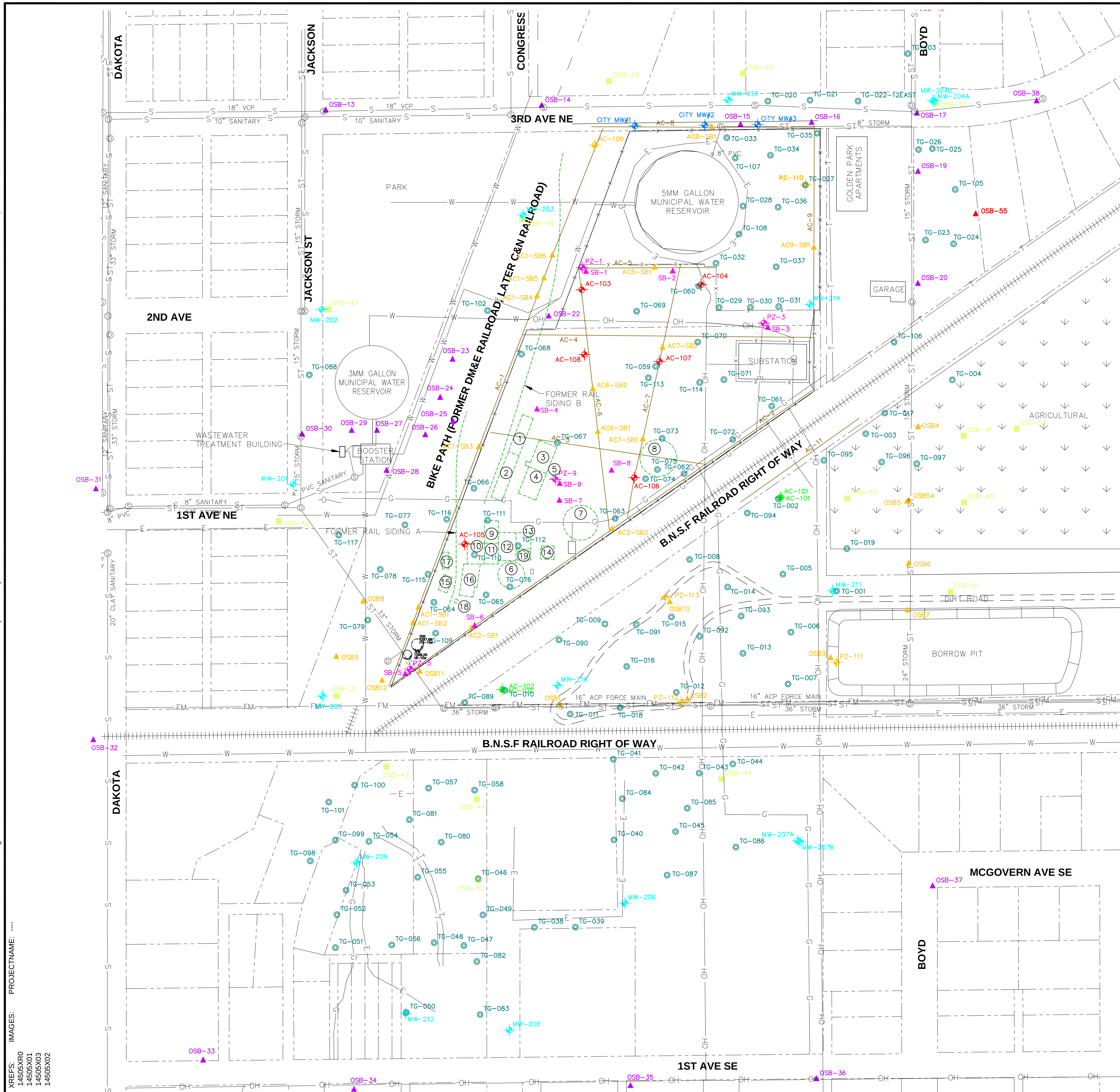
NOTE:
THIS IS A CONCEPTUAL CROSS-SECTION THROUGH THE SITE THAT IS REPRESENTATIVE OF OVERALL SUBSURFACE GEOLOGY. GEOTECHNICAL DATA ARE PROVIDED FROM SPECIFIC SAMPLES COLLECTED FROM EACH STRATUM FROM VARIOUS BORING LOCATIONS AS IDENTIFIED IN THE DATA BOXES.

NORTHWESTERN ENERGY
ABERDEEN, SOUTH DAKOTA
FORMER MANUFACTURED GAS PLANT

HYDROSTRATIGRAPHIC UNITS

ARCADIS

FIGURE
4



MGP BUILDING LEGEND:

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14. STORAGE
15. WATER RESERVOIR
16. COAL SHED (PRE-1917)
17. CRUDE OIL TANK
18. PRODUCTION WELL
19. METER ROOM

LEGEND:

— — —	PROPERTY BOUNDARY
—x—x—	FENCE
++++++	RAILROAD TRACKS
—G—	NATURAL GAS
—OH—	OVERHEAD ELECTRIC
—E—	BURIED ELECTRIC
—T—	QWEST COMMUNICATIONS LINE
—W—	CITY WATER
—FM—	FORCEMAIN
—S—	SANITARY SEWER
—ST—	STORM SEWER
- - - -	APPROXIMATE LOCATION OF HISTORICAL STRUCTURES
CITY MW#1	CITY 1980 MONITORING WELL
SB-8	BARR 1999 SOIL BORING
PZ-9	BARR 1999 MONITORING WELL
AC-106	BARR 2002 MONITORING WELL
AC-102	URS 2002 MONITORING WELL
AC7SB1	ELM 2004 SOIL BORING
PZ-113	ELM 2004 MONITORING WELL
OSB-20	ELM 2005 SOIL BORING
OSB-47	ARCADIS NOVEMBER 2008 SOIL BORING
MW-209	ARCADIS AUGUST 2009 MONITORING WELL
TG-027	ARCADIS AUGUST 2009 TARGOST LOCATION
OSB-55	ARCADIS 2009 SOIL BORING
—AC-4—	ELM 2005 GEOPHYSICS SYRVEY TRANSECT

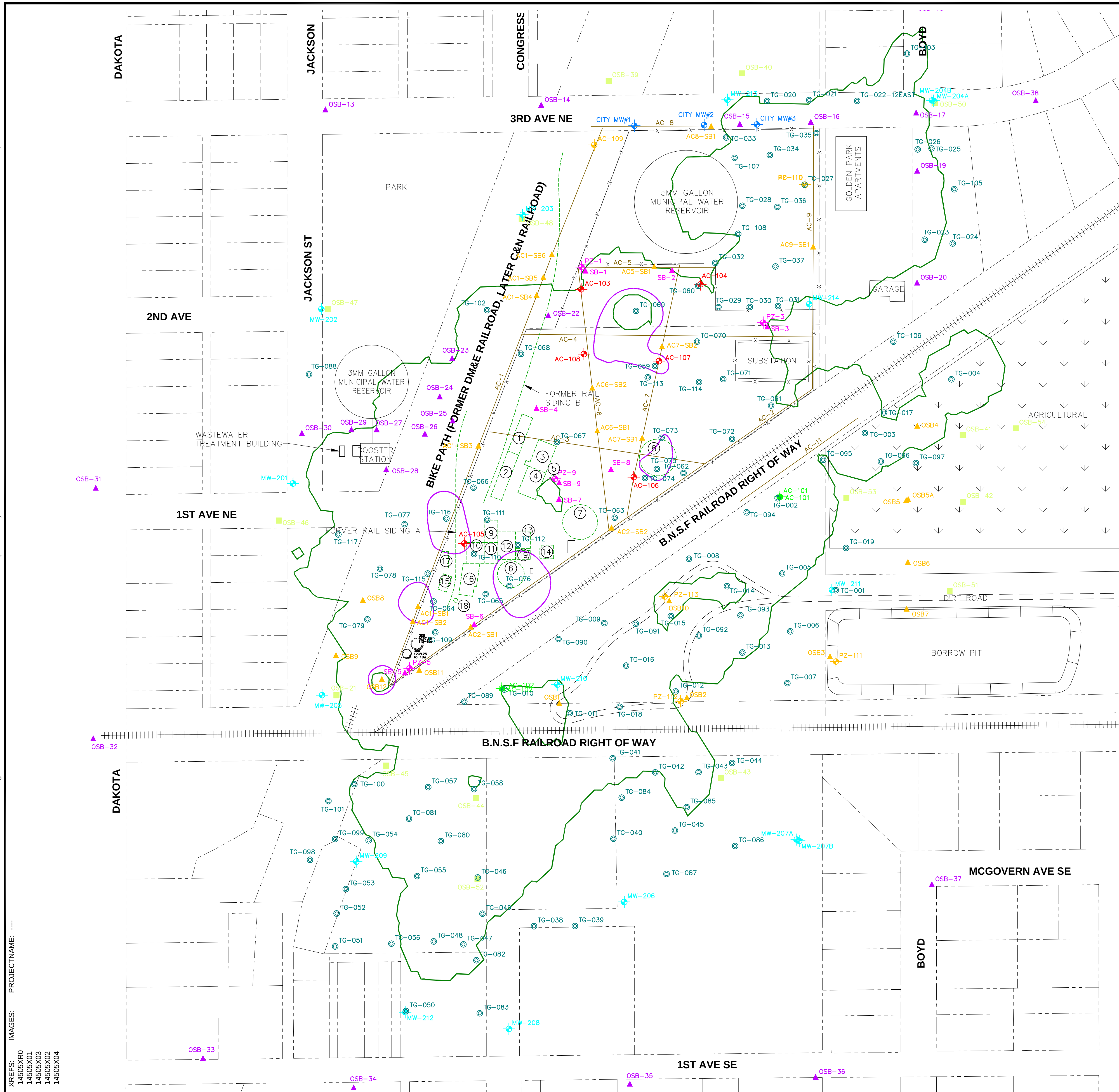
0 100' 200'
GRAPHIC SCALE

NORTHWESTERN ENERGY
ABERDEEN, SOUTH DAKOTA
FORMER MANUFACTURED GAS PLANT SITE

SOIL, GROUNDWATER, AND GEOPHYSICS TEST LOCATIONS

ARCADIS

FIGURE
5



MGP BUILDING LEGEND:

1. COAL BINS
2. COKE BINS
3. ENGINE ROOM #2 (POST-1917
4. GENERATOR ROOM #2 (POST-1917)
5. ARTESIAN WELL
6. GASOMETER #1
7. GASOMETER #2
8. GASOMETER #3
9. REPAIR SHOP
10. BOILER ROOM #1 (PRE-1917)
11. GENERATOR ROOM #1 (PRE-1917)
12. PURIFIER ROOM
13. OFFICE
14. STORAGE
15. WATER RESERVOIR
16. COAL SHED (PRE-1917)
17. CRUDE OIL TANK
18. PRODUCTION WELL
19. METER ROOM

LEGEND:

PROPERTY BOUNDARY
FENCE
RAILROAD TRACKS
APPROXIMATE LOCATION OF HISTORICAL STRUCTURES
AREAS OF FREE PRODUCT 0'-15' BELOW GROUND SURFACE
AREAS OF FREE PRODUCT 15' BELOW GROUND SURFACE
CITY MW#1 — CITY 1980 MONITORING WELL
SB-8 — BARR 1999 SOIL BORING
PZ-9 — BARR 1999 MONITORING WELL
AC-106 — BARR 2002 MONITORING WELL
AC-102 — URS 2002 MONITORING WELL
AC7SB1 — ELM 2004 SOIL BORING
PZ-113 — ELM 2004 MONITORING WELL
OSB-20 — ELM 2005 SOIL BORING
OSB-47 — ARCADIS NOVEMBER 2008 SOIL BORING
MW-209 — ARCADIS AUGUST 2009 MONITORING WELL
TG-027 — ARCADIS AUGUST 2009 TARGOST LOCATION
AC-4 — ELM 2005 GEOPHYSICS SYRVEY TRANSECT

NOTE:

1. THE EXTENT OF NON-AQUEOUS PHASE LIQUID DEPICTED ON THIS FIGURE IS PROJECTED BASED ON INTERPOLATION BETWEEN AND NEAR TEST LOCATIONS AND IS THEREFORE APPROXIMATE.

0 100' 200'
GRAPHIC SCALE

NORTHWESTERN ENERGY
ABERDEEN, SOUTH DAKOTA
FORMER MANUFACTURED GAS PLANT SITE

AREAL EXTENT OF NON-AQUEOUS PHASE LIQUID IN SUBSURFACE

ARCADIS

FIGURE
6

CITY:(Reqd) DIV/GROUP:(Reqd) DB:(Reqd) LD:(Opt) PIC:(Opt) PM:(Reqd) TM:(Opt) LYR:(Opt)ON=*;OFF=*REF*
G:\ENVCAD\SYRACUSE\ACT\B0036653\0001\00301\DWG\PHASE3\REPORT\36653G05.dwg LAYOUT: 6 SAVED: 3/31/2010 1:02 PM ACADVER: 17.0S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 3/31/2010 2:04 PM BY: KOWALCZYK, STEVE
XREFS: IMAGES: PROJECTNAME: ----
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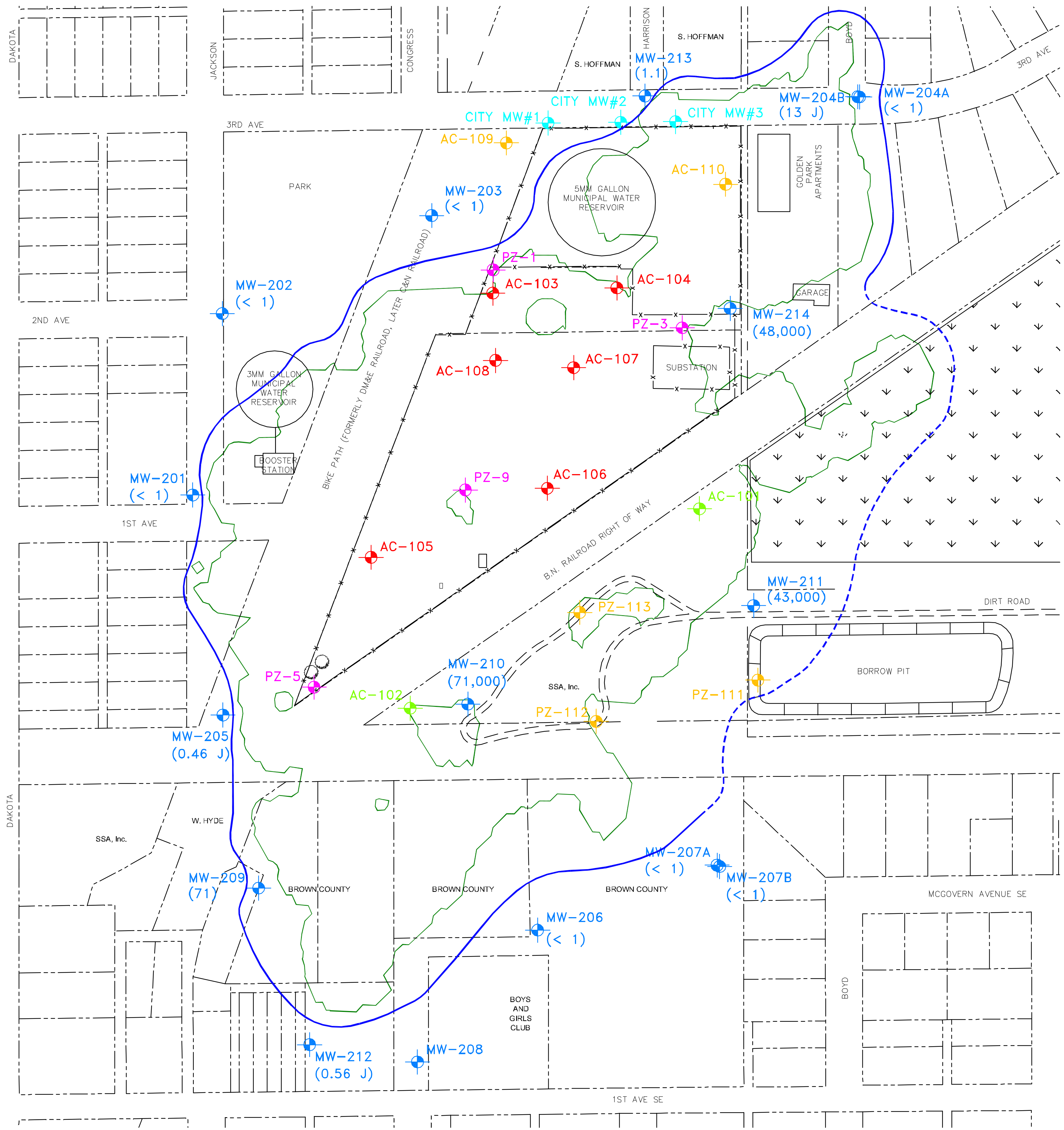
14505X01
14505X03
14505X02
14505X04



LEGEND:

(green line)	AREAS OF NON-AQUEOUS PHASE LIQUID 15' BELOW GROUND SURFACE OR DEEPER [EVS MODEL OUTPUT]
(dash-dot line)	PROPERTY BOUNDARY
—x—x—	FENCE
CITY MW#1	CITY 1980 MONITORING WELL
PZ-9	BARR 1999 MONITORING WELL
AC-106	BARR 2002 MONITORING WELL
AC-102	URS 2002 MONITORING WELL
PZ-113	ELM 2004 MONITORING WELL
MW-209	ARCADIS AUGUST 2009 MONITORING WELL
(< 1)	BENZENE CONCENTRATION IN MICROGRAMS PER LITER (ug/L) [AUGUST 2009 SAMPLING EVENT]
(blue line)	5 ug/L BENZENE DISSOLVED PHASE BOUNDARY (DASHED WHERE INFERRED)

NOTE:

1. THE EXTENT OF NON-AQUEOUS PHASE LIQUID DEPICTED ON THIS FIGURE IS PROJECTED BASED ON INTERPOLATION BETWEEN AND NEAR TEST LOCATIONS AND IS THEREFORE APPROXIMATE.

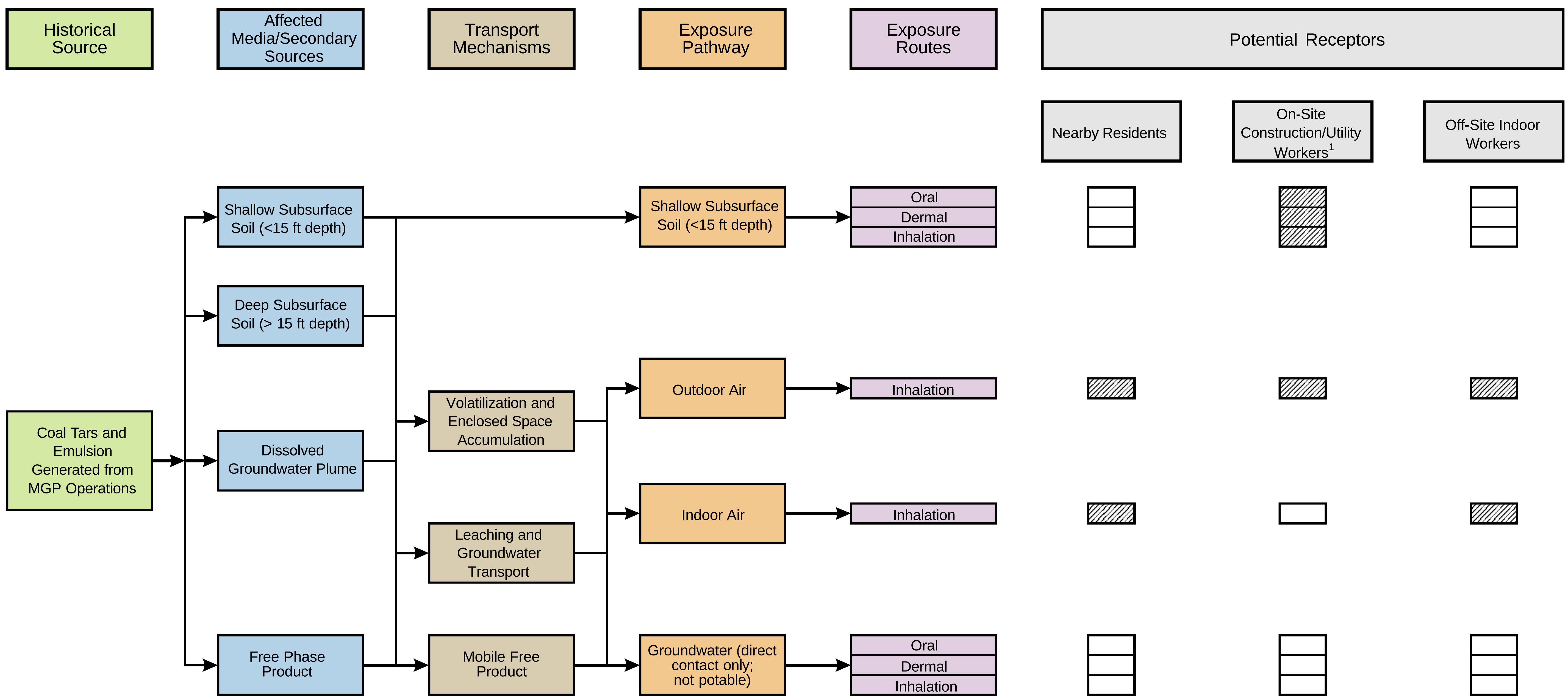
0 100' 200'
GRAPHIC SCALE

NORTHWESTERN ENERGY
ABERDEEN, SOUTH DAKOTA
FORMER MANUFACTURED GAS PLANT SITE

DISOLVED PHASE BENZENE PLUME FROM AUGUST 2009

ARCADIS

FIGURE
7



Notes:

[1] Figure presents potential exposure to workers.

Actual exposure can be minimized or eliminated through the use of personal protective equipment.

Legend

- (open box) Pathway not complete; no evaluation necessary
- (hatched box) Pathway is or may be complete; however, data indicate potential exposure and risk are minimal
- (solid box) Pathway is complete and may be significant

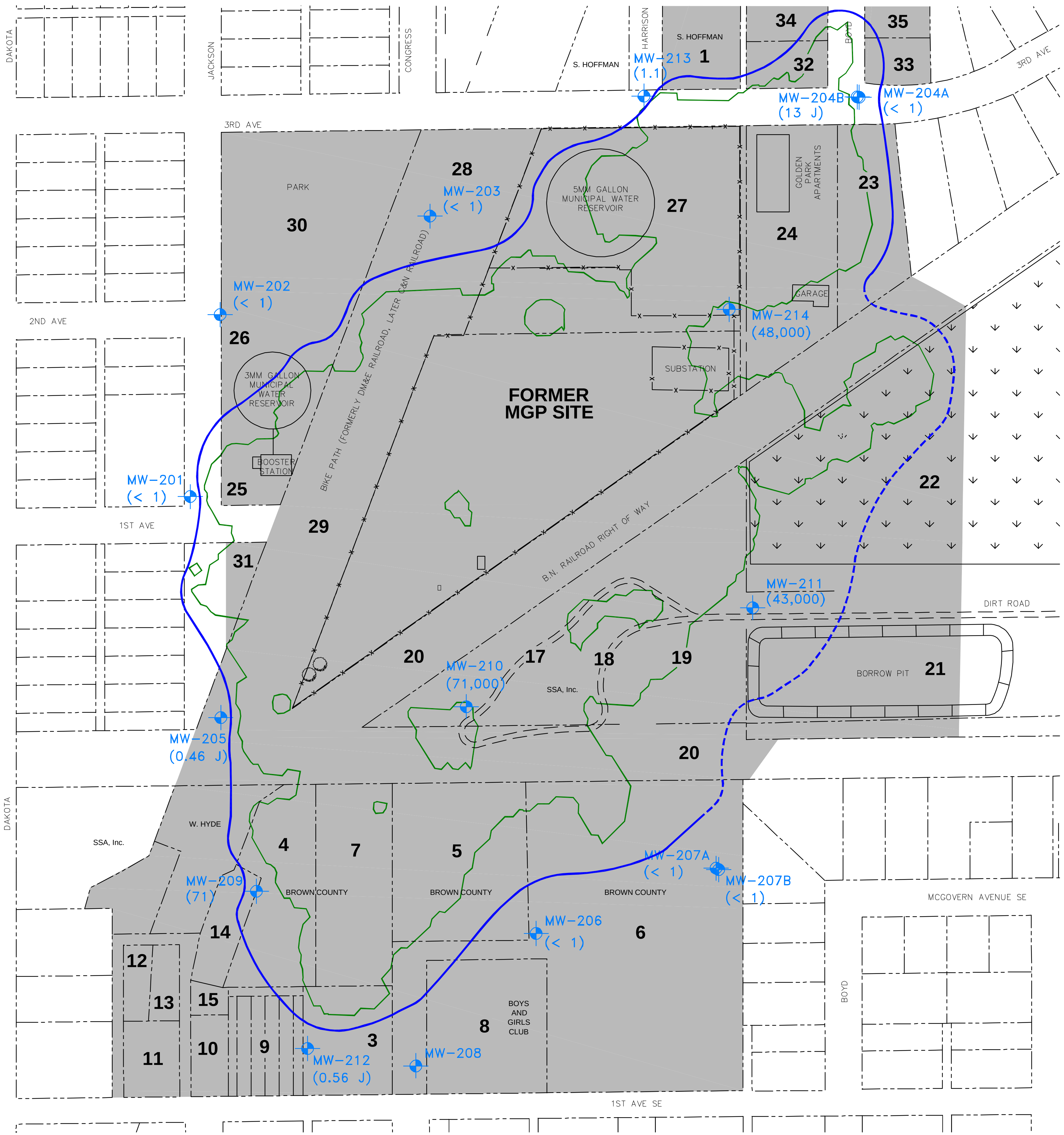
NORTHWESTERN ENERGY
ABERDEEN, SOUTH DAKOTA
FORMER MANUFACTURED GAS PLANT SITE

CONCEPTUAL SITE MODEL FOR POTENTIAL HUMAN EXPOSURES

ARCADIS

FIGURE
8

03/10/2010 SYRACUSE, NY-ENV/CAD-DJHOWES
B0014505/0000/04200/CDR/14505F03.CDR



LEGEND:

- AREAS OF NON-AQUEOUS PHASE LIQUID 15' BELOW GROUND SURFACE OR DEEPER [EVS MODEL OUTPUT]
- PROPERTY BOUNDARY
- FENCE
- MW-209 ARCADIS AUGUST 2009 MONITORING WELL
- (< 1) BENZENE CONCENTRATION IN MICROGRAMS PER LITER (ug/L) [AUGUST 2009 SAMPLING EVENT]
- 5 ug/L BENZENE DISSOLVED PHASE BOUNDARY (DASHED WHERE INFERRED)
- 20 INSTITUTIONAL CONTROLS PROPOSED

REMEDIAL ALTERNATIVE 1:

(A) INSTITUTIONAL CONTROLS PROPOSED FOR SHADED PROPERTIES
(B) LONG-TERM GROUNDWATER MONITORING PROPOSED FOR ARCADIS 2009 MONITORING WELLS AND UP TO SIX ADDITIONAL WELLS (TO BE INSTALLED)
(C) SITE SECURITY FENCE TO BE MAINTAINED
(D) WASTEWATER TREATMENT SYSTEM AT MUNICIPAL BOOSTER STATION TO CONTINUE OPERATION INDEFINITELY

MAP ID	PROPERTY
MGP	NORTHWESTERN ENERGY
1	RESIDENTIAL – VACANT
3–7	BROWN COUNTY
8	BOYS & GIRLS CLUB
9	TELSERV COMMUNICATIONS
10–15	FIRST MINI-STORAGE
17–19	STEEL STRUCTURES OF ABERDEEN
20	BNSF RAILWAY
21–22	SACRED HEART CATHOLIC CHURCH
23	RESIDENTIAL – VACANT
24	RESIDENTIAL – APARTMENTS
25–30	CITY OF ABERDEEN
31	VACANT
32	RESIDENTIAL – APARTMENTS
33	RESIDENTIAL – APARTMENTS
34	RESIDENTIAL
35	RESIDENTIAL

NOTE:

1. THE EXTENT OF NON-AQUEOUS PHASE LIQUID DEPICTED ON THIS FIGURE IS PROJECTED BASED ON INTERPOLATION BETWEEN AND NEAR TEST LOCATIONS AND IS THEREFORE APPROXIMATE.

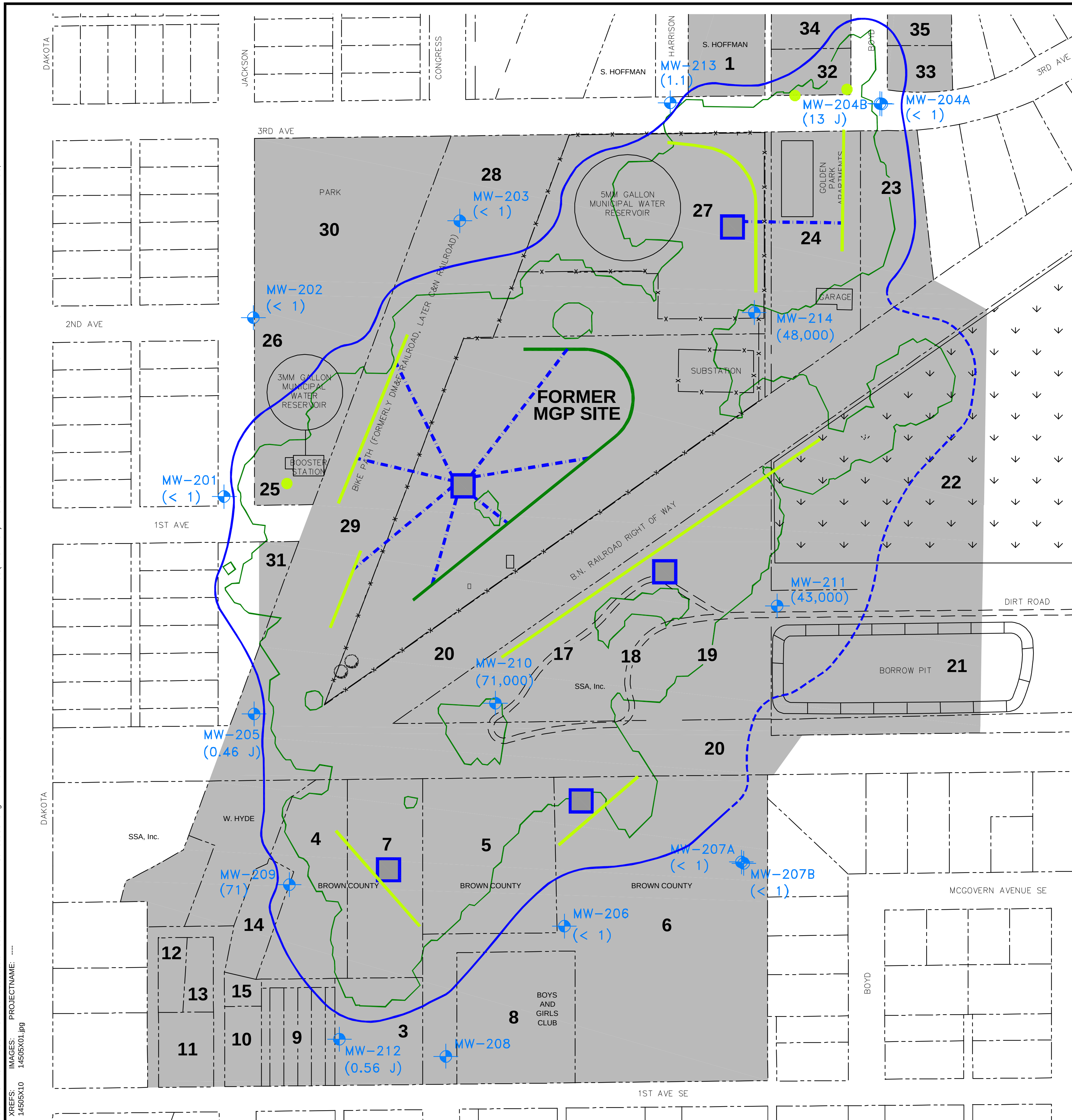
0 100' 200'
GRAPHIC SCALE

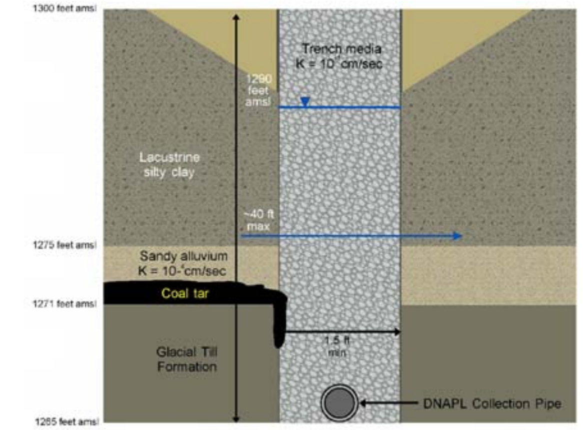
NORTHWESTERN ENERGY
ABERDEEN, SOUTH DAKOTA
FORMER MANUFACTURED GAS PLANT SITE

REMEDIAL ALTERNATIVE 1

ARCADIS

FIGURE
9-1





DNAPL BARRIER CONCEPTUAL DESIGN

LEGEND:

- AREAS OF NON-AQUEOUS PHASE LIQUID 15' BELOW GROUND SURFACE OR DEEPER [EVS MODEL OUTPUT]
- PROPERTY BOUNDARY
- FENCE
- MW-209 — ARCADIS AUGUST 2009 MONITORING WELL
- (< 1) — BENZENE CONCENTRATION IN MICROGRAMS PER LITER (ug/L) [AUGUST 2009 SAMPLING EVENT]
- 5 ug/L BENZENE DISSOLVED PHASE BOUNDARY (DASHED WHERE INFERRED)
- 20 — INSTITUTIONAL CONTROLS PROPOSED
- STAGE 1 FREE PRODUCT COLLECTION GALLERY (CONCEPTUAL)
- STAGE 2 FREE PRODUCT COLLECTION GALLERY (CONCEPTUAL)
- STAGE 2 FREE PRODUCT RECOVERY WELL (CONCEPTUAL)
- TRANSFER PIPING (CONCEPTUAL)
- NAPL STORAGE/SUPPORT AREA (CONCEPTUAL)

REMEDIAL ALTERNATIVE 2:

(A) INSTITUTIONAL CONTROLS PROPOSED FOR SHADED PROPERTIES
(B) LONG-TERM GROUNDWATER MONITORING PROPOSED FOR ARCADIS 2009 MONITORING WELLS AND UP TO SIX ADDITIONAL WELLS (TO BE INSTALLED)
(C) SITE SECURITY FENCE TO BE MAINTAINED
(D) WASTEWATER TREATMENT SYSTEM AT MUNICIPAL BOOSTER STATION TO CONTINUE OPERATION INDEFINITELY
(E) NAPL COLLECTION TRENCHES/WELLS TO BE CONSTRUCTED AND OPERATED IN PASSIVE MODE UNTIL A PRE-DETERMINED RECOVERY CRITERION IS ATTAINED (TO BE ESTABLISHED IN REMEDIAL ACTION PLAN)

NOTE:

1. THE EXTENT OF NON-AQUEOUS PHASE LIQUID DEPICTED ON THIS FIGURE IS PROJECTED BASED ON INTERPOLATION BETWEEN AND NEAR TEST LOCATIONS AND IS THEREFORE APPROXIMATE.

GRAPHIC SCALE: 0 — 100' — 200'

MAP ID	PROPERTY
MGP	NORTHWESTERN ENERGY
1	RESIDENTIAL – VACANT
3–7	BROWN COUNTY
8	BOYS & GIRLS CLUB
9	TELSERV COMMUNICATIONS
10–15	FIRST MINI-STORAGE
17–19	STEEL STRUCTURES OF ABERDEEN
20	BNSF RAILWAY
21–22	SACRED HEART CATHOLIC CHURCH
23	RESIDENTIAL – VACANT
24	RESIDENTIAL – APARTMENTS
25–30	CITY OF ABERDEEN
31	VACANT
32	RESIDENTIAL – APARTMENTS
33	RESIDENTIAL – APARTMENTS
34	RESIDENTIAL
35	RESIDENTIAL

NORTHWESTERN ENERGY
ABERDEEN, SOUTH DAKOTA
FORMER MANUFACTURED GAS PLANT SITE

REMEDIAL ALTERNATIVE 2

ARCADIS

FIGURE **9-2**

CITY: SYRACUSE, NY DIV/GROUP: ENV/CAD DB: AGS KLS AGS LD: PIC: PM: T. FISCHER TM: LYR: ON=*;OFF=*REF*
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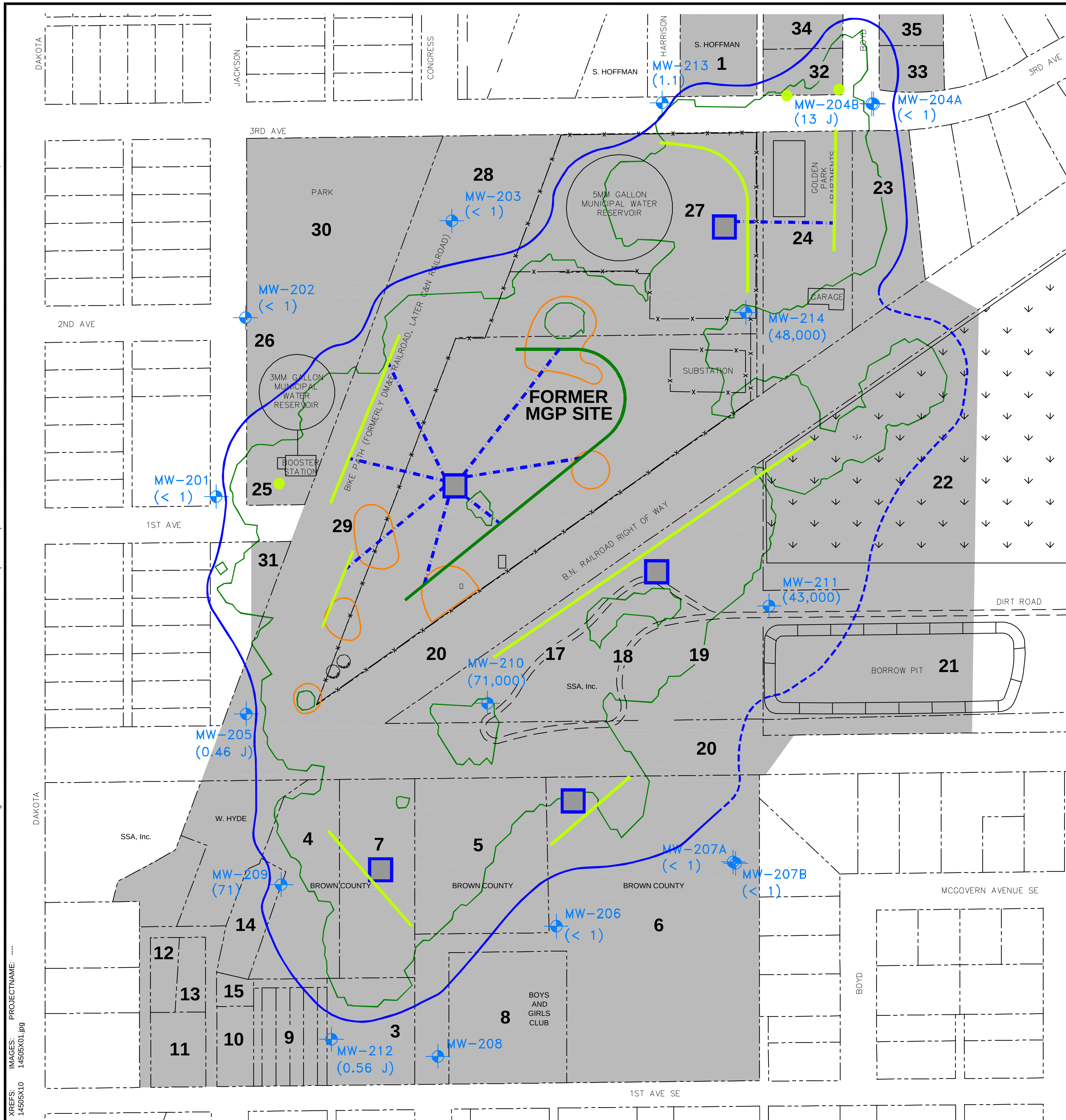

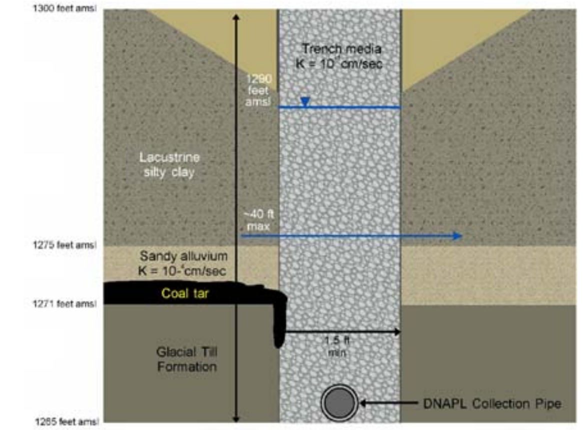

DNAPL BARRIER CONCEPTUAL DESIGN

LEGEND:

- AREAS OF NON-AQUEOUS PHASE LIQUID 15' BELOW GROUND SURFACE OR DEEPER [EVS MODEL OUTPUT]
- PROPERTY BOUNDARY
- FENCE
- MW-209 — ARCADIS AUGUST 2009 MONITORING WELL
- (< 1) — BENZENE CONCENTRATION IN MICROGRAMS PER LITER (ug/L) [AUGUST 2009 SAMPLING EVENT]
- 5 ug/L BENZENE DISSOLVED PHASE BOUNDARY (DASHED WHERE INFERRED)
- 20 — INSTITUTIONAL CONTROLS PROPOSED
- STAGE 1 FREE PRODUCT COLLECTION GALLERY (CONCEPTUAL)
- STAGE 2 FREE PRODUCT COLLECTION GALLERY (CONCEPTUAL)
- STAGE 2 FREE PRODUCT RECOVERY WELL (CONCEPTUAL)
- TRANSFER PIPING (CONCEPTUAL)
- NAPL STORAGE/SUPPORT AREA (CONCEPTUAL)
- AREA OF TARGETED EXCAVATION

REMEDIAL ALTERNATIVE 3:

(A) INSTITUTIONAL CONTROLS PROPOSED FOR SHADED PROPERTIES
(B) LONG-TERM GROUNDWATER MONITORING PROPOSED FOR ARCADIS 2009 MONITORING WELLS AND UP TO SIX ADDITIONAL WELLS (TO BE INSTALLED)
(C) SITE SECURITY FENCE TO BE MAINTAINED
(D) WASTEWATER TREATMENT SYSTEM AT MUNICIPAL BOOSTER STATION TO CONTINUE OPERATION INDEFINITELY
(E) NAPL COLLECTION TRENCHES/WELLS TO BE CONSTRUCTED AND OPERATED IN PASSIVE MODE UNTIL A PRE-DETERMINED RECOVERY CRITERION IS ATTAINED (TO BE ESTABLISHED IN REMEDIAL ACTION PLAN)
(F) TARGETED EXCAVATION AREAS TO DEPTH OF APPROXIMATELY 15 FEET BGS

NOTE:

1. THE EXTENT OF NON-AQUEOUS PHASE LIQUID DEPICTED ON THIS FIGURE IS PROJECTED BASED ON INTERPOLATION BETWEEN AND NEAR TEST LOCATIONS AND IS THEREFORE APPROXIMATE.

0 100' 200'
GRAPHIC SCALE

MAP ID	PROPERTY
MGP	NORTHWESTERN ENERGY
1	RESIDENTIAL – VACANT
3–7	BROWN COUNTY
8	BOYS & GIRLS CLUB
9	TELSERV COMMUNICATIONS
10–15	FIRST MINI-STORAGE
17–19	STEEL STRUCTURES OF ABERDEEN
20	BNSF RAILWAY
21–22	SACRED HEART CATHOLIC CHURCH
23	RESIDENTIAL – VACANT
24	RESIDENTIAL – APARTMENTS
25–30	CITY OF ABERDEEN
31	VACANT
32	RESIDENTIAL – APARTMENTS
33	RESIDENTIAL – APARTMENTS
34	RESIDENTIAL
35	RESIDENTIAL

NORTHWESTERN ENERGY
ABERDEEN, SOUTH DAKOTA
FORMER MANUFACTURED GAS PLANT SITE

REMEDIAL ALTERNATIVE 3

ARCADIS

FIGURE
9-3

CITY: SYRACUSE, NY DIV/GROUP: ENV/CAD DB: AGS KLS AGS LD: PIC: PM: T. FISCHER TM: LYR: ON=*;OFF=*REF*
G:\ENVCAD\SYRACUSE\ACT\B0014505\0000\04200\DWG\REMEDIAL-ALTS\14505G01.dwg LAYOUT: 9-3 SAVED: 4/20/2010 2:57 PM ACADVER: 17.0S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 4/20/2010 2:58 PM BY: SAMIOS, ALEX
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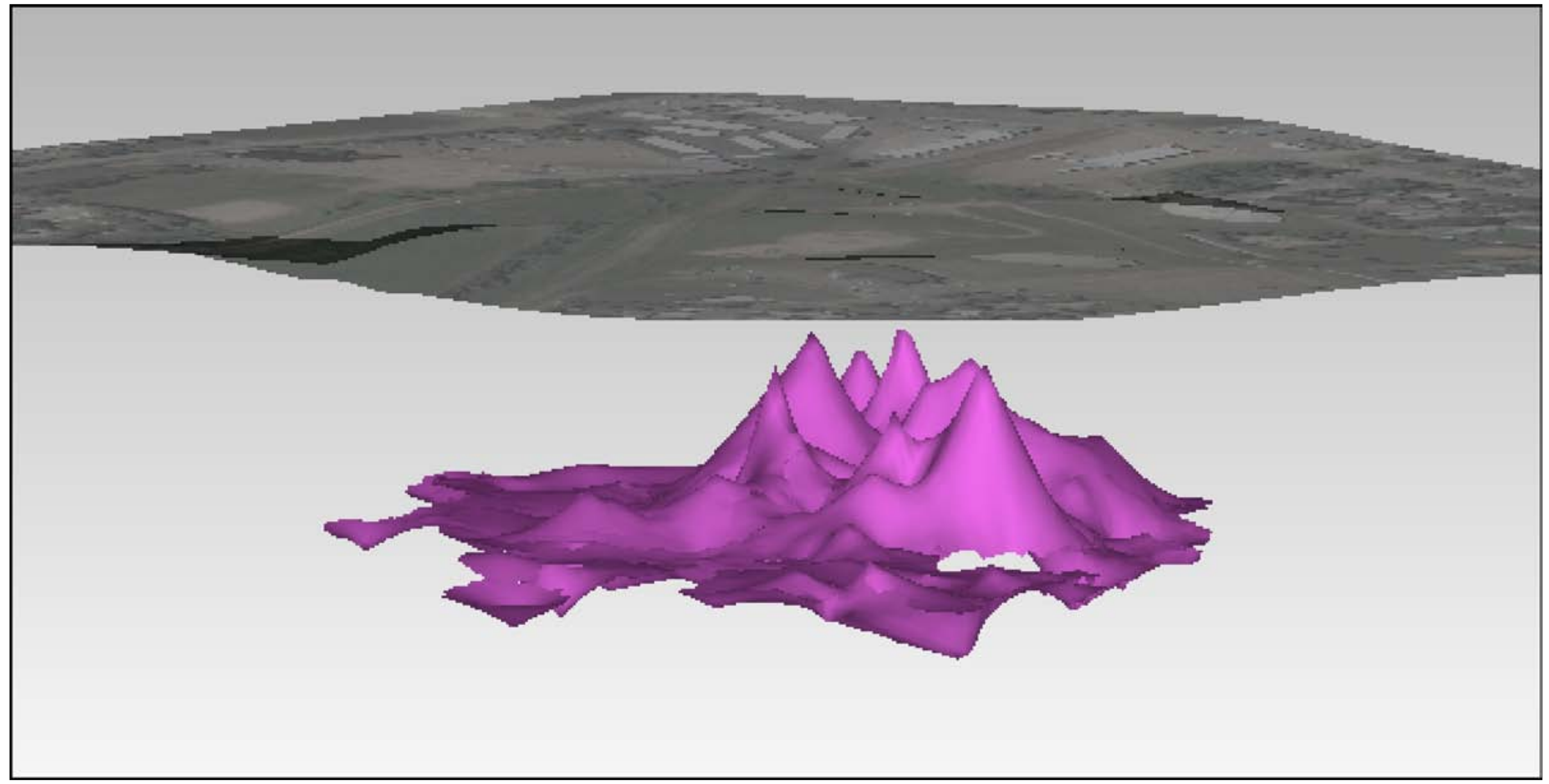
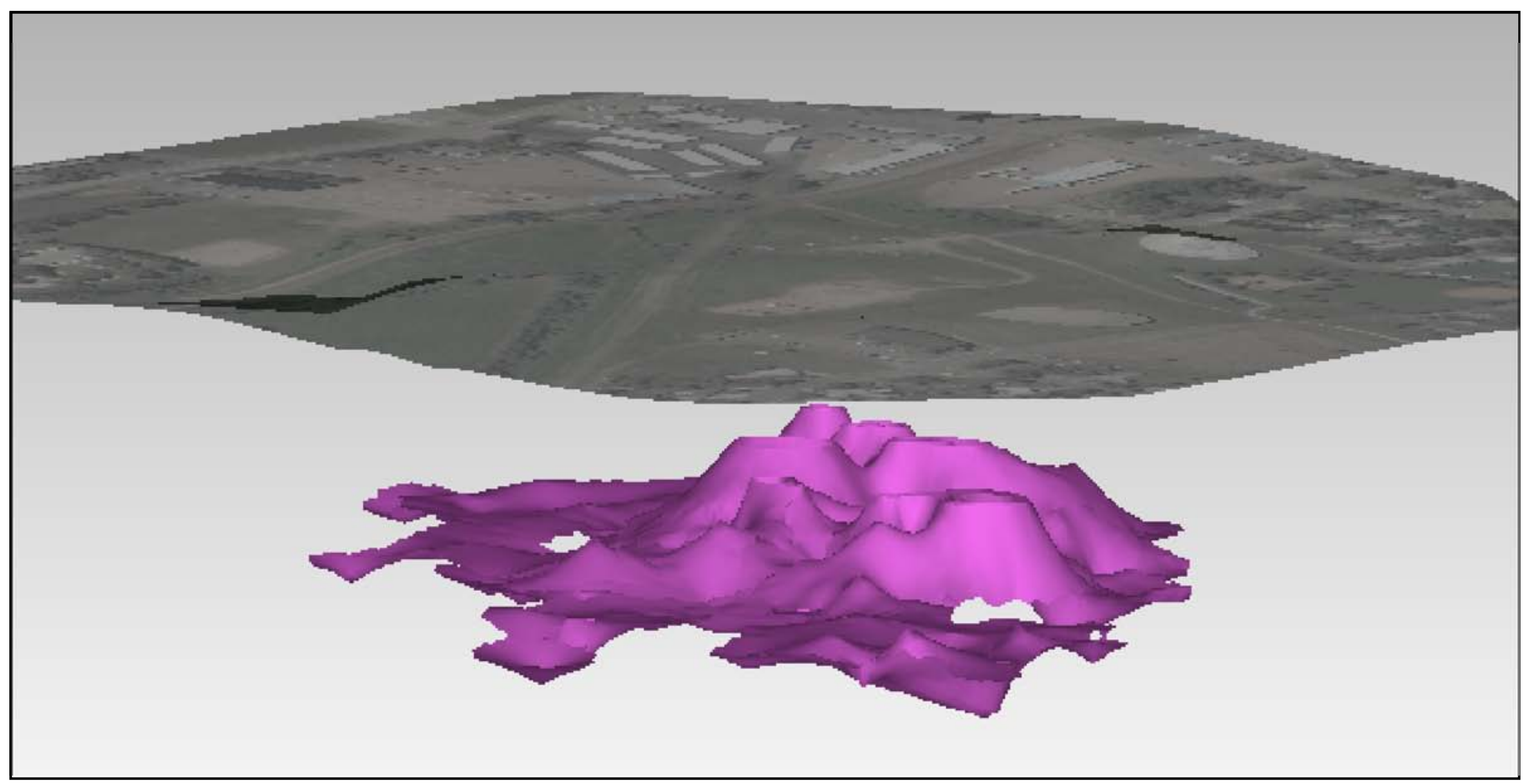


Baseline Representation of Non-Aqueous Phase Liquid in Subsurface



Representation of Non-Aqueous Phase Liquid in the Subsurface Following Potential Targeted Excavation

Note:
View is from northeast to southwest

NOT TO SCALE

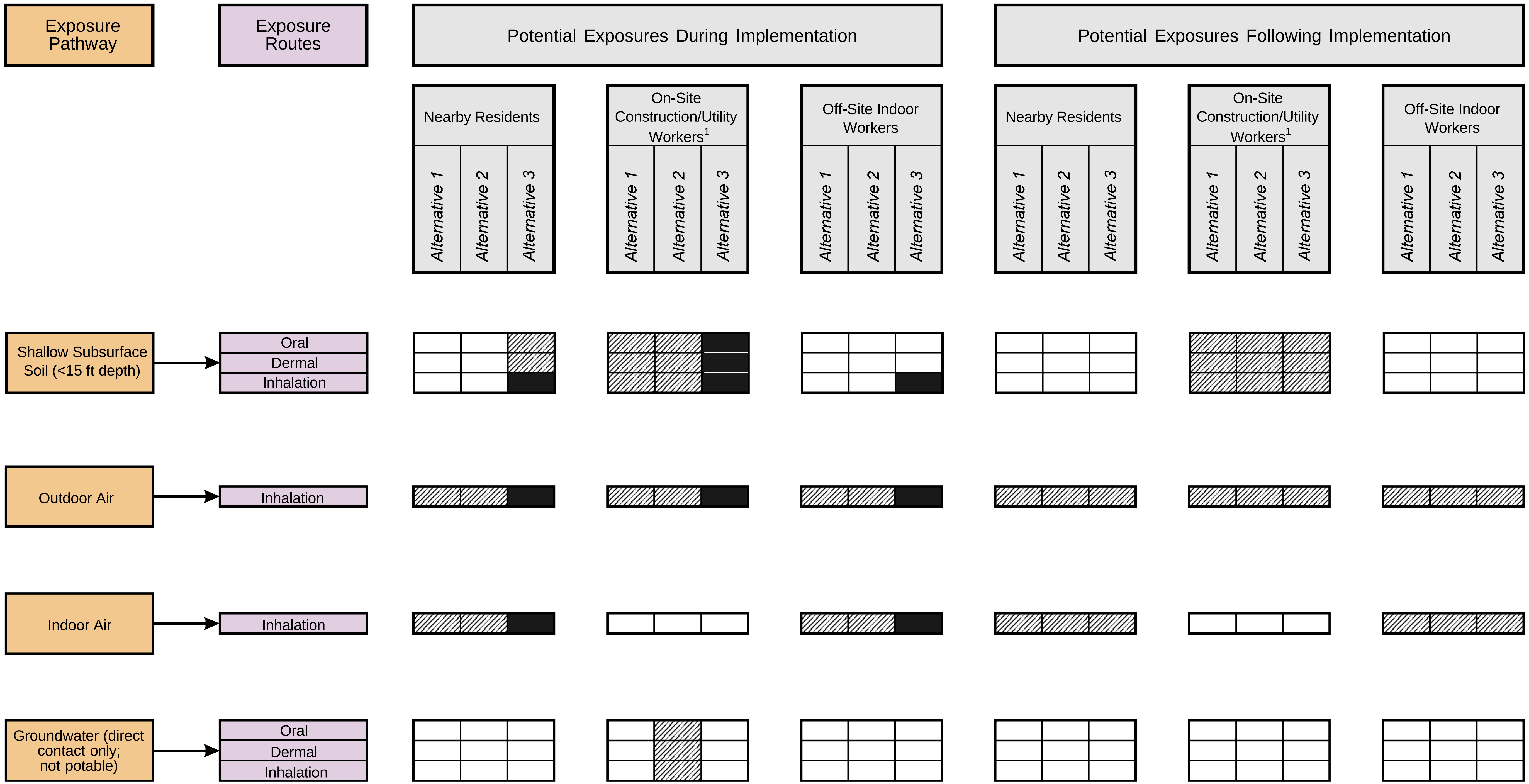
NORTHWESTERN ENERGY
ABERDEEN, SOUTH DAKOTA
FORMER MANUFACTURED GAS PLANT SITE

THREE DIMENSIONAL REPRESENTATION OF NON-AQUEOUS PHASE LIQUID IN THE SUBSURFACE

ARCADIS

FIGURE
10

03/30/2010 SYRACUSE, NY-ENV/CAD-K.SARTORI, DJHOWES
B0014505/0000/04200/CDR/14505G08.CDR



Notes:

Figure presents potential exposure to workers.

[1] Actual exposure can be minimized or eliminated through the use of personal protective equipment.

Legend

- (white box) Pathway not complete; no evaluation necessary
- (hatched box) Pathway is or may be complete; however, data indicate potential exposure and risk are minimal
- (black box) Pathway is complete and may be significant

NORTHWESTERN ENERGY
ABERDEEN, SOUTH DAKOTA
FORMER MANUFACTURED GAS PLANT SITE

POTENTIAL EXPOSURE TO RECEPTORS DURING AND FOLLOWING IMPLEMENTATION OF ALTERNATIVES

ARCADIS

FIGURE **11**

03/30/2010 SYRACUSE, NY-ENV/CAD-DJHOWES
B0014505/0000/04200/CDR/14505F02.CDR

ARCADIS

Appendix A

Remedial Alternative Cost Details

NORTHWESTERN ENERGY
ABERDEEN FORMER MANUFACTURED GAS PLANT
ABERDEEN, SOUTH DAKOTA

ALTERNATIVE 1 - COST ESTIMATE
Institutional Controls with Long-Term Groundwater Monitoring

Alt.	Item #	Description	Quantity	Unit	Unit Price	Amount
Institutional Controls with Long-Term Groundwater Monitoring						
1	**Capital Costs**					
	1	Legal/Administrative/Institutional Controls	1	LS	$1,100,000	$1,100,000
	2	Site Management Plan	1	LS	$25,000	$25,000
	3	Groundwater Monitoring Well Installation	6	each	$3,000	$18,000
					Subtotal Capital Cost	$1,143,000
					Engineering (15%)	$171,450
					Contingency (25%)	$285,750
					Project Management / Construction Management (10%)	$114,300
					Total Capital Cost	$1,714,500
	Annual Operation and Maintenance (O&M) Costs					
	4	Existing Wastewater Treatment System	1	LS	$53,000	$53,000
	5	Groundwater Sampling Labor & Expenses (Annual)	1	event	$16,800	$16,800
	6	Laboratory Analytical	1	event	$6,000	$6,000
	7	Reporting	1	LS	$10,000	$10,000
	8	Verification of Institutional Controls	1	LS	$10,000	$10,000
					Subtotal O&M Costs	$95,800
					Contingency (25%)	$23,950
					Total Annual O&M Costs	$119,750
					Present Worth Factor (30 years at 7%)	12.41
					Present Worth O&M Cost	$1,485,978
					Alternative 1 - Total Estimated Cost:	**$3,200,478**
					Rounded to:	**$3,210,000**

General Notes:

1. Cost estimate is based on ARCADIS U.S., Inc.'s (ARCADIS') past experience and vendor estimates using 2010 dollars.
2. This estimate has been prepared for the purposes of comparing potential remedial alternatives. The information in this cost estimate is based on the available information regarding the site investigation and the anticipated scope of the remedial alternative. Changes in cost elements are likely to occur as a result of new information and data collected during the engineering design of the remedial alternative. This cost estimate is expected to be within -30% to +50% of the actual projected cost. Utilization of this cost estimate information beyond the stated purpose is not recommended. ARCADIS is not licensed to provide financial or legal consulting services; as such; this cost estimate information is not intended to be utilized for complying with financial reporting requirements associated with liability services.
3. Present worth is estimated based on a 7% beginning-of-year discount rate (adjusted for inflation) in accordance with United States Environmental Protection Agency (USEPA) Office of Solid Waste and Emergency Response (OSWER) Directive 9355.3-20 "Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis" (USEPA, 1993). It is assumed that "year zero" is 2011.
4. Costs do not include legal fees, negotiations or agency oversight.

Notes:

1. Legal/administrative/institutional controls cost estimate includes labor and materials necessary to institute deed restrictions to:
   (a) restrict future use of the Site to commercial/industrial activities;
   (b) restrict future use of site groundwater. The use restriction would apply to groundwater beneath the Site and, if acceptable to land parcels adjacent to the site;
   (c) notify future property owners of the presence of manufactured gas plant- (MGP-) related constituents in soil and groundwater at the Site;
   (d) notify future property owners of the applicability of the Site Management Plan; and
   (e) purchasing and compensation to adjacent property owners.

NORTHWESTERN ENERGY
ABERDEEN FORMER MANUFACTURED GAS PLANT
ABERDEEN, SOUTH DAKOTA

ALTERNATIVE 1 - COST ESTIMATE
Institutional Controls with Long-Term Groundwater Monitoring

2. Site management plan cost estimate includes labor and materials necessary to prepare a site management plan for the Site that will:
   (a) identify known locations of MGP-impacts at the Site;
   (b) address possible future intrusive activities that would result in the potential for contact with MGP-impacts; and
   (c) set forth the inspection and maintenance activities for the fencing and vegetation/cover materials.
3. Groundwater monitoring well installation cost estimate includes labor, equipment, and materials necessary to install new groundwater monitoring wells. Cost estimate includes oversight by a geologist, and drill rig and crew. Cost estimate assumes polyvinyl chloride (PVC) well construction to a depth of approximately 25 feet bgs.

4. Existing wastewater treatment system cost estimate includes labor, equipment, and materials necessary to continue operation of the existing wastewater treatment system installed in 2006 and includes quarterly sampling, semiannual carbon change-outs, and annual sump cleaning.

5-7. Groundwater sampling labor and expenses (annual) cost estimate includes labor, equipment, and materials necessary to conduct annual sampling events for 22 monitoring wells, analyze groundwater samples, and prepare an annual groundwater monitoring report to summarize the results of the groundwater monitoring activities. This cost estimate also includes containerizing groundwater and NAPL (if present) waste materials generated during the sampling activities. This cost estimate also includes transportation of the containerized liquid waste for disposal as a non-hazardous waste at an appropriate treatment/disposal facility.

8. Annual costs associated with institutional controls include verifying the status of institutional controls and preparing/submitting notification to the South Dakota Department of Environmental and Natural Resources (SD DENR) to demonstrate that the institutional controls are being maintained and remain effective.

NORTHWESTERN ENERGY
ABERDEEN FORMER MANUFACTURED GAS PLANT
ABERDEEN, SOUTH DAKOTA

ALTERNATIVE 2 - COST ESTIMATE
Institutional Controls with Passive NAPL Recovery and Long-Term Groundwater Monitoring

Alt.	Item #	Description	Quantity	Unit	Unit Price	Amount
Institutional Controls with Long-Term Groundwater Monitoring						
	Capital Costs					
1,2	1	Legal/Administrative/Institutional Controls	1	LS	$1,100,000	$1,100,000
	2	Site Management Plan	1	LS	$25,000	$25,000
	3	Groundwater Monitoring Well Installation	6	each	$3,000	$18,000
					Subtotal Capital Cost	$1,143,000
					Engineering (15%)	$171,450
					Contingency (25%)	$285,750
					Project Management / Construction Management (10%)	$114,300
					Total Capital Cost	$1,714,500
	Annual Operation and Maintenance (O&M) Costs					
	4	Existing Wastewater Treatment System	1	LS	$53,000	$53,000
	5	Groundwater Sampling Labor & Expenses (Annual)	1	event	$16,800	$16,800
	6	Laboratory Analytical	1	event	$6,000	$6,000
	7	Reporting	1	LS	$10,000	$10,000
	8	Verification of Institutional Controls	1	LS	$10,000	$10,000
					Subtotal O&M Costs	$95,800
					Contingency (25%)	$23,950
					Total Annual O&M Costs	$119,750
					Present Worth Factor (30 years at 7%)	12.41
					Present Worth O&M Cost	$1,485,978
					Alternative 1 - Total Estimated Cost:	**$3,200,478**
					Rounded to:	**$3,210,000**
Passive NAPL Recovery and Off-site Disposal						
	Capital Costs					
2	9 (i)	Mobilization/Demobilization - One-Pass Trenching	1	LS	$100,000	$100,000
	(ii)	Mobilization/Demobilization/Permitting - LTTD	1	LS	$125,000	$125,000
	10	Construction Permits and Erosion and Sedimentation Plans	1	LS	$10,000	$10,000
	11	Brown County Landfill - Temporary Land-Use Lease	1	LS	$50,000	$50,000
	12	Health and Safety Program	1	LS	$25,000	$25,000
	13	Surveying	1	LS	$12,000	$12,000
	14	Pre-Design Investigation	1	LS	$75,000	$75,000
	15	Construction and Maintenance of Decontamination Pad	1	LS	$15,000	$15,000
	16	Construction and Maintenance of Soil Staging Areas	1	LS	$40,000	$40,000
	17	Silt Fence	6,200	LF	$5	$31,000
	18	Install Temporary Fencing	2,650	LF	$25	$66,250
	19	Passive Wall Pre-Excavation	670	CY	$50	$33,500
	20	Passive NAPL Recovery Wall Installation - One Pass Trenching	105,000	SF	$40	$4,200,000
	21	Well Vault and Trench NAPL Recovery Well/Sump	13	each	$17,250	$224,250
	22	NAPL Recovery Wells	3	each	$4,000	$12,000
	23	20' x 20' Equipment/Pumping Shed	5	each	$8,000	$40,000
	24	Piping (2" HDPE Line)	1,700	LF	$3	$5,100
	25	Piping (1/2" PVC Line)	1,700	LF	$1.50	$2,550
	26	Electrical Conduit	1,000	LF	$12	$12,000
	27	Pipe Trenching	2,700	LF	$20	$54,000
	28	Pipe Bedding and Backfilling Material	400	CY	$25	$10,000
	29	Electrical Drop to Building	3	each	$15,000	$45,000
	30	Air Compressor	5	each	$10,500	$52,500
	31	1,000 Gallon Cone Bottomed NAPL Storage Tank	5	each	$1,500	$7,500
	32	200 Gallon Cone Bottomed Water Decant Tank	5	each	$500	$2,500

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ALTERNATIVE 2 - COST ESTIMATE
Institutional Controls with Passive NAPL Recovery and Long-Term Groundwater Monitoring

Alt.	Item #	Description	Quantity	Unit	Unit Price	Amount
Passive NAPL Recovery and Off-site Disposal (con't)						
2	33	System Installation	1	LS	$25,000	$25,000
	34	Miscellaneous Mechanical	1	LS	$5,000	$5,000
	35 (i)	Excavated Soil Amendment/Stabilization	1,750	ton	$125	$218,750
	35 (ii)	Low Temperature Thermal Desorption (LTTD) Soil Treatment	8,800	ton	$45	$396,000
	36 (i)	Amended/Stabilized - Solid Waste Transportation and Disposal (T&D) - Nonhaz	9,400	ton	$55	$517,000
	36 (ii)	LTTD - Solid Waste T&D - Nonhaz	9,400	ton	$45	$423,000
	37	Waste Characterization	1	LS	$3,000	$3,000
	38	Miscellaneous Waste Disposal	1	LS	$10,000	$10,000
	39	Air Monitoring	48	day	$1,600	$76,800
	40	Dust/Vapor/Odor Control	8	week	$3,000	$24,000
	41	Street Surface Washing	8	week	$1,500	$12,000
	42	Surface Restoration - Grassed Areas	1	LS	$25,000	$25,000
	43	Weekly Monitoring/Inspection (1st Month)	4	each	$2,900	$11,600
					Stabilized (i)	**LTTD (ii)**
		Subtotal Capital Cost			$6,053,300	$6,261,550
		Engineering (15%)			$907,995	$939,233
		Contingency (25%)			$1,513,325	$1,565,388
		Project Management / Construction Management (10%)			$605,330	$626,155
		Total Capital Cost			$9,079,950	$9,392,325
	Additional Annual O&M Costs					
	44	Treatment Equipment/Materials Replacement	1	LS	$40,000	$40,000
	45	Monthly Monitoring/Inspection	8	each	$2,900	$23,200
	46	Reporting	1	LS	$5,000	$5,000
	47	Water, NAPL and Waste Disposal	1	LS	$61,000	$61,000
	48	Electricity/Heating for Sheds/Pumps	1	LS	$18,000	$18,000
		Subtotal O&M Costs				$147,200
		Contingency (25%)				$36,800
		Present Worth Factor (15 years at 7%)				9.11
		Total O&M Costs				$1,675,854
					Stabilized (i)	**LTTD (ii)**
		Alternative 2 - Total Estimated Cost			**$13,956,281**	**$14,268,656**
		Rounded to			**$13,960,000**	**$14,270,000**

General Notes:

1. Cost estimate is based on ARCADIS U.S., Inc.'s (ARCADIS') past experience and vendor estimates using 2010 dollars.
2. This estimate has been prepared for the purposes of comparing potential remedial alternatives. The information in this cost estimate is based on the available information regarding the site investigation and the anticipated scope of the remedial alternative. Changes in cost elements are likely to occur as a result of new information and data collected during the engineering design of the remedial alternative. This cost estimate is expected to be within -30% to +50% of the actual projected cost. Utilization of this cost estimate information beyond the stated purpose is not recommended. ARCADIS is not licensed to provide financial or legal consulting services; as such; this cost estimate information is not intended to be utilized for complying with financial reporting requirements associated with liability services.
3. Present worth is estimated based on a 7% beginning-of-year discount rate (adjusted for inflation) in accordance with United States Environmental Protection Agency (USEPA) Office of Solid Waste and Emergency Response (OSWER) Directive 9355.3-20 "Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis" (USEPA, 1993). It is assumed that "year zero" is 2011.
4. Costs do not include legal fees, negotiations or agency oversight.

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ALTERNATIVE 2 - COST ESTIMATE
Institutional Controls with Passive NAPL Recovery and Long-Term Groundwater Monitoring

Notes:

1. Legal/administrative/institutional controls cost estimate includes labor and materials necessary to institute deed restrictions to:
   (a) restrict future use of the Site to commercial/industrial activities;
   (b) restrict future use of site groundwater. The use restriction would apply to groundwater beneath the Site and, if acceptable to land parcels adjacent to the site;
   (c) notify future property owners of the presence of manufactured gas plant- (MGP-) related constituents in soil and groundwater at the Site;
   (d) notify future property owners of the applicability of the Site Management Plan; and
   (e) purchasing and compensation to adjacent property owners.
2. Site management plan cost estimate includes labor and materials necessary to prepare a site management plan for the Site that will:
   (a) identify known locations of MGP-impacts at the Site;
   (b) address possible future intrusive activities that would result in the potential for contact with MGP-impacts; and
   (c) set forth the inspection and maintenance activities for the fencing and vegetation/cover materials.
3. Groundwater monitoring well installation cost estimate includes labor, equipment, and materials necessary to install new groundwater monitoring wells. Cost estimate includes oversight by a geologist, and drill rig and crew. Cost estimate assumes polyvinyl chloride (PVC) well construction to a depth of approximately 25 feet bgs.
4. Existing wastewater treatment system cost estimate includes labor, equipment, and materials necessary to continue operation of the existing wastewater treatment system installed in 2006 and includes quarterly sampling, semiannual carbon change-outs, and annual sump cleaning.

5-7. Groundwater sampling labor and expenses (annual) cost estimate includes labor, equipment, and materials necessary to conduct annual sampling events for 22 monitoring wells, analyze groundwater samples, and prepare an annual groundwater monitoring report to summarize the results of the groundwater monitoring activities. This cost estimate also includes containerizing groundwater and NAPL (if present) waste materials generated during the sampling activities. This cost estimate also includes transportation of the containerized liquid waste for disposal as a non-hazardous waste at an appropriate treatment/disposal facility.

8. Annual costs associated with institutional controls include verifying the status of institutional controls and preparing/submitting notification to the South Dakota Department of Environmental and Natural Resources (SD DENR) to demonstrate that the institutional controls are being maintained and remain effective.
9. Mobilization/demobilization cost estimate includes:
   (i) Mobilization and demobilization of labor, equipment, and material necessary to install the passive NAPL recovery system. Assumes the mobilization will take place from DeWind's Holland, Michigan office to the Aberdeen site. Also includes equipment necessary to handle spoils at the Brown County Landfill for either soil amendment/stabilization or LTTD.
   (ii) Mobilization and demobilization of labor, equipment, and material necessary to thermally treat the spoils at the Brown County Landfill via a mobile low temperature thermal desorption (LTTD) unit; includes permitting.
10. Construction permits and erosion and sedimentation plans cost estimate includes costs to obtain appropriate permits necessary for the full-scale construction activities and prepare erosion and sedimentation plans.
11. Brown County Landfill, temporary land-use lease costs includes compensation to Brown County for temporary use of the landfill property to manage material during the amendment/solidifying or thermal treatment processes.
12. Health and safety program cost estimate includes labor for the development of a site-specific health and safety plan and assumes onsite workers within the exclusion zone will be in Level B for 30% of the duration that source material is handled.
13. Surveying cost estimate includes labor, equipment, and materials necessary to locate and identify underground utilities at the site. Cost assumes that utility location and markout would be conducted by a private utility locating company over a period of 5 days at a daily rate of $1,000 per day. Surveying cost estimate includes approximately $7,000 for establishing control points, base mapping, as-builts, etc.
14. Pre-design investigation cost estimate includes labor, equipment, and materials necessary to collect additional information to facilitate completion of the remedial design for this alternative, including a test boring/geotechnical program.

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15. Construction and maintenance of decontamination pad cost estimate includes labor, equipment, and materials necessary to construct and remove a 60-foot by 30-foot decontamination pad and appurtenances. The decontamination pad would consist of 40-mil high-density polyethylene (HDPE) with a 6-inch gravel drainage layer placed over the HDPE liner, surrounded by a one-foot high berm and sloped to a collection sump for the collection of decontamination water.
16. Construction and maintenance of soil staging areas cost estimate includes labor, equipment, and materials to construct an approximate 75-foot by 75-foot material staging area consisting of a 40-mil HDPE liner below a 12-inch sacrificial gravel fill layer with bermed sidewalls and sloped to a lined collection sump. Maintenance costs include inspecting and repairing staging area as necessary and covering staged soil with polyethylene sheeting or odor suppressing foam, as necessary.
17. Silt fence cost estimate includes installation of silt fence for erosion control along the perimeter of the trenching area.
18. Install temporary fencing cost estimate includes labor, equipment, and materials necessary to install and remove temporary fencing around the working area.
19. Passive wall pre-excavation cost estimate includes labor, equipment, and materials necessary to pre-excavate a trench along the passive wall alignments to verify presence/absence and location of underground utilities prior to installation of passive walls. Cost estimate assumes excavation activities to be completed using a backhoe and hand digging. Cost estimate assumes pre-excavation activities completed to a depth of 4 feet below grade for length of the passive barrier wall (approximately 3,000 feet).
20. Passive NAPL recovery wall installation - one pass trenching cost estimate includes labor, equipment, and materials necessary to install a passive barrier wall. Cost estimate includes site-preparation for trenching equipment along the trench alignment, excavating, placing pea-gravel stone backfill, and placing PVC sump, and assumes activities to be completed using a one-pass trencher. Cost estimate assumes approximately 3,000 linear-feet of wall at an average installation depth of 35 feet below ground surface (bgs), keyed one foot into till, with a width of 1.5 feet. Assumes the cost includes importation and placement of backfill. Assumes no dewatering will be required for trenching.
21. Well vault and trench NAPL recovery well/sump cost estimate includes labor, equipment, and materials necessary to install well vaults, 14-inch diameter stainless steel recovery wells to 35 feet bgs, and 10-inch diameter stainless steel sump extensions from 35- to 40-feet bgs following completion of site remedial activities.
22. NAPL recovery wells cost estimate includes labor, equipment, and materials necessary to install NAPL recovery wells following completion of site remedial activities. Cost estimate includes oversight by a geologist, and drill rig and crew. Cost estimate assumes PVC well construction to a depth of 25 feet bgs.
23. 20' X 20' equipment/pumping shed cost includes the cost to furnish and construct a 20-foot by 20-foot shed and associated slab where the pump and equipment will be stored.
24. Piping (2" HDPE line) cost estimate includes cost to furnish piping for product recovery from trench NAPL recovery wells to the equipment/pumping shed.
25. Piping (1/2" PVC line) cost estimate includes cost to furnish piping for air compressor supply lines from trench NAPL recovery well pumps to the equipment/pumping shed.
26. Electrical conduit cost estimate includes cost to furnish electrical conduit between nearby equipment/pumping shed onsite and south of the site.
27. Pipe trenching cost estimate includes labor, equipment, and materials necessary to excavate trenching associated with the NAPL collection piping and air lines from the NAPL wells to the equipment shed and the trenching associated with the electrical conduit. Trench assumes a depth of approximately 48-inches and a width of approximately 12-inches.
28. Pipe bedding and backfilling material cost estimate includes labor and equipment to furnish and place bedding and backfill material for the pipe trench excavation. Assumes excavated trench material will be disposed of offsite and not re-used.
29. Electrical drop to building cost estimate includes cost to furnish electric power to a treatment building on-site, south of the Site, and southeast of the Site (between the convergence of the two railroads).
30. Air compressor cost estimate includes cost to furnish a 20 horse power reciprocating compressor capable of producing approximately 70 cubic feet per minute of air.
31. 1,000 gallon cone bottomed NAPL storage tank cost estimate includes cost to furnish a cone bottomed HDPE storage tank for NAPL.

ALTERNATIVE 2 - COST ESTIMATE
Institutional Controls with Passive NAPL Recovery and Long-Term Groundwater Monitoring

32. 200 gallon cone bottomed water decant tank cost estimate includes cost to furnish a cone bottomed HDPE storage tank for decanting water.
33. System installation cost estimate includes labor, equipment and materials necessary to install the pumping systems, which includes, but is not limited to, installation of 2" HDPE piping and electrical conduit within the trench to each trench NAPL recovery well/sump; backfilling the trench; installation of pumping system components; and site restoration.
34. Miscellaneous mechanical cost estimate includes labor, equipment and materials necessary to complete system installation, label equipment, piping, and the sheds.
35. Soil removed from the passive NAPL recovery trench will either be:
    (i) Excavated soil amendment/stabilization cost estimate includes labor, equipment, and materials necessary to purchase and import stabilizing agent (e.g., Portland cement) to amend excavated soil. Estimated quantity based on an assumed 15% addition of amendment (by weight) to be amended at 2.0 tons per cubic-yard; or
    (ii) Treated via low temperature thermal desorption.
36. Solid waste transportation and disposal - non-hazardous cost estimate includes all labor, equipment, and materials necessary to transport non-hazardous excavated material off-site for disposal at a solid waste landfill. Estimated quantity based on soil excavated to facilitate installation of passive NAPL collection walls and pipe trenching. Cost estimate assumes a material density of 1.5 tons per cubic-yard. Cost estimate assumes soil would be managed at Brown County Landfill located in Aberdeen, South Dakota. Cost estimate includes transportation fuel charge and applicable taxes.
    (i) T&D costs includes the handling of material once it arrives at the landfill for amendment/stabilization.
    (ii) T&D does not include the handling of material for LTTD once it arrives at the landfill - costs for LTTD handling included in the treatment unit cost.
37. Waste characterization cost estimate includes costs for the analysis of soil samples for soil destined for off-site disposal at the Brown County Landfill. Costs assumes that existing analytical data will be the primary source of characterization data.
38. Miscellaneous waste disposal cost estimate includes disposal of personal protective equipment (PPE), staging area and decontamination pad materials, and disposable equipment and materials at a facility permitted to accept the waste.
39. Air monitoring cost estimate includes air sampling per TO-13 and TO-15 (4 samples per day) during trenching activities - cost per day from AirToxics quote.
40. Dust/vapor/odor control cost estimate includes equipment, labor, and materials necessary to monitor dust/vapor/odor emission during intrusive site activities. Cost estimate includes application of vapor/odor suppressing foam to excavated materials staged on-site.
41. Street surface washing cost estimate includes the equipment, labor, and materials necessary to wash the first two blocks adjacent to the site (approximately 750' by 70').
42. Surface restoration of grassed areas includes labor, equipment, and materials necessary to return approximately 60,000 square feet to original condition (i.e., topsoil, sod, or seed vegetated areas).
43. Weekly monitoring/inspection (1st month) cost estimate include costs for monitoring/inspection of the passive NAPL pumping system during the initial startup and operation of the system once a week for the first month of operation.
44. Treatment equipment/materials replacement cost estimate includes labor, equipment, and materials necessary for treatment of separated water including a bag filtration and carbon adsorption unit. Costs provided from H2K Technologies and includes piping and headers. Costs also include maintenance/replacement of pumps, carbon filters, etc.
45. Monthly monitoring/inspection cost estimate include costs for monthly monitoring/inspection and maintenance of the passive NAPL pumping system. Assumes monthly events will only be performed during the months of pumping operation when temperatures are above freezing. Assumed duration of operation is 15 years, after which it is assumed recovery reaches point of diminishing returns.
46. Reporting cost estimate includes the additional cost to summarize the passive NAPL recovery wall monitoring activities.
47. Water, NAPL, and waste disposal cost estimate includes off-site disposal of water to the POTW (approx. 100,000 per year at $0.01/gallon), disposal of NAPL (20,000 gallons per year at $3.00/gallon).

48. Electricity/heating for sheds/pumps cost estimates includes the cost to provide utilities for the sheds. Cost assumes eight months will require only electricity for pumping at $200 per shed per month. The remaining four months will require only heating at $500 per shed per month.

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ALTERNATIVE 3 - COST ESTIMATE

Targeted Source Removal and Stabilization/Disposal with Institutional Controls, Passive NAPL Recovery, and Long-Term Groundwater Monitoring

Alt.	Item #	Description	Quantity	Unit	Unit Price	Amount
Institutional Controls with Long-Term Groundwater Monitoring						
	Capital Costs					
	1	Legal/Administrative/Institutional Controls	1	LS	$1,100,000	$1,100,000
	2	Site Management Plan	1	LS	$25,000	$25,000
	3	Groundwater Monitoring Well Installation	6	each	$3,000	$18,000
					Subtotal Capital Cost	$1,143,000
					Engineering (15%)	$171,450
					Contingency (25%)	$285,750
					Project Management / Construction Management (10%)	$114,300
					Total Capital Cost	$1,714,500
	Annual Operation and Maintenance (O&M) Costs					
1,2,3	4	Existing Wastewater Treatment System	1	LS	$53,000	$53,000
	5	Groundwater Sampling Labor & Expenses (Annual)	1	event	$16,800	$16,800
	6	Laboratory Analytical	1	event	$6,000	$6,000
	7	Reporting	1	LS	$10,000	$10,000
	8	Verification of Institutional Controls	1	LS	$10,000	$10,000
					Subtotal O&M Costs	$95,800
					Contingency (25%)	$23,950
					Total Annual O&M Costs	$119,750
					Present Worth Factor (30 years at 7%)	12.41
					Present Worth O&M Cost	$1,485,978
					Alternative 1 - Total Estimated Cost:	**$3,200,478**
					Rounded to:	**$3,210,000**
Passive NAPL Recovery and Off-site Disposal						
	Capital Costs					
	9 (i)	Mobilization/Demobilization - One-Pass Trenching	1	LS	$100,000	$100,000
	(ii)	Mobilization/Demobilization/Permitting - LTTD	1	LS	$125,000	$125,000
	10	Construction Permits and Erosion and Sedimentation Plans	1	LS	$10,000	$10,000
	11	Brown County Landfill - Temporary Land-Use Lease	1	LS	$50,000	$50,000
	12	Health and Safety Program	1	LS	$25,000	$25,000
	13	Surveying	1	LS	$12,000	$12,000
	14	Pre-Design Investigation	1	LS	$75,000	$75,000
	15	Construction and Maintenance of Decontamination Pad	1	LS	$15,000	$15,000
	16	Construction and Maintenance of Soil Staging Areas	1	LS	$40,000	$40,000
	17	Silt Fence	6,200	LF	$5	$31,000
	18	Install Temporary Fencing	2,650	LF	$25	$66,250
2,3	19	Passive Wall Pre-Excavation	670	CY	$50	$33,500
	20	Passive NAPL Recovery Wall Installation - One Pass Trenching	105,000	SF	$40	$4,200,000
	21	Well Vault and Trench NAPL Recovery Well/Sump	13	each	$17,250	$224,250
	22	NAPL Recovery Wells	3	each	$4,000	$12,000
	23	20' x 20' Equipment/Pumping Shed	5	each	$8,000	$40,000
	24	Piping (2" HDPE Line)	1,700	LF	$3	$5,100
	25	Piping (1/2" PVC Line)	1,700	LF	$1.50	$2,550
	26	Electrical Conduit	1,000	LF	$12	$12,000
	27	Pipe Trenching	2,700	LF	$20	$54,000
	28	Pipe Bedding and Backfilling Material	400	CY	$25	$10,000
	29	Electrical Drop to Building	3	each	$15,000	$45,000
	30	Air Compressor	5	each	$10,500	$52,500
	31	1,000 Gallon Cone Bottomed NAPL Storage Tank	5	each	$1,500	$7,500
	32	200 Gallon Cone Bottomed Water Decant Tank	5	each	$500	$2,500

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ALTERNATIVE 3 - COST ESTIMATE

Targeted Source Removal and Stabilization/Disposal with Institutional Controls, Passive NAPL Recovery, and Long-Term Groundwater Monitoring

Alt.	Item #	Description	Quantity	Unit	Unit Price	Amount
Passive NAPL Recovery and Off-site Disposal (con't)						
2, 3	33	System Installation	1	LS	$25,000	$25,000
	34	Miscellaneous Mechanical	1	LS	$5,000	$5,000
	35 (i)	Excavated Soil Amendment/Stabilization	1,750	ton	$125	$218,750
	35 (ii)	Low Temperature Thermal Desorption (LTTD) Soil Treatment	8,800	ton	$45	$396,000
	36 (i)	Amended/Stabilized - Solid Waste Transportation and Disposal (T&D) - Nonhaz	9,400	ton	$55	$517,000
	36 (ii)	LTTD - Solid Waste T&D - Nonhaz	9,400	ton	$45	$423,000
	37	Waste Characterization	1	LS	$3,000	$3,000
	38	Miscellaneous Waste Disposal	1	LS	$10,000	$10,000
	39	Air Monitoring	48	day	$1,600	$76,800
	40	Dust/Vapor/Odor Control	8	week	$3,000	$24,000
	41	Street Surface Washing	8	week	$1,500	$12,000
	42	Surface Restoration - Grassed Areas	1	LS	$25,000	$25,000
	43	Weekly Monitoring/Inspection (1st Month)	4	each	$2,900	$11,600
					Stabilized (i)	**LTTD (ii)**
		Subtotal Capital Cost			$6,053,300	$6,261,550
		Engineering (15%)			$907,995	$939,233
		Contingency (25%)			$1,513,325	$1,565,388
		Project Management / Construction Management (10%)			$605,330	$626,155
		Total Capital Cost			$9,079,950	$9,392,325
	Additional Annual O&M Costs					
	44	Treatment Equipment/Materials Replacement	1	LS	$40,000	$40,000
	45	Monthly Monitoring/Inspection	8	each	$2,900	$23,200
	46	Reporting	1	LS	$5,000	$5,000
	47	Water, NAPL and Waste Disposal	1	LS	$61,000	$61,000
	48	Electricity/Heating for Sheds/Pumps	1	LS	$18,000	$18,000
		Subtotal O&M Costs				$147,200
		Contingency (25%)				$36,800
		Present Worth Factor (15 years at 7%)				9.11
		Total O&M Costs				$1,675,854
					Stabilized (i)	**LTTD (ii)**
		Alternative 2 - Total Estimated Cost			**$13,956,281**	**$14,268,656**
		Rounded to			**$13,960,000**	**$14,270,000**

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ALTERNATIVE 3 - COST ESTIMATE

Targeted Source Removal and Stabilization/Disposal with Institutional Controls, Passive NAPL Recovery, and Long-Term Groundwater Monitoring

Alt.	Item #	Description	Quantity	Unit	Unit Price	Amount
Targeted Source Removal and Stabilization/Off-site Disposal						
3	**Capital Costs**					
	49	Additional Mobilization/Demobilization	1	LS	$35,000	$35,000
	50	Additional Construction Permits and Erosion and Sedimentation Plans	1	LS	$5,000	$5,000
	51	Additional Surveying	1	LS	$10,000	$10,000
	52	Additional Pre-Design Investigation	1	LS	$25,000	$25,000
	53	Additional Construction and Maintenance of Soil Staging Area	1	LS	$60,000	$60,000
	54	Additional Silt Fence	2,000	LF	$5	$10,000
	55	Additional Temporary Fencing	660	LF	$25	$16,500
	56	Install and Remove Temporary Steel Sheetpiling	9,100	SF	$50	$455,000
	57	Soil Excavation, Handling, and Screening of Excavated Materials	35,500	CY	$50	$1,757,250
	58	Backfill	35,500	CY	$35	$1,242,500
	59	Demarcation Layer	4,800	SY	$3	$14,400
	60 (i)	Excavated Soil Amendment/Stabilization	10,700	ton	$125	$1,337,500
	(ii)	LTTD Soil Treatment	53,250	ton	$35	$1,863,750
	61 (i)	Amended/Stabilized - Solid Waste T&D - Nonhaz	53,250	ton	$55	$2,928,750
	(ii)	LTTD - Solid Waste T&D - Nonhaz	53,250	ton	$45	$2,396,250
	62	Miscellaneous Waste Disposal	1	LS	$10,000	$10,000
	63	Air Monitoring	156	day	$1,600	$249,600
	64	Additional Dust/Vapor/Odor Control	26	week	$3,000	$78,000
	65	Excavation Area Dewatering and Water Treatment	7	month	$50,000	$350,000
	66	Street Surface Washing	26	week	$1,500	$39,000
	67	Asphalt Milling - Road Surface Adjacent to Site	52,500	SF	$0.75	$39,375
	68	Surface Restoration - Installation of 3" Bituminous Asphalt Top Course	1,000	ton	$50	$50,000
	69	Additional Surface Restoration - Grassed Areas	1	LS	$20,000	$20,000
					Stabilized (i)	**LTTD (ii)**
		Subtotal Capital Cost			$8,732,875	$8,726,625
		Engineering (15%)			$1,309,931	$1,308,994
		Contingency (25%)			$2,183,219	$2,181,656
		Project Management / Construction Management (10%)			$873,288	$872,663
		Total Capital Cost			$13,099,313	$13,089,938
		Alternative 3 - Total Estimated Cost			**$27,059,313**	**$27,359,938**
		Rounded to			**$27,100,000**	**$27,400,000**

General Notes:

1. Cost estimate is based on ARCADIS U.S., Inc.'s (ARCADIS') past experience and vendor estimates using 2010 dollars.
2. This estimate has been prepared for the purposes of comparing potential remedial alternatives. The information in this cost estimate is based on the available information regarding the site investigation and the anticipated scope of the remedial alternative. Changes in cost elements are likely to occur as a result of new information and data collected during the engineering design of the remedial alternative. This cost estimate is expected to be within -30% to +50% of the actual projected cost. Utilization of this cost estimate information beyond the stated purpose is not recommended. ARCADIS is not licensed to provide financial or legal consulting services; as such; this cost estimate information is not intended to be utilized for complying with financial reporting requirements associated with liability services.
3. Present worth is estimated based on a 7% beginning-of-year discount rate (adjusted for inflation) in accordance with United States Environmental Protection Agency (USEPA) Office of Solid Waste and Emergency Response (OSWER) Directive 9355.3-20 "Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis" (USEPA, 1993). It is assumed that "year zero" is 2011.
4. Costs do not include legal fees, negotiations or agency oversight.

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ABERDEEN FORMER MANUFACTURED GAS PLANT
ABERDEEN, SOUTH DAKOTA

ALTERNATIVE 3 - COST ESTIMATE

Targeted Source Removal and Stabilization/Disposal with Institutional Controls, Passive NAPL Recovery, and Long-Term Groundwater Monitoring

Notes:

1. Legal/administrative/institutional controls cost estimate includes labor and materials necessary to institute deed restrictions to:
   (a) restrict future use of the Site to commercial/industrial activities;
   (b) restrict future use of site groundwater. The use restriction would apply to groundwater beneath the Site and, if acceptable to land parcels adjacent to the site;
   (c) notify future property owners of the presence of manufactured gas plant- (MGP-) related constituents in soil and groundwater at the Site;
   (d) notify future property owners of the applicability of the Site Management Plan; and
   (e) purchasing and compensation to adjacent property owners.
2. Site management plan cost estimate includes labor and materials necessary to prepare a site management plan for the Site that will:
   (a) identify known locations of MGP-impacts at the Site;
   (b) address possible future intrusive activities that would result in the potential for contact with MGP-impacts; and
   (c) set forth the inspection and maintenance activities for the fencing and vegetation/cover materials.
3. Groundwater monitoring well installation cost estimate includes labor, equipment, and materials necessary to install new groundwater monitoring wells. Cost estimate includes oversight by a geologist, and drill rig and crew. Cost estimate assumes polyvinyl chloride (PVC) well construction to a depth of approximately 25 feet bgs.
4. Existing wastewater treatment system cost estimate includes labor, equipment, and materials necessary to continue operation of the existing wastewater treatment system installed in 2006 and includes quarterly sampling, semiannual carbon change-outs, and annual sump cleaning.

5-7. Groundwater sampling labor and expenses (annual) cost estimate includes labor, equipment, and materials necessary to conduct annual sampling events for 22 monitoring wells, analyze groundwater samples, and prepare an annual groundwater monitoring report to summarize the results of the groundwater monitoring activities. This cost estimate also includes containerizing groundwater and NAPL (if present) waste materials generated during the sampling activities. This cost estimate also includes transportation of the containerized liquid waste for disposal as a non-hazardous waste at an appropriate treatment/disposal facility.

8. Annual costs associated with institutional controls include verifying the status of institutional controls and preparing/submitting notification to the South Dakota Department of Environmental and Natural Resources (SD DENR) to demonstrate that the institutional controls are being maintained and remain effective.
9. Mobilization/demobilization cost estimate includes:
   (i) Mobilization and demobilization of labor, equipment, and material necessary to install the passive NAPL recovery system. Assumes the mobilization will take place from DeWind's Holland, Michigan office to the Aberdeen site. Also includes equipment necessary to handle spoils at the Brown County Landfill for either soil amendment/stabilization or LTTD.
   (ii) Mobilization and demobilization of labor, equipment, and material necessary to thermally treat the spoils at the Brown County Landfill via a mobile low temperature thermal desorption (LTTD) unit; includes permitting.
10. Construction permits and erosion and sedimentation plans cost estimate includes costs to obtain appropriate permits necessary for the full-scale construction activities and prepare erosion and sedimentation plans.
11. Brown County Landfill, temporary land-use lease costs includes compensation to Brown County for temporary use of the landfill property to manage material during the amendment/solidifying or thermal treatment processes.
12. Health and safety program cost estimate includes labor for the development of a site-specific health and safety plan and assumes onsite workers within the exclusion zone will be in Level B for 30% of the duration that source material is handled.
13. Surveying cost estimate includes labor, equipment, and materials necessary to locate and identify underground utilities at the site. Cost assumes that utility location and markout would be conducted by a private utility locating company over a period of 5 days at a daily rate of $1,000 per day. Surveying cost estimate includes approximately $7,000 for establishing control points, base mapping, as-builts, etc.
14. Pre-design investigation cost estimate includes labor, equipment, and materials necessary to collect additional information to facilitate completion of the remedial design for this alternative, including a test boring/geotechnical program.

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15. Construction and maintenance of decontamination pad cost estimate includes labor, equipment, and materials necessary to construct and remove a 60-foot by 30-foot decontamination pad and appurtenances. The decontamination pad would consist of 40-mil high-density polyethylene (HDPE) with a 6-inch gravel drainage layer placed over the HDPE liner, surrounded by a one-foot high berm and sloped to a collection sump for the collection of decontamination water.
16. Construction and maintenance of soil staging areas cost estimate includes labor, equipment, and materials to construct an approximate 75-foot by 75-foot material staging area consisting of a 40-mil HDPE liner below a 12-inch sacrificial gravel fill layer with bermed sidewalls and sloped to a lined collection sump. Maintenance costs include inspecting and repairing staging area as necessary and covering staged soil with polyethylene sheeting or odor suppressing foam, as necessary.
17. Silt fence cost estimate includes installation of silt fence for erosion control along the perimeter of the trenching area.
18. Install temporary fencing cost estimate includes labor, equipment, and materials necessary to install and remove temporary fencing around the working area.
19. Passive wall pre-excavation cost estimate includes labor, equipment, and materials necessary to pre-excavate a trench along the passive wall alignments to verify presence/absence and location of underground utilities prior to installation of passive walls. Cost estimate assumes excavation activities to be completed using a backhoe and hand digging. Cost estimate assumes pre-excavation activities completed to a depth of 4 feet below grade for length of the passive barrier wall (approximately 3,000 feet).
20. Passive NAPL recovery wall installation - one pass trenching cost estimate includes labor, equipment, and materials necessary to install a passive barrier wall. Cost estimate includes site-preparation for trenching equipment along the trench alignment, excavating, placing pea-gravel stone backfill, and placing PVC sump, and assumes activities to be completed using a one-pass trencher. Cost estimate assumes approximately 3,000 linear-feet of wall at an average installation depth of 35 feet below ground surface (bgs), keyed one foot into till, with a width of 1.5 feet. Assumes the cost includes importation and placement of backfill. Assumes no dewatering will be required for trenching.
21. Well vault and trench NAPL recovery well/sump cost estimate includes labor, equipment, and materials necessary to install well vaults, 14-inch diameter stainless steel recovery wells to 35 feet bgs, and 10-inch diameter stainless steel sump extensions from 35- to 40-feet bgs following completion of site remedial activities.
22. NAPL recovery wells cost estimate includes labor, equipment, and materials necessary to install NAPL recovery wells following completion of site remedial activities. Cost estimate includes oversight by a geologist, and drill rig and crew. Cost estimate assumes PVC well construction to a depth of 25 feet bgs.
23. 20' X 20' equipment/pumping shed cost includes the cost to furnish and construct a 20-foot by 20-foot shed and associated slab where the pump and equipment will be stored.
24. Piping (2" HDPE line) cost estimate includes cost to furnish piping for product recovery from trench NAPL recovery wells to the equipment/pumping shed.
25. Piping (1/2" PVC line) cost estimate includes cost to furnish piping for air compressor supply lines from trench NAPL recovery well pumps to the equipment/pumping shed.
26. Electrical conduit cost estimate includes cost to furnish electrical conduit between nearby equipment/pumping shed onsite and south of the site.
27. Pipe trenching cost estimate includes labor, equipment, and materials necessary to excavate trenching associated with the NAPL collection piping and air lines from the NAPL wells to the equipment shed and the trenching associated with the electrical conduit. Trench assumes a depth of approximately 48-inches and a width of approximately 12-inches.
28. Pipe bedding and backfilling material cost estimate includes labor and equipment to furnish and place bedding and backfill material for the pipe trench excavation. Assumes excavated trench material will be disposed of offsite and not re-used.
29. Electrical drop to building cost estimate includes cost to furnish electric power to a treatment building on-site, south of the Site, and southeast of the Site (between the convergence of the two railroads).
30. Air compressor cost estimate includes cost to furnish a 20 horse power reciprocating compressor capable of producing approximately 70 cubic feet per minute of air.
31. 1,000 gallon cone bottomed NAPL storage tank cost estimate includes cost to furnish a cone bottomed HDPE storage tank for NAPL.
32. 200 gallon cone bottomed water decant tank cost estimate includes cost to furnish a cone bottomed HDPE storage tank for decanting water.

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33. System installation cost estimate includes labor, equipment and materials necessary to install the pumping systems, which includes, but is not limited to, installation of 2" HDPE piping and electrical conduit within the trench to each trench NAPL recovery well/sump; backfilling the trench; installation of pumping system components; and site restoration.
34. Miscellaneous mechanical cost estimate includes labor, equipment and materials necessary to complete system installation, label equipment, piping, and the sheds.
35. Soil removed from the passive NAPL recovery trench will either be:
(i) Excavated soil amendment/stabilization cost estimate includes labor, equipment, and materials necessary to purchase and import stabilizing agent (e.g., Portland cement) to amend excavated soil. Estimated quantity based on an assumed 15% addition of amendment (by weight) to be amended at 2.0 tons per cubic-yard; or
(ii) Treated via low temperature thermal desorption.
36. Solid waste transportation and disposal - non-hazardous cost estimate includes all labor, equipment, and materials necessary to transport non-hazardous excavated material off-site for disposal at a solid waste landfill. Estimated quantity based on soil excavated to facilitate installation of passive NAPL collection walls and pipe trenching. Cost estimate assumes a material density of 1.5 tons per cubic-yard. Cost estimate assumes soil would be managed at Brown County Landfill located in Aberdeen, South Dakota. Cost estimate includes transportation fuel charge and applicable taxes.
(i) T&D costs includes the handling of material once it arrives at the landfill for amendment/stabilization.
(ii) T&D does not include the handling of material for LTTD once it arrives at the landfill - costs for LTTD handling included in the treatment unit cost.
37. Waste characterization cost estimate includes costs for the analysis of soil samples for soil destined for off-site disposal at the Brown County Landfill. Costs assumes that existing analytical data will be the primary source of characterization data.
38. Miscellaneous waste disposal cost estimate includes disposal of personal protective equipment (PPE), staging area and decontamination pad materials, and disposable equipment and materials at a facility permitted to accept the waste.
39. Air monitoring cost estimate includes air sampling per TO-13 and TO-15 (4 samples per day) during trenching activities - cost per day from AirToxics quote.
40. Dust/vapor/odor control cost estimate includes equipment, labor, and materials necessary to monitor dust/vapor/odor emission during intrusive site activities. Cost estimate includes application of vapor/odor suppressing foam to excavated materials staged on-site.
41. Street surface washing cost estimate includes the equipment, labor, and materials necessary to wash the first two blocks adjacent to the site (approximately 750' by 70').
42. Surface restoration of grassed areas includes labor, equipment, and materials necessary to return approximately 60,000 square feet to original condition (i.e., topsoil, sod, or seed vegetated areas).
43. Weekly monitoring/inspection (1st month) cost estimate include costs for monitoring/inspection of the passive NAPL pumping system during the initial startup and operation of the system once a week for the first month of operation.
44. Treatment equipment/materials replacement cost estimate includes labor, equipment, and materials necessary for treatment of separated water including a bag filtration and carbon adsorption unit. Costs provided from H2K Technologies and includes piping and headers. Costs also include maintenance/replacement of pumps, carbon filters, etc.
45. Monthly monitoring/inspection cost estimate include costs for monthly monitoring/inspection and maintenance of the passive NAPL pumping system. Assumes monthly events will only be performed during the months of pumping operation when temperatures are above freezing. Assumed duration of operation is 15 years, after which it is assumed recovery reaches point of diminishing returns.
46. Reporting cost estimate includes the additional cost to summarize the passive NAPL recovery wall monitoring activities.
47. Water, NAPL, and waste disposal cost estimate includes off-site disposal of water to the POTW (approx. 100,000 per year at $0.01/gallon), disposal of NAPL (20,000 gallons per year at $3.00/gallon).
48. Electricity/heating for sheds/pumps cost estimates includes the cost to provide utilities for the sheds. Cost assumes eight months will require only electricity for pumping at $200 per shed per month. The remaining four months will require only heating at $500 per shed per month.
49. Mobilization/demobilization cost includes mobilization and demobilization of additional labor, equipment, and material necessary to excavate soil and install and remove temporary sheetpiling.

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50. Construction permits and erosion and sedimentation plans cost estimate includes additional costs to obtain appropriate permits necessary for the full-scale construction activities and prepare erosion and sedimentation plans.
51. Surveying cost estimate includes additional labor, equipment, and materials necessary to locate and identify underground utilities at the site. Cost assumes that utility location and markout would be conducted by a private utility locating company over a period of 4 days at a daily rate of $1,000 per day. Surveying cost estimate includes approximate $6,000 for establishing control points, base mapping, as-builts, etc.
52. Pre-design investigation cost estimate includes labor, equipment, and materials necessary to collect additional information to facilitate completion of the remedial design for this alternative, including a test boring/geotechnical program.
53. Construction and maintenance of soil staging areas cost estimate includes additional labor, equipment, and materials to construct an approximate 150-foot by 150-foot material staging area consisting of a 40-mil HDPE liner below a 12-inch sacrificial gravel fill layer with bermed sidewalls and sloped to a lined collection sump. Maintenance costs include inspecting and repairing staging area as necessary and covering staged soil with polyethylene sheeting or odor suppressing foam, as necessary.
54. Silt fence cost estimate includes installation of additional silt fence for erosion control along the perimeter of the trenching and excavation areas.
55. Install temporary fencing cost estimate includes additional labor, equipment, and materials necessary to install and remove temporary fencing around the working area.
56. Install and remove temporary sheet piling cost estimate includes labor, equipment, and materials necessary to install and remove temporary steel sheet pile for excavation parallel to the railroad. Cost estimate assumes cantilever sheet piling (with an embedment depth of 2.5 times the excavation depth) would be utilized and reinforced with tie backs and/or interior bracing. Cost includes an additional 15% of sheet pile for interior sheeting.
57. Soil excavation, handling, and screening of excavated materials cost estimate includes labor, equipment, transfer excavated material to an on-site staging area, and materials necessary to excavate material and load staged material for transportation off-site. Estimated quantity based on in-place volume of soil for focused excavation. Assumes the sides of excavations will be sloped at a ratio of 0.5:1. The two excavations located along the railroad right of way will have temporary steel sheeting installed on the side of the excavation nearest and parallel to the railroad. Assumes an additional 25% volume of visually impacted soil to be removed beyond the identified excavation limits.
58. Backfill cost estimate includes labor, equipment, and materials necessary to import, place, compact, and grade general fill to replace excavated material. Cost estimate is based on in-place soil volume. It is assumed that fill can be imported, placed, compacted and graded at approximately the same rate as soil excavation activities (300 CY per day), and that approximately 50% of fill importation, placement, compaction and grading activities will be performed simultaneously with excavation.
59. Demarcation layer cost estimate includes labor, equipment, and materials necessary to place a woven, light-weight, non-biodegradable, high-visibility demarcation layer at the bottom of the focused soil excavation areas.
60. Soil will either be:
    (i) Excavated soil amendment/stabilization cost estimate includes labor, equipment, and materials necessary to purchase and import stabilizing agent (e.g., Portland cement) to amend excavated soil. Estimated quantity based on an assumed 15% addition of amendment (by weight) to be amended at 2.0 tons per cubic-yard; or
    (ii) Treated via low temperature thermal desorption.
61. Solid waste transportation and disposal - non-hazardous cost estimate includes all labor, equipment, and materials necessary to transport non-hazardous excavated material off-site for disposal at a solid waste landfill. Estimated quantity based on soil excavated to facilitate installation of passive NAPL collection walls and pipe trenching. Cost estimate assumes a material density of 1.5 tons per cubic-yard. Cost estimate assumes soil would be managed at Brown County Landfill located in Aberdeen, South Dakota. Cost estimate includes transportation fuel charge and applicable taxes.
    (i) T&D costs includes the handling of material once it arrives at the landfill for amendment/stabilization.
    (ii) T&D does not include the handling of material for LTTD once it arrives at the landfill - costs for LTTD handling included in the treatment unit cost.
62. Air monitoring cost estimate includes air sampling per TO-13 and TO-15 (4 samples per day) during the excavation activities - cost per day from AirToxics quote.

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63. Miscellaneous waste disposal cost estimate includes disposal of personal protective equipment (PPE), staging area and decontamination pad materials, and disposable equipment and materials at a facility permitted to accept the waste.
64. Dust/vapor/odor control cost estimate includes additional equipment, labor, and materials necessary to monitor dust/vapor/odor emission during intrusive site activities. Cost estimate includes application of vapor/odor suppressing foam to excavated materials staged onsite.
65. Excavation area dewatering and water treatment cost estimate includes installation of sumps within excavation areas and rental of a portable water treatment system capable of operating at 50 gallons-per-minute. Cost estimate assumes water treatment system includes pumps, influent piping and hoses, frac tanks, carbon filters, bag filters, discharge piping and hoses, and flow meter. Cost estimate assumes bag filters will require change out approximately once per day of operation. Estimate assumes treated water would be discharge to local storm sewer at no additional cost.
66. Street surface washing cost estimate includes the additional equipment, labor, and materials necessary to wash the first two blocks adjacent to the site (approximately 750' by 70').
67. Asphalt milling - road surface adjacent to site cost estimate includes labor, equipment, and materials necessary to mill the top 3" of asphalt from 2 blocks adjacent to the Site (750' by 70').
68. Surface restoration - installation of 3" bituminous asphalt top course cost estimate includes labor, equipment, and materials necessary to install 3" of asphalt top course. Assumes asphalt is 2.0 tons per cubic yard.
69. Surface restoration of grassed areas includes additional labor, equipment, and materials necessary to return 43,000 square feet to original condition (i.e, topsoil, sod, or seed vegetated areas).