Remedial Investigation and Focused Feasibility Study
Fargo Manufactured Gas Plant (MGP) and Vicinity

Fargo, Cass County, North Dakota

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Northern States Power Co.
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Abbreviations

ac	Acre
ARAR	Applicable or Relevant and Appropriate Requirement
BaPTEQ	Benzo[a]pyrene Toxicity Equivalent
bgs	Below Ground Surface
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
CC	Coal Carbonization
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CFC-12	Dichlorodifluoromethane
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
CRG	Confidence Response Goal
CSM	Conceptual Site Model
CUG	Cleanup Goal
Culligan	Culligan Water Conditioning of Fargo
CWG	Carbureted Water Gas
DRO	Diesel Range Organics
DROSI	Diesel Range Organics with Silica Gel Extraction Cleanup
EF	Exposure Frequency
EM Survey	Electromagnetic Survey
EPC	Exposure Point Concentration
EPD	Effective Predictive Domain
FFS	Focused Feasibility Study
GLA	Glacial Lake Agassiz
GPR	Ground Penetrating Radar
GRO	Gasoline Range Organics
Heartland	Heartland Apartments
HI	Hazard Index
Historic Union	Union Storage and Transfer Facility
HQ	Hazard Quotient
in	Inch
IR	Ingestion Rate
ISCO	*In Situ* Chemical Oxidation
ISS	*In Situ* Solidification and Stabilization
MAH	Monocyclic Aromatic Hydrocarbon
MGP	Manufactured Gas Plant
MNA	Monitored Natural Attenuation
MSL	Mean Sea Level
NAPL	Non-aqueous Phase Liquid
NDDH	North Dakota Department of Health
NP Avenue	Northern Pacific Avenue
NSP	Northern States Power Co.

NTE	Not to Exceed
O&M	Operation and Maintenance
PAH	Polycyclic Aromatic Hydrocarbon
PCE	Perchloroethylene (*aka* Tetrachloroethylene)
PID	Photoionization Detector
QAPP	Quality Assurance Project Plan
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial Action Objective
RfC	Reference Concentration
RfD	Reference Dose
RI	Remedial Investigation
ROW	Right of Way
RSL	Regional Screening Level
SI	Silica Gel Extraction Cleanup
SVE	Soil Vapor Extraction
tMAH	Total Monocyclic Aromatic Hydrocarbons
tPAH	Total Polycyclic Aromatic Hydrocarbons
TPH	Total Petroleum Hydrocarbons
UCLM	Upper Confidence Limit on the Mean
URI	United Refrigeration, Inc.
US EPA	United States Environmental Protection Agency
UST	Underground Storage Tank
VCA	Voluntary Cleanup Agreement
VISL	Vapor Intrusion Screening Level
VOC	Volatile Organic Compound

Executive Summary

This Remedial Investigation and Focused Feasibility Study (RI/FFS) report was prepared on behalf of Northern States Power Co. (NSP) to document the findings of the multi-media environmental site investigations, human health risk assessment, and focused feasibility analysis of remediation alternatives conducted for the former manufactured gas plant (MGP) in Fargo, North Dakota (Site), and in its vicinity. The former MGP operated on the north side of Northern Pacific (NP) Avenue between 11th Street North and North University Drive.[1] Between July 2015 and September 2016, investigations were performed on the following properties in accordance with work plans submitted to and accepted by the North Dakota Department of Health (NDDH):

- The Heartland Apartments property (Heartland);
- The United Refrigeration, Inc. property (URI);
- Various city streets, alleys, and sidewalks (Rights of Way [ROWs]) between and around these properties;[2]
- The former Union Storage and Transfer Facility property (Historic Union);
- The Culligan Water Conditioning of Fargo property (Culligan); and
- The 1213 NP Avenue property.

The Heartland and URI properties comprise the former MGP Site; the remaining properties are in its vicinity.

ES.1 Objectives and Scope

This report provides a holistic summary and interpretation of the environmental investigations conducted at the Site to-date and evaluates the results with the following overall objectives:

1. Characterize the source(s) of constituents associated with the former MGP Site;
2. Delineate the extent of potential MGP constituents in soil, groundwater, and soil gas at the former MGP Site and in its vicinity;
3. Characterize hydrogeology at the former MGP Site and its vicinity;
4. Develop a conceptual site model (CSM) to explain the sources and environmental fate and transport of MGP constituents;
5. Evaluate whether other, non-MGP sources are impacting Site environmental conditions;
6. Determine whether there are unacceptable risks to human health posed by exposure to potential MGP constituents, based on current and reasonably foreseeable future conditions at the Site and its vicinity; and

[1] The Fargo MGP Site was located at 1150 NP Avenue, Fargo, Cass County, North Dakota, and encompassed two parcels (01-2382-04070-000 and 01-2382-04120-000), which are separated by 12th Street North.
[2] Including 11th Street North, 12th Street North, NP Avenue, and alleys north of the Heartland property, north of the URI property, and south of the URI property.

7. Develop a remedial approach for the Site and its vicinity based on an FFS of viable remediation alternatives.

To meet these objectives, NSP performed the following work:

- Implemented a comprehensive, multi-media sampling program that included the collection of more than 265 soil, 115 water, and 125 vapor samples from nearly 300 locations to characterize environmental conditions throughout the Site and in its vicinity.
- Performed a geophysical survey, consisting of a ground penetrating radar (GPR) and electromagnetic survey (EM survey), over portions of the Site to locate underground structures and features.
- Excavated and properly disposed of more than 2,378 tons of soil from the City ROWs adjacent to the Site where former impacts were encountered and removed.
- Established a permanent monitoring network of 34 sub-slab soil gas monitoring points and 22 groundwater monitoring wells.
- Performed extensive historical research to understand former MGP operations as well as other industrial operations in the area that may be potential sources.
- Performed a quantitative human health risk assessment to determine whether there are unacceptable risks posed by current conditions or based on reasonably anticipated future land use conditions.
- Performed an FFS of remediation alternatives for the properties that comprise the Site and its vicinity.
- Conducted public outreach activities, including hosting a public meeting, outreach to affected property owners and interested members of the public, and hosting an informational website.

The main conclusions from this work are summarized as follows.

ES.2 MGP Sources and Impacts

MGP impacts consist primarily of non-aqueous phase liquid (NAPL) and its associated impacts to soil, groundwater, and soil gas. The NAPLs, which consisted of oily and/or tarry material that is consistent with historic releases of MGP drip oil, petroleum feedstock, and tar, were encountered as "blebs,"[3] sheens, and free product. The distribution of NAPL relative to the location of former MGP structures shows that there are four main source areas at the MGP Site:

1. **Tar production and storage operations** located in the southern parking lot area at the Heartland property, where NAPL impacts were observed during the field investigations. NAPL was encountered in 13 of 36 locations in the southern parking lot area, most frequently at depths from 2-7 ft below ground surface (bgs), with NAPL "stringers"[4] encountered at depths of up to 32 ft bgs.
2. **Tar transfer areas**, including former rail lines, pipes, and wooden tanks in portions of the NP Avenue ROW and at the Heartland property that were likely used to convey tar for off-Site sale. NAPL was found in, beneath, and around these tar transfer areas. NAPL-related impacts were

[3] Trace spheres of residual NAPL present in the pores of the surrounding soil matrix.
[4] Thin seams of residual NAPL present in the surrounding soil matrix.

shallow (2-8 ft bgs) in this area and encountered in borings along the north-south rail spur, and inside and around pipes leading to the southern rail spur and in a former tank in the NP Avenue ROW.

3. **MGP petroleum storage and conveyances**, used for carbureted water gas (CWG) production and located in the northern parking lot area at the Heartland property, where petroleum impacts were observed. A light sheen was observed at depths up to 8 ft bgs at four locations in the northern parking lot area, and small blebs of NAPL were observed at 9 ft bgs over a 1- to 2-in depth interval.
4. **Drip oil sheens**, encountered near the former gas distribution holder at the URI property. A shallow sheen was observed at depths up to 8 ft bgs at borings in the alley south of the URI property and the southeastern corner of the URI property.

Former MGP piping in close proximity to the former MGP Site may have also acted as preferential pathways for limited historical NAPL migration based on the presence of sheen in/adjacent to those pipes.

These MGP NAPLs are comprised primarily of organic hydrocarbons (in various proportions) that, over time, transfer to the environmental media that they contact. Consistent with the presence of these NAPLs, a range of organic hydrocarbons that are potential MGP constituents were detected in soil and groundwater, both on- and off-Site, including:[5]

- Polycyclic aromatic hydrocarbons (PAHs), including naphthalene, 2-methylnaphthalene, pyrene, and fluoranthene.
- Monocyclic aromatic hydrocarbons (MAHs), including benzene, toluene, ethylbenzene, and xylenes (BTEX) and their alkylated homologs.
- Total petroleum hydrocarbons (TPH), including diesel range organics (DRO) and gasoline range organics (GRO) fractions.

The potential MGP constituents detected in soil gas samples included BTEX compounds and naphthalene.

The highest concentrations of these potential MGP constituents in soil were located in proximity with NAPL and concentrations decreased with distance from the identified NAPL, confirming that the NAPL acts as a source of contamination and its impacts are sufficiently delineated by the analytical data collected in the investigation. In turn, groundwater and soil gas impacts were co-located with the elevated soil impacts and have also been sufficiently delineated.

In addition to NAPL and its related impacts, inorganic potential MGP constituents, including cyanide (total and free) and ammonia, were detected in soil and groundwater. The presence of cyanide is consistent with historical manufactured gas purification operations (iron oxide media was used to remove sulfide from manufactured gas; strongly complexed cyanides were often bound to the oxide media), although no purifier box waste (*i.e.*, a current source) was encountered at the MGP Site during the investigations. Notably, the concentrations of free cyanide, which is more physiologically relevant from a human health perspective, were significantly lower than total cyanide concentrations. The presence of ammonia is consistent with ammonia recovery operations at the Site; ammonia was historically recovered as a byproduct of coal gas production for sale. Metals concentrations were generally within the range of naturally occurring background concentrations for North Dakota soils.

[5] As described in ES.2, these constituents are not unique to MGPs, and there is some evidence of contribution from other sources.

Surface soils on the MGP Site showed no evidence of source material or significant MGP-related contamination (*i.e.*, showed low to non-detectable levels of MAHs, PAHs, DRO, GRO, and free cyanide).

Consistent with the hydrogeological setting of the Site, the analytical data that has been collected, and the observations during the field investigations, the bulk transport of MGP-related constituents in the subsurface is limited except along preferential pathways. The Site is underlain by low-permeability silts/clays (measured horizontal hydraulic conductivity on the order of 10^{-8} to 10^{-7} cm/s) to a depth of at least 100 ft bgs, and the limited subsurface migration potential of the contamination was evident from the rapid attenuation of potential MGP constituents in groundwater and soil gas with distance from the source material. Further, sub-slab soil gas sampling results for the Heartland, URI, Historic Union, Culligan, and 1213 NP Avenue properties showed low concentrations in sub-slab soil gas samples underneath the buildings. At the Heartland, URI, and Historic Union properties, where MGP-related impacts were identified, constituent concentrations in sub-slab samples were lower than at soil gas sampling locations in the surrounding areas, which provided evidence of vapor attenuation with distance from the source(s).

The lateral extent of MGP-related impacts to soil and groundwater has been sufficiently delineated in all directions as part of the investigation activities. Vertical delineation was not completed in all areas of the Site, but is not warranted because: (1) the low-conductivity native silts/clays extend to a depth of at least 100 ft bgs; (2) groundwater monitoring wells screened below the source areas in the clay at 60 ft bgs, with the exception of ammonia and cyanide, had no detections of MGP impacts; and (3) there is no identified use of shallow groundwater within the vicinity of the MGP Site. Overall, the extent of the impacts are well-defined and located only in the low-conductivity subsurface silt/clays sequestered above the deep groundwater aquifer.

ES.3 Non-MGP Impacts

The Fargo MGP Site is located in an urban area with many other known or potential sources of contamination, including petroleum storage and transfer facilities, dry cleaning operations, and railroad operations, contributing to both the suite of potential MGP constituents (DRO, GRO, PAH, MAH), as well as distinct constituents, such as dichlorodifluoromethane (CFC-12). In addition, there are elevated concentrations of naturally occurring metals in soil and groundwater. In delineating the nature and extent of MGP contamination, and in evaluating human health risks, it is important to recognize these non-MGP contributions. For example:

- DRO was detected in soil and groundwater at locations absent of other potential MGP constituents near the periphery of the investigations, indicating that the background level of DRO in the vicinity of the Site may be elevated by other sources.
- Chemical fingerprinting analyses identified several locations in the City ROWs that showed evidence of petroleum contributions from off-Site sources and/or more recent sources than those associated with the former MGP.
- Multiple properties, including the URI, Historic Union, and Culligan properties, had detections of compounds that are not potential MGP constituents (*e.g.*, chloroform, isopropyl alcohol, CFC-12) at magnitudes exceeding risk-based screening levels in sub-slab soil gas.
- Multiple metals were detected in surface soil, subsurface soil, and groundwater, some at concentrations exceeding United States Environmental Protection Agency (US EPA) screening levels (*e.g.*, aluminum, arsenic, chromium, lead, and manganese). However, these are generally consistent with naturally occurring concentrations of these metals found in Fargo and

Cass County, based on a comparison to metals data collected by the United States Geological Survey (USGS).

ES.4 Human Health Risk Evaluation

A human health risk evaluation was performed as part of the Site investigation.[6] The risk evaluation characterized priority[7] exposure pathways to evaluate whether these pathways present a risk to human health under current conditions. Priority pathways include:

- Exposure to surface soil for a current Resident at the Heartland property.
- Exposure to soil vapors potentially infiltrating residential and commercial buildings at the Heartland, URI, Historic Union, and Culligan properties.
- Exposure to shallow groundwater infiltrating basements at the Heartland property for a Resident and Historic Union for a Maintenance Worker.

In addition, the risk evaluation characterized non-priority[8] exposure pathways for which data were collected during the Site investigation. These pathways include:

- Potential exposure to shallow soil (0-15 ft bgs) for a future Utility Worker and Construction Worker at the Heartland, URI, City ROWs, Historic Union, and Culligan properties.
- Potential exposure to groundwater (0-15 ft bgs) during future subsurface excavation for a future Utility Worker and Construction Worker at the Heartland, URI, City ROWs, Historic Union, and Culligan properties.

Based on the results of this risk evaluation, there are no unacceptable risks to human health based on current conditions as determined by the current dataset. There are, however, elevated risks associated with future potential exposures for a Utility Worker at the Heartland property and a Construction Worker at the Heartland, URI, City ROWs, and Historic Union properties. There are seven compounds contributing to elevated risk at these properties: DRO, GRO, benzo[a]pyrene, 2-methylnaphthalene, naphthalene, dibenzofuran, and benzene. While these are potential MGP constituents, they are also commonly associated with petroleum hydrocarbons; as described above, there are multiple non-MGP sources of petroleum hydrocarbons in the area.

ES.5 Focused Feasibility Study

An FFS was conducted to identify and evaluate viable remediation alternatives to address MGP-related impacts throughout the MGP Site and its vicinity.[9] In order to guide the remedy evaluation and selection process to specific endpoints that ensure protectiveness, risk reduction- and mass reduction-based Remedial Action Objectives (RAOs) were developed for the impacted media at the Site and its vicinity. Further, Site-specific risk-based cleanup goals (CUGs) and Not to Exceed values (NTE) were established

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[6] The scope of the risk evaluation included all properties that were investigated except for the 1213 NP Avenue property, because MGP-related impacts were not identified at this property.
[7] Priority exposure pathways were defined as potentially complete exposure pathways for current property occupants.
[8] Non-priority exposure pathways consisted of potentially complete exposure pathways under reasonably foreseeable future use of the properties.
[9] Similar to the risk evaluation, the scope of the FFS included all properties that were investigated except for the 1213 NP Avenue property, because MGP-related impacts were not identified at this property.

for each of the properties that have been investigated and used in concert with other criteria defined by the RAOs (*i.e.*, the presence of NAPL and heavily impacted soil) to define remediation target areas for each property.

A preliminary screening of a robust set of remedial technologies and process options was performed to identify remedial technologies for each of the media of concern at the Site and properties in the vicinity. Using these selected remedial technologies, remediation alternatives were developed for each of the five evaluated properties. The range of remediation alternatives for each property generally included:

- A baseline option of no further action;
- Source removal options for source material and surface soil (as applicable) remediation;
- Piping removal/grouting to eliminate preferential pathways;
- Monitored natural attenuation (MNA) or no further action for groundwater impacts;
- Vapor mitigation, MNA, or no further action for soil gas impacts; and
- Engineering and institutional controls to limit exposures and manage residual risks.

Due to the relative abundance of NAPL and heavily impacted media on the Heartland property in comparison to other properties, additional source remediation options including NAPL extraction and *in situ* solidification and stabilization (ISS) were included in the range of alternatives for the Heartland property.

A detailed assessment of the remediation alternatives was performed based on the Comprehensive Environmental Response, Compensation, and Liability Act's (CERCLA) remedy evaluation criteria.[10] The results of the comparative analysis demonstrate that the <u>Targeted Source Removal</u> alternative is the preferred remedial approach for all five of the properties evaluated, assuming regulatory approval and cooperation from the property owners, because it provides long-term effectiveness and protectiveness with a higher level of certainty in comparison to the other alternatives, while also being cost-effective, implementable, and more likely to receive regulatory approval. Through the removal of source material and elimination of preferential pathways (pipes), the Targeted Source Removal alternative limits direct exposure to impacted media, while also promoting the long-term stability and attenuation of associated groundwater and soil gas impacts. This alternative is readily implementable and cost-effective, and any short-term impacts and logistical challenges associated with implementation can be managed through the use of safety measures and engineering controls. The use of institutional and engineering controls, a critical component of this alternative, will allow for the long-term management of any residual risks, such as those associated with source material and/or impacted media left in place outside the remediation zones. Further, a monitoring program will be implemented at permanent groundwater and soil gas monitoring points at the Site and properties in the vicinity to evaluate MNA of impacts to both media.

[10] Overall protection of human health and the environment; long-term effectiveness and permanence; reduction of toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; cost; regulatory approval; and community acceptance. The 9th CERCLA criterion, compliance with Applicable or Relevant and Appropriate Requirements (ARARs), was not used as a separate evaluation criterion for this FFS because it is assumed that the NDDH will evaluate the remediation alternatives in the context of State regulations and highlight the need for compliance with additional requirements, if any.

ES.6 Next Steps

Pending approval of the RI/FFS by the agencies, the provision of access by the relevant property owners, and public outreach to interested parties, NSP is planning to perform the following next steps:

- Prepare and submit a work plan for each property that specifies how the selected remedy may be implemented in order to achieve RAOs.
- Work with individual property owners, the City, and NDDH to develop and implement appropriate institutional controls to ensure long-term protectiveness.
- Consistent with US EPA guidance, collect two additional rounds of sub-slab soil gas samples from the existing vapor pins at the Culligan and 1213 NP Avenue properties.
- Develop a monitoring plan for groundwater and soil gas to evaluate the temporal stability of the MGP impacts.

1 Introduction

This Remedial Investigation and Focused Feasibility Study report (RI/FFS Report) was prepared on behalf of Northern States Power Co. (NSP) to document the findings of the environmental site investigations, human health risk assessment, and focused feasibility analysis of remediation alternatives conducted for the former manufactured gas plant (MGP) in Fargo, North Dakota (the Site; see Figure 1.1). The former MGP operated on the north side of Northern Pacific (NP) Avenue between 11th Street North and North University Drive. Investigations were undertaken both at the property formerly occupied by the MGP and at off-Site locations in its vicinity in accordance with work plans submitted to and accepted by the North Dakota Department of Health (NDDH) (Barr, 2015a,b; Barr, 2016a-f; Heimbach and Sands, 2016; Gradient, 2015a).

The data collected during the multiple phases of investigations of the Site and its vicinity was provided to NDDH in a series of technical memoranda (Barr, 2015c-h; 2016g-l).[11] The results of the investigations were also shared with the relevant property owners. This report provides a holistic interpretation of all the investigations conducted at the Site and its vicinity to-date, and evaluates the results with the following overall objectives:

- Characterize the source(s) of constituents associated with the former MGP Site;
- Delineate the extent of potential MGP constituents in soil, groundwater, and soil gas at the former MGP Site and its vicinity;
- Characterize hydrogeology at the former MGP Site and its vicinity;
- Develop a conceptual site model (CSM) to explain the sources and environmental fate and transport of MGP constituents;
- Evaluate whether other, non-MGP sources are impacting Site environmental conditions;
- Determine if there are unacceptable risks to human health posed by exposure to potential MGP constituents based on current and reasonably foreseeable future conditions at the Site and its vicinity; and
- Develop a remedial approach for the Site and its vicinity based on an FFS of viable remediation alternatives.

The following sections of the report provide a discussion of the Site background (Section 2), the field work that was performed and a summary of the results (Section 3), interpretation of the investigation results (Section 4), a human health risk evaluation (Section 5), and an FFS of remediation alternatives (Section 6). Attachments provide supporting data (Attachments A-C), supporting details for the risk evaluation (Attachment D), and supporting technical memoranda (Attachments E-K). This report presents information at a Site-wide level; separate, property-specific reports discuss the components of this report that are relevant to each property, forming the Site and its vicinity. This report has been prepared pursuant to North Dakota Century Code Section 23-20.3-03.1 and applicable NDDH regulations; North Dakota guidance (NDDH, 2006a,b) and United States Environmental Protection Agency (US EPA) criteria, regulations, and guidance have been used when appropriate.

[11] Several additional technical memoranda are included as attachments to this report.

2 Background

2.1 Site Description

2.1.1 Current Site Conditions

Investigations were conducted on six properties that either occupy the former MGP Site or are located in its immediate vicinity (Figure 2.1):

- The Heartland Apartments property (Heartland);
- The United Refrigeration, Inc. property (URI);
- Several City Rights of Way (ROWs), including 11th Street North, 12th Street North, NP Avenue, and nearby alleys;[12]
- The former Union Storage and Transfer Facility property (Historic Union);
- The Culligan Water Conditioning of Fargo property (Culligan); and
- The 1213 NP Avenue property.

The Heartland and URI properties occupy the former MGP Site (see Figures 2.1, 2.2a, and 2.2b[13]). These two properties are separated by the 12th Street North ROW. The 11th Street North ROW bounds the east end of the Site, and the NP Avenue ROW bounds the south end of the former MGP Site. South of NP Avenue and the eastern half of Heartland is the Historic Union property. South of NP Avenue and the western half of Heartland is the Culligan property (Figure 2.2c). 1213 NP Avenue is located south of the URI property. The current condition for each of these properties is described below; additional information about the properties is provided in Table 2.1. A historical composite of the buildings and features associated with the former MGP[14] is overlain on a 2014 Site aerial photo in Figure 2.3, and the Site's history is discussed in Section 2.1.2.

Heartland

The 2.1-acre (ac) Heartland property consists of three residential apartment buildings, a central atrium connecting the three buildings, a storage building connected to one of the apartment buildings, and a free-standing storage shed on the northwest corner of the property (Figure 2.2a). Each apartment building consists of three floors, including one at garden level. A laundry room and a manager's apartment unit are also on the garden level. The apartment buildings have a total of 88 units, which have a high occupancy rate. Most of the units are occupied by short-term residents (a few years or less), although a handful of units are occupied by longer-term residents. The footprint of each wing is approximately 7,000 ft^2. Each building has a 4-in (inch) drain tile and sump system around its perimeter. The remaining spaces on

[12] Alleys located north of the Heartland property, north of the URI property, and south of the URI property.

[13] While the figures identify the historical MGP site, the project boundary also includes the Historic Union and Culligan properties and the portions of NP Avenue and 12th Street immediately adjacent to the historical MGP site.

[14] This historical composite was prepared using the sources listed on Figure 2.3 and may be refined as part of the ongoing historical review. Refer to the 2015 Historical Review Report (Gradient, 2015b) for further details.

the property are a mix of unpaved areas and paved parking lots. The majority of the former MGP equipment and operations were in areas that are now occupied by the paved parking lots. The apartment buildings currently occupying the Site were constructed in 1969, in approximately the same configuration as they stand today.

URI

The 0.4-ac URI property includes a rectangular free-standing building used for commercial purposes, including a warehouse, retail space, and offices; the rest of the property consists of a paved parking lot. The approximately 12,000-ft^2 building was constructed in 1968, overlying approximately half the area of the distribution gas holder that was constructed in 1913. The other half of the gas holder underlies the URI property parking lot. MGP process/distribution piping beneath 12th Street North connected the Heartland and URI properties (Figure 2.4).

City Rights of Way

The 11th Street North, 12th Street North, the alley north of the Heartland property, the alley north of the URI property, the alley south of the URI property, and the NP Avenue ROWs are paved roads and/or sidewalks that abut the former MGP Site and are owned and maintained by the City of Fargo. In addition to an extensive current urban piping network, piping and distribution infrastructure associated with the former MGP were located beneath these ROWs (Figure 2.4) and have been encountered during recent field investigations (*e.g.*, beneath NP Avenue; Barr, 2015c). MGP gas distribution piping beneath 12th Street North connected the Heartland property to the URI property. MGP piping was also present beneath NP Avenue. Some former MGP equipment (*e.g.*, coal bin, water tank) appears to have been present in the current ROWs configuration (Figure 2.3).

Historic Union

The Historic Union property is comprised of two abutting buildings that were previously occupied by a food processing and refrigerated storage warehouse constructed in approximately 1929 (Wenck, 2015a). The western building is three stories tall and the eastern building is four stories tall. The complex has a footprint of about 22,000 ft^2 (Barr, 2015b). Both buildings comprising the complex have been remodeled. The western building has been remodeled for use as office space, including a basement level for storage. The eastern building has been remodeled for residential use with a basement for underground parking (NTI, 2014). A 10,000-gallon fuel oil underground storage tank (UST), reportedly inactive since the mid-1980s, was removed from the southwest corner of the Historic Union property in 2014. Impacted soils were encountered and 60 cubic yards of soil were excavated as a corrective action. The analytical results for seven post-excavation soil samples collected from the sidewalls and bottom of the excavation did not show evidence of additional contamination that exceeded the NDDH Cleanup Action Level for gasoline and other petroleum hydrocarbons (100 mg/kg; Wenck, 2015a), leading NDDH to issue a No Further Action Letter (NDDH, 2015).

Culligan

The 0.3-ac Culligan property is occupied by an approximately 6,700-ft^2 building constructed in 1968, a small, concrete-paved parking lot, and grassy areas. The building includes an office and warehouse spaces. The parking lot is present on the northwest side of the building, and the grassy areas are on the east, south, and north sides of the building (Barr, 2016d).

1213 NP Avenue

The property at 1213 NP Avenue is occupied by two adjoined buildings aligned along the northern property boundary; the rest of the property is a paved parking lot. The eastern building is a 2,400-ft^2 slab-on-grade structure that was constructed in approximately 1910. The western building is a 9,500-ft^2 structure with a basement that was constructed in 1950. The western building is currently undergoing renovation for use as a co-op grocery store (Barr, 2016f).

2.1.2 Site History

The Fargo MGP operated from approximately 1885-1960, producing both coal gas and carbureted water gas (CWG) during its 75 years of operation (Gradient, 2015b). Coal gas was produced from the thermal destruction of coal in the absence of air (pyrolization). CWG was made by blowing steam through red-hot coke and/or coal to create water gas, followed by spraying (carbureting) petroleum into the hot water gas to enrich it. During this period, the plant was reconfigured and expanded several times.

Key events in the Fargo MGP's history, based on currently available information, include the following (all dates are approximate):

- **1885:** Gas was first delivered to mains.
- **1904:** The original coal gas plant was dismantled and a new coal gas plant was built.
- **1913:** A 400,000-ft^3 gas holder was constructed on the parcel west of 12th Street North.
- **1925:** A new vertical retort coal gas plant was constructed (operational by 1927).
- **1929:** CWG production began.
- **1952:** The coal gas plant was retired, while CWG production continued. The MGP began distributing propane.
- **1960:** CWG production ceased and was replaced by natural gas.
- **1962:** The MGP was demolished.
- **1966 & 1969:** The MGP property was sold.

Historical records, including accounting journal entries, indicate that large quantities of Fargo MGP byproducts, including ammonia, tar, and coke, were recovered and sold.

2.1.3 Potential MGP Constituents

The byproducts and residuals typically generated at MGPs include tars, drip oil, coke, effluent wastewater, ammonia, and spent oxide materials. A summary of the main chemical constituents associated with each of these materials is provided in Table 2.2.

Table 2.2 MGP Materials and Chemical Constituents

Material	Description of Material	Chemical Constituents
Tar	Black, dense non-aqueous phase liquid (DNAPL)	Polycyclic aromatic hydrocarbons (PAHs), monocyclic aromatic hydrocarbons (MAHs) (*e.g.*, benzene, toluene, ethylbenzene, and xylenes [BTEX] and their alkylated homologs), phenolic compounds, diesel range organics (DRO), gasoline range organics (GRO)
Drip Oil	Light non-aqueous phase liquid (LNAPL)	BTEX, naphthalene, phenolic compounds, DRO, GRO
Coke	Solid material similar in appearance to charcoal	Primarily carbon with trace levels of PAHs, metals
Effluent Wastewater	Clear to dark-colored liquid	PAHs, BTEX, ammonia, phenolic compounds
Ammonia	Clear liquid with a strong scent similar to household cleaners	Ammonia
Spent Oxide Materials	Bright blue wood chips	Cyanide, iron, sulfur

Note:
Adapted from lists compiled in Environmental Research and Technology, Inc. and Koppers Co., Inc. (1984) and RTI (1988).

As common natural and anthropogenic contaminants, polycyclic aromatic hydrocarbons (PAHs) and metals are widespread in soils and sediments at background levels. Background concentrations of PAHs and metals can be found even in remote, undeveloped areas; however, in areas with a long history of industrial operations (*e.g.*, railroads[15]), such as Fargo, concentrations are generally higher. Attachment G provides additional discussion of background concentrations of metals and PAHs.

MGP residuals, such as tars and oils, have been encountered in and near former MGP structures, such as in the former tar well and a wooden tar tank. These tars and oils are NAPLs in the environment. The more soluble and volatile NAPL constituents (*e.g.*, benzene, toluene, ethylbenzene, and xylenes [BTEX] and naphthalene) may leach into groundwater and volatilize into the soil vapor phase. Vapors may potentially migrate into on-Site structures.

2.1.4 Prior Environmental Investigations

In 1994, a US EPA contractor performed a preliminary Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) site assessment (Morrison Knudsen Corp., 1994). Based on the assessment, US EPA did not identify significant contaminant releases at the Site and indicated that there was "no further remedial action planned" (Morrison Knudsen Corp., 1994).

In 2015, in advance of a City road improvement project along NP Avenue, NSP reported to NDDH the discovery of legacy MGP piping under NP Avenue between 10th and 12th Street North and at the Historic Union property, located to the south of NP Avenue, and undertook the excavation of the piping and impacted soils. Following the excavation project, NSP established a Voluntary Cleanup Agreement (VCA) with NDDH and initiated the investigation of the former MGP and its vicinity (Coss, 2015).

15 "The significance of these railroads to Fargo's urban development cannot be overstressed. Not only were the railroads major local employers in their own rights, but they also facilitated numerous other business developments" (Holzkamm and Dormanen, 2001, pp. 20, 23).

The subsequent investigation of the NP Avenue ROW and the former MGP and adjoining properties that was initiated by NSP as part of the VCA is the subject of this report.

2.2 Other Sources in the MGP Site Vicinity

Other possible sources of environmental impacts in the MGP vicinity were identified based on historical Sanborn maps, an EDR Radius Map Report for the area within half a mile of the Fargo MGP, NDDH files, and other historical photos and Site reports. Figure 2.5 shows the locations of these potential sources. These locations, several of which are discussed in more detail in Gradient (2015b), include the following.

Automotive and fuel storage-related facilities (*e.g.*, gas stations), are often associated with potential NAPL, PAH, and BTEX impacts. Legacy filling stations and automotive facilities are located adjacent to the northern boundary of the Heartland property, on and west of the URI property, and on the 1213 NP Avenue parcel south of the URI property. A UST was removed from the Historic Union property in 2014.

The Border Cities site, located to the northwest of the URI property at 30 University Drive, had USTs removed in 1992 and 2007. During UST installation activities in 1993, petroleum impacts to soil and groundwater related to leaking USTs were discovered. A site assessment was performed and 200 cubic yards of petroleum contaminated soil was removed. The site was closed by NDDH in 1995 after four groundwater monitoring events showed decreasing dissolved concentrations.

The Berke Block or Berkley Block, located to the east of the Heartland property at 10th Street North and 1st Avenue, once housed a gas station and an automobile dealership with a service department. An environmental site investigation performed in 1994 reported the removal of four hydraulic pits and four USTs. Three 3,000-gallon USTs had severe surface pitting and contributed to soil contamination. In addition, a vein of sand contaminated with NAPL and diesel range organics (DRO) in soil of up to 5,700 mg/kg was identified during the investigation. The contaminated sand was delineated, excavated, and disposed of as part of the investigation. Confirmation sampling conducted after the removal was completed showed photoionization detector (PID) readings below the detection limit for all but one sample adjacent to the vein of sand. Laboratory analysis of the soil sample near the PID detection showed a trace DRO detection that was below NDDH Action Levels, which was left in place. Contaminated soil from other parts of the property was similarly removed and the report concluded that no additional testing was required at the site. Fargo Fire Department records indicated that five 50-gallon drums used to store petroleum liquid products should have been present at the site, but the drums were not located during the investigations (Great Plains Environmental, 1994).

A filling station once occupied the 1213 NP Avenue property. Branick, a vulcanizing company, built the property's western building and the filling station in 1950. BF Goodrich & Company occupied the western building in the early 1960s through approximately 1972, and the filling station remained present on the property during this time (Gradient, 2015b).

The Jacque Stockman property, reportedly located at the southwest corner of 11th Street and 1st Avenue North, was contaminated with subsurface hydrocarbons associated with a former gas station and removed USTs that were allowed to degrade in place in the northeast corner of the property. Institutional controls were recommended for future construction at the site, to include slab-at-grade construction and a functioning drain tile or passive soil vapor venting system (NDDH, 2003).

Dry cleaning and laundry facilities are potential sources of chlorinated volatile organic compounds (VOCs) and petroleum-based solvents (*e.g.*, Stoddard solvent, a dry cleaning solvent containing up to 20% monocyclic aromatic hydrocarbons [MAHs] and PAHs by mass; ATSDR, 1995). Historical laundry/dry cleaning facilities are located to the north and west of the Heartland and URI properties.

The nearest former dry cleaning operation to the Site is the Fredrick Estate, located to the west of the URI property at 20 University Avenue North. Impacts of chlorinated solvents (including perchloroethylene [PCE] and its degradation products) and petroleum hydrocarbons (including BTEX, DRO, and gasoline range organics [GRO]) were identified in soil, groundwater, and soil gas during environmental investigations at this site. The petroleum hydrocarbon impacts in soil "indicate past use of Stoddard solvents, which was a common dry cleaning petroleum based solvent" (Wenck, 2015b). DRO up to 1,170 mg/kg in soil and up to 4,600 µg/L in water, GRO up to 1,820 mg/kg in soil and up to 12,200 µg/L in water, and 1,2,4-trimethylbenzene up to 9,670 µg/m^3 in soil vapor were detected at the property. Groundwater elevation measurements from the environmental investigations indicated that the shallow groundwater leaving the Fredrick Estate property flows to the east by northeast (*i.e.*, toward the URI property). Four USTs of undetermined historical use were removed in 2010. In 2015, the Fredrick Estate recommended to NDDH that a sub-slab vapor mitigation system be installed.

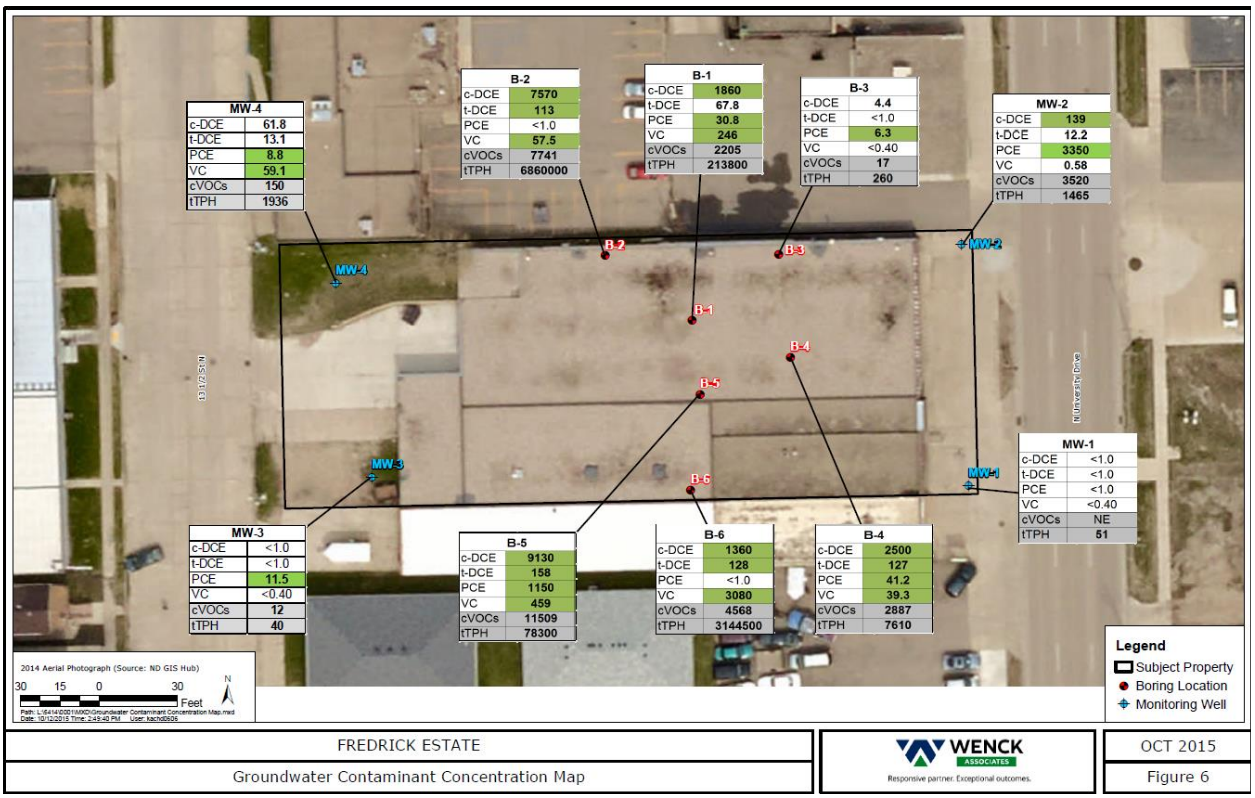


Figure 2.6 Contaminant Concentrations in Groundwater at Frederick Estate. The units of reported concentrations are in micrograms per liter (µg/L). Source: Wenck Associates, Inc. (Wenck, 2015b).

A rail yard with numerous railroads and spurs existed in the area south of NP Avenue, north of Main Avenue, and parallel to both roadways. Multiple spurs led to the MGP property, including the "N-S Rail Spur" that paralleled the western boundary of the Heartland property adjacent to the 12th Street North ROW and the "Northern Rail Spur" that paralleled the southern boundary of the Heartland property, and the "Southern Rail Spur" that abutted and paralleled the northern boundary of the Historic Union property (see Figure 2.5). These rail spurs were likely used to transfer feedstock materials, such as coal and petroleum, to the MGP as well as saleable byproducts, including tar, ammonia, and coke, from the MGP. Railroads are common sources of NAPL, BTEX, metals, and PAHs (US EPA, 2002a).

Asphalt plants are potential sources of NAPLs, PAHs, and phenolic compounds. The James Kennedy asphalt plant was located within the railroad area west of the former MGP Site.

Figure 2.7 Photograph of James Kennedy's Asphalt Plant (July 25, 1913). Source: Dewey (1913a).

In addition to the sources of environmental impacts discussed in this section, 16 additional facilities with industrial, manufacturing, or commercial operations, including storage facilities, lumber yards, and paper mills, are located near the Site.

2.3 Physical Setting

The City of Fargo is located in the southeastern plains of North Dakota, in the Red River of the North Valley. The Site is located in the southeastern portion of Fargo, less than 1 mile west of the Red River, which forms the border between the states of North Dakota and Minnesota and flows north into Canada. The Site is located in a mixed-use residential/commercial setting, as shown in Figure 2.1, with historical industrial use. The population of Fargo is approximately 110,000 and growing, and urban redevelopment initiatives are ongoing in the area of the Site (Fargo, North Dakota, 2012).

The surface of the Site is generally flat and located at an elevation of about 910 ft above mean sea level (MSL) (Barr, 2015h; Morrison Knudsen Corp., 1994). The flatness of the Red River of the North Valley promotes winds in Fargo in the north-south and northwest-southeast directions, with average yearly wind speeds of 11 miles per hour. The average annual temperature is about 42°F, with warm summers (average temperature of 71°F) and cold winters (average temperature of 7°F). Annual rainfall is approximately 21 in, with an additional annual snowfall of 40 in (NOAA, 2002).

Surface runoff from the paved portions of the Site primarily flows to the City of Fargo underground stormwater management system (Barr, 2015h). In unpaved areas, most of the rainfall infiltrates into the ground, with runoff flowing to the stormwater sewers on adjacent streets (Barr, 2015h). Local buildings (*e.g.*, Heartland, Historic Union) use sumps to manage infiltration. The University Drive underpass between NP Avenue and Main Avenue may collect stormwater runoff and/or influence the groundwater flow direction. The point of discharge from the storm sewers to the Red River is approximately 1 mile east of the Site (Morrison Knudsen Corp., 1994). The nearest surficial aquifer is located more than half a mile to the west of the Site. A survey of wells in the Site vicinity showed that only one domestic well and one municipal well were located within half a mile of the Site, to the south (Figure 2.8). Both wells are screened in the deep (Fargo) aquifer that is described below.

Regionally, Fargo is underlain by stratified Glacial Lake Agassiz (GLA) soils comprised of fat clay, silty fat clay, and clayey silt with varying color, moisture content, and unit weight, to a depth of at least 100 ft below ground surface (bgs). The uppermost portion of the clay layer is the Sherack laminated silt clay, present in the top 16 ft bgs. The Sherack formation is underlain by the Brenna/Argusville fat clay formation. Glacial till is present at depths below the top 100 ft of clay at thicknesses of up to 200 ft, and the Fargo Aquifer is present in glacial outwash deposits within the till layer (Attachment F). A generalized cross-section of the regional geology underlying the Site is shown in Figure 2.9. Field investigations indicate that the Site is locally underlain by fill material comprised mainly of soil with some trash and miscellaneous debris (*e.g.*, match boxes, chunks of wood). Soils in the region have naturally high background levels of many metals, including aluminum, iron, and magnesium, in both shallow soils and in deeper clay and mineral deposits down to layers approaching bedrock (USGS, 2001, 2005). Further discussion of Site-specific conditions based on the results of the field investigations is provided in Section 3.2.

Consistent with the regional water table, groundwater at the Site and its vicinity was encountered at depths of 10 ft bgs or less. As described in Section 3.2.1, the shallow monitoring wells exhibited extremely low recharge rates due to the low hydraulic conductivity of the screened formation. Thus, these groundwater elevation measurements may represent a localized, transient condition rather than an equilibrium measurement of the actual potentiometric surface (*i.e.*, water table). A technical memorandum summarizing the hydrogeologic conditions at the Site and its vicinity is provided as Attachment F.

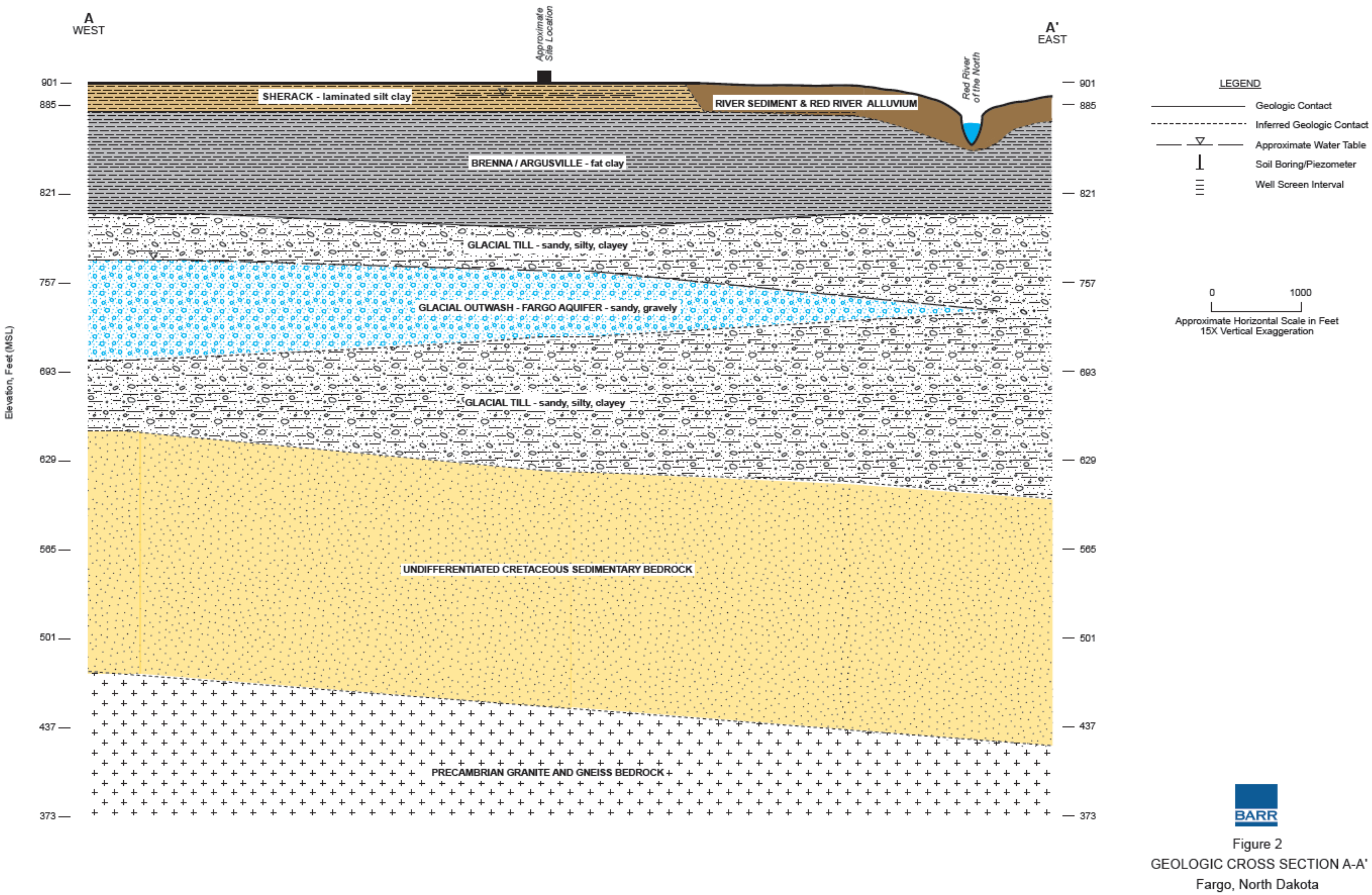


Figure 2.9 Generalized Cross-section. Source: See Attachment F.

3 Field Work Performed

3.1 Investigation Activities

Between July 2015 and October 2016, NSP performed a multi-media investigation of the former MGP Site and its vicinity. The scope of the field work is summarized below and includes properties that occupy the former MGP (Heartland and URI) as well as adjoining properties (Historic Union, Culligan, City ROWs, and 1213 NP Avenue). Descriptions of the field work and draft sampling results are provided in technical memoranda that were submitted to the NDDH (Carlson McCain, 2015a; Barr, 2015c-g; 2016g-l) or included as attachments to this report (Attachments J-K). Figure 3.1a shows the sample locations and Table 3.1 provides a sampling summary matrix organized by media, property, and analyte type.[16] The sampling program included sampling surface soil (soil less than 6 in bgs), subsurface soil, shallow groundwater (groundwater less than 20 ft bgs), intermediate groundwater (groundwater 20-50 ft bgs), deep groundwater (groundwater more than 50 ft bgs), building sump water, soil gas and sub-slab soil gas, and NAPLs. In total, more than 268 soil, 116 water, 126 soil gas, and 7 NAPL samples were collected from throughout the Site and its vicinity (Table 3.1). A permanent monitoring network consisting of 34 sub-slab soil gas monitoring points, 16 shallow groundwater wells, 3 intermediate groundwater wells, and 3 deep groundwater wells was installed at the Site and in its vicinity. A sample count by property and media is provided in Table 3.2.

Table 3.2 Summary of Samples Collected

Property	Surface Soil	Subsurface Soil	Shallow GW	Intermediate GW	Deep GW	Sump Water	Soil Gas	Sub-slab Soil Gas	NAPL
Heartland	30	87	17	3	1	1	19	14	7
URI	0	19	11	0	1	0	7	17	0
City ROWs	0	117	49	0	1	0	20	0	0
Historic Union	0	9	18	0	0	4	9	33	0
Culligan	0	6	6	0	0	0	0	4	0
1213 NP Avenue	0	0	4	0	0	0	0	3	0
Total	**30**	**238**	**105**	**3**	**3**	**5**	**55**	**71**	**7**

Notes:
GW = Groundwater; NAPL = Non-aqueous Phase Liquid; NP = Northern Pacific; ROW = Right of Way; URI = United Refrigeration, Inc.
Field duplicates are counted as independent samples.

3.1.1 Former MGP

Heartland Apartments

An initial investigation of the Heartland property was performed in November 2015. Fifteen surface soil samples and fifteen exterior soil gas samples were collected and submitted for laboratory analysis (Barr, 2015f) (Table 3.1). A geophysical survey, consisting of ground penetrating radar (GPR) and electromagnetic survey (EM survey), was also performed over part of the property (Attachment H).

[16] Samples collected from locations that were later excavated (pre-remediation samples) and samples collected from excavation sidewalls or bottoms following completion of excavation (post-excavation samples) are included in all tables and figures in Sections 3 and 4 to provide a complete representation of the contamination identified at the Site prior to remediation.

In February 2016, seven sub-slab soil gas samples were collected from the west apartment building (Figure 3.1b). Between May 16 and June 16, 2016, MGP source characterization sampling was performed on the property, primarily in the southern parking lot. Forty-one borings were advanced, and 11 permanent monitoring wells were completed at locations guided by the historical information discussed in Section 2. Additionally, the prior 15 surface soil sampling locations were sampled again to address data quality issues previously identified for samples analyzed for free cyanide and DRO, as discussed in Section 3.1.3. A total of 99 soil samples (15 surface soil and 84 subsurface soil), 21 groundwater samples, 1 sump sample, 7 samples from encountered NAPL, and 4 exterior soil gas samples were collected and submitted for laboratory analysis (Barr, 2016i) (Table 3.1). In July 2016, four test pits were excavated on the Heartland property to assess subsurface conditions in the vicinity of historical MGP features. Three soil samples were collected from the excavations (Attachment J). Seven sub-slab soil gas samples were collected from storage buildings at the Heartland property in July and August 2016 (Table 3.1).

URI

The URI property was investigated in October-November 2015. Seven soil borings, one permanent monitoring well, and seven vapor monitoring points were completed in the URI property parking lot and along the eastern edge of the URI building (Figure 3.1c). Five permanent sub-slab vapor sampling points were installed within the URI building. Thirteen soil samples, seven groundwater samples, and thirteen vapor samples were collected and submitted for laboratory analysis (Barr, 2015e) (Table 3.1). A geophysical survey, consisting of GPR and EM survey, was also performed over part of the property (Attachment H). The permanent sub-slab vapor sampling points were sampled a second time in February 2016 (6 samples) and again in May 2016 (5 samples[17]). The permanent monitoring well was sampled twice in February 2016. Two additional soil borings were installed in May 2016, and 4 soil samples were submitted for laboratory analysis. A second, deeper permanent monitoring well was installed on the southwestern corner of the property in June 2016 and two soil samples from the borehole were submitted for laboratory analysis. Both the shallow and deep permanent monitoring wells were sampled in June 2016, and 3 groundwater samples were submitted for laboratory analysis (Barr, 2016k) (Table 3.1).

3.1.2 Off-Site Properties

NP Avenue ROW

Investigation activities were initiated in July 2015, in advance of a City of Fargo road improvement project along NP Avenue. Eight borings were completed along the southern boundary of the NP Avenue ROW and three borings were completed along the northern boundary of the NP Avenue ROW (B-NP01 to B-NP11) (Figure 3.1d). Two soil samples, six groundwater samples, and ten soil gas samples were collected from these borings and submitted for laboratory analysis (Barr, 2015c) (Table 3.1). Approximately 2,000 tons of soil were excavated during the construction efforts, which included collection of 54 post-excavation samples, 7 groundwater samples and 1 air sample (Carlson McCain, 2015b). Three of the fifty-four soil samples were collected from pipes encountered during the excavation, as discussed in Section 3.2.3. During excavation in NP Avenue, two old wooden tanks were encountered near the location of soil boring B-NP09. Thirteen additional soil samples collected from around and within the wooden tanks were submitted for laboratory analysis (Carlson McCain, 2015a) (Figure 3.1d).

[17] The number of samples differs between the February and May sampling events because a field duplicate sample was collected from one of the sub-slab locations in February but was not collected in May.

Additional excavation work was performed by the City of Fargo at NP Avenue to support utility replacement.

11th Street North and 12th Street North ROWs, and Nearby Alleys[18]

The 11th Street North and 12th Street North ROWs, and the alley north of the Heartland property were investigated October-November 2015. Eleven soil borings were advanced in the City ROWs around the perimeter of the Heartland property, and three of these borings were completed as permanent monitoring wells (Figure 3.1b). Seventeen soil samples and thirteen groundwater samples were submitted for laboratory analysis (Barr, 2015g) (Table 3.1). The permanent monitoring wells were sampled again in February 2016 (*i.e.*, 3 groundwater samples were collected). In June 2016, two additional permanent monitoring wells were installed and all of the wells were sampled (*i.e.*, five groundwater samples were collected). In May and June 2016, 18 additional soil borings were completed in 11th Street North and the alleys north and south of the URI property. Twenty-five soil samples, sixteen groundwater samples, and nine soil gas samples were collected from these borings and submitted for laboratory analysis (Barr, 2016g) (Table 3.1). In June and July 2016, six additional soil samples were collected from exploratory excavations and a corridor excavation for storm sewers in the alley south of the URI property and 12th Street North (Attachment K).

Historic Union

The Historic Union property was investigated in September 2015 in conjunction with its renovation. Five soil samples were collected as part of pipe removal and excavation work. Twelve borings, three of which were completed as permanent monitoring wells, were advanced around the property perimeter (Figure 3.1d). Additionally, four borings were drilled, and 10 permanent soil vapor monitoring points were installed in the building basement. Four soil samples, twelve groundwater samples, two samples from the building's basement sump, and nineteen soil gas samples were collected and submitted for laboratory analysis (Barr, 2015d) (Table 3.1). A second round of soil gas and water samples, including 3 groundwater samples, 10 soil gas samples, and 1 sump sample, were collected from the permanent monitoring points in February 2016. A third round of soil gas and water samples, including 3 groundwater samples, 13 soil gas samples, and 1 sump sample were collected from the permanent monitoring points in May and June 2016 (Barr, 2016j) (Table 3.1).

Culligan

The Culligan property was investigated in May and June 2016. Five soil borings were advanced on the property and one permanent monitoring well was installed. Four permanent sub-slab soil gas sampling points were installed within the buildings on the property (Figure 3.1d). Six soil, six groundwater, and four soil gas samples were collected and submitted for laboratory analysis (Barr, 2016h) (Table 3.1).

1213 NP Avenue

The northeastern portion of the property at 1213 NP Avenue was investigated in September 2016. Three direct push borings were advanced and three permanent sub-slab soil vapor monitoring points were installed on the northeast portion of the property (Figure 3.1c). Four groundwater and three sub-slab soil gas samples were collected (Table 3.1).

[18] Alleys located north of the Heartland property, north of the URI property, and south of the URI property.

3.1.3 Work Plan Deviations and Data Quality

The Site investigation was conducted in general accordance with the approved work plans (Barr, 2015a,b; Barr, 2016a-f; Heimbach and Sands, 2016; Gradient, 2015a) and the Site-specific Quality Assurance Project Plan (QAPP; Barr, 2016m). Deviations from the work plans were limited to the advancement of 10 additional direct push borings on the Heartland property.

Analytical laboratory data were evaluated to ensure consistency with the data quality objectives outlined in the Site-specific QAPP. During the evaluation of analytical data collected in 2015, free cyanide data for soil and groundwater samples collected in 2015 were determined to be biased high based on comparisons with total cyanide results, and were deemed unusable (Barr, 2016n). Interferences associated with the turbidity of the samples were determined to be the likely cause of the unusable data, and the analytical method for free cyanide was changed to US EPA Method OIA-1677 for samples collected in 2016, to reduce the potential for the interferences that detrimentally affected the 2015 results. Additionally, interferences from naturally present organic matter were determined to be contributing to elevated concentrations of DRO in surface soil samples collected on the Heartland property in 2015. The surface soil locations on the Heartland property sampling were resampled in 2016 and analyzed using a silica gel extraction cleanup (SI) method to remove native organic matter from the samples prior to analysis. The SI method was used for all soil and groundwater samples collected in 2016, and for the locations where two sets of data (*i.e.*, for both 2015 and 2016 samples) were available, the data for the 2016 samples, analyzed using the SI method, superseded the 2015 data.

Groundwater data collected on June 28, 2016, from monitoring wells MW-ROW-01S, MW-ROW-02S, MW-ROW-03S, and MW-ROW-04 are not included because the data were unavailable when the report was being developed. Inclusion of this data would not have a material change on the report findings because these wells had previously been sampled and those results were available for inclusion. A field duplicate sub-slab soil gas sample was collected from location SS-KBP-02, but it is not included in this report because the data were unavailable when the report was being developed. Inclusion of this data would not have a material change because the non-duplicate sub-slab soil gas sample was available for inclusion.

The features depicted on the figures in the report represent the most spatially accurate data available, with field-verified locations being used to the extent possible. The property boundaries shown are the best approximations to field conditions, derived from multiple sources. The boundaries depicted are based on parcels from the City of Fargo (Fargo, North Dakota, 2015b), which were updated according to field surveys performed by Barr Engineering Co. (Barr) and Wenck Associates, Inc. (Wenck). The Heartland, URI, and adjoining property boundaries were updated using spatial data from the Barr survey. The northern boundary of the Historic Union and Culligan properties along NP Avenue was updated through georectification based on the Wenck survey, while the eastern and western boundaries were delineated based on the Wenck survey and City of Fargo parcels combined, making those boundaries less precise. Locations of samples collected in 2015 from NP Avenue were digitized from a map rather than being surveyed in the field, and may contain more location error relative to other depicted locations.

3.2 Results Summary

3.2.1 Hydrogeology

The Site investigation results provided information regarding Site-specific hydrogeology. Field notes from the investigations conducted in the vicinity of the Site show that shallow soils consist of fill comprised of re-worked native silt and clay, sand and gravel fill (*e.g.*, as pavement base), and/or rubble up to a depth of approximately 14 ft bgs. On the Heartland property, the shallow soils contain bricks and other material potentially associated with former MGP structures. Boring logs and monitoring well construction logs from the investigations are presented in Attachment A and B, respectively.

These shallow soils are regionally underlain by GLA silts and clays to a depth of at least 60 ft bgs, based on drilling conducted during the Site investigation, and most likely to at least 100 ft bgs based on records for nearby, off-Site soil borings (Attachment F). The lithology at the Site and its vicinity is depicted in cross-sections A-A' through D-D' (Figures 3.2a-d). Physical parameter testing results for soil samples collected in the Site at a depth of 4 ft and below showed that the percentage of organic matter ranges from 0.5-2.3% and that the percentage of organic carbon ranges from 0.3-0.5% (Attachment C). Falling head permeability tests showed that the horizontal hydraulic conductivity in the clays is on the order of 10^{-8} to 10^{-7} cm/s and that the vertical hydraulic conductivity is on the order of 10^{-8} cm/s (Table 3.11), indicating the clay at the Site is relatively impermeable and shallow groundwater transport through the clay is limited. This is supported by field observations that the recovery of groundwater from both temporary and permanent wells was extremely slow during the investigation. For example, water levels recorded 12-18 hours after drilling boreholes and installing temporary well screens at locations DP-1 through DP-4 varied by up to 7 ft (Attachment A). The direction of shallow groundwater flow varies locally due to the slow migration rate of groundwater and is influenced by multiple anthropogenic features, including local building sumps and the City of Fargo urban drainage network. There are downward vertical flow gradients at the Site based on the difference between groundwater elevation measurements in the shallow *vs.* intermediate and deep wells (Attachment F).

Table 3.11 Site Investigation Hydraulic Conductivity Measurements

Sampling Location	Sampling Depth	Hydraulic Conductivity Measurement Type	Hydraulic Conductivity Value (cm/s)
B-ROW-03	5-7.5 ft	Horizontal	3.6×10^{-8}
B-ROW-05	7.5-9 ft	Horizontal	3.1×10^{-8}
B-URI-19	10-12.5 ft	Horizontal	5.0×10^{-8}
MW-ROW-01S	10-12.5 ft	Horizontal	1.6×10^{-8}
MW-ROW-02S	7-9.5 ft	Horizontal	2.7×10^{-8}
MW-ROW-03S	9-11.5 ft	Horizontal	3.0×10^{-7}
MW-URI-04S	6-8.5 ft	Horizontal	$1.8 \times 10\text{-}^{7}$
B-ROW-03	5-7.5 ft	Vertical	1.3×10^{-8}
B-ROW-05	7.5-9 ft	Vertical	1.5×10^{-8}
MW-ROW-02S	7-9.5 ft	Vertical	4.5×10^{-8}
MW-ROW-03S	9-11.5 ft	Vertical	2.3×10^{-8}
MW-URI-04S	6-8.5 ft	Vertical	1.6×10^{-8}

Note:
Based on data reported in Attachment C.

Given the relative impermeability of the native soils to a depth of at least 100 ft bgs, lateral and vertical bulk subsurface contaminant transport is expected to be minimal. To the extent that contaminant transport occurs, it would primarily occur *via* preferential pathways, either natural (*e.g.*, sand seams, bedding planes, discontinuous vertical fractures) or artificial (*e.g.*, pipes). Field observations showed no significant evidence of natural preferential pathways in the formation, although bedding planes and piping networks (*e.g.*, remnant MGP process/distribution piping), could potentially serve as preferential pathways for contaminant migration. A review of the regional hydrogeology indicates that the glacial outwash deposits of the Fargo Aquifer would not be encountered until approximately 100 ft bgs (Figure 2.9; Attachment F).

Groundwater was encountered at depths ranging from 2-10 ft bgs during the field investigations (Table 3.3). This is consistent with the regional water table, which is typically encountered at a depth of less than 10 ft bgs (Attachment F). Note that the groundwater wells defined as shallow, intermediate, and deep in this report are all screened in the Brenna clay, not the deeper, underlying Fargo Aquifer (Figure 2.9).

3.2.2 Geophysical Survey

The geophysical survey conducted on the Heartland and URI properties and the intervening 12th Street ROW was partially successful. GPR did not yield useful results due to interference from the shallow, water-bearing clays that were present throughout the survey area. The EM survey, however, successfully identified several buried metallic features, as shown in Figure 3.3. The depth range of an EM survey investigation can vary based on the soil conditions and spacing of sensors. For the survey conducted as part of this investigation, the anticipated depth of the survey is about 10 m, but the precise depth of the anomalies identified by the survey cannot be determined. The linear anomalies shown on Figure 3.3 potentially indicate the presence of old gas distribution piping that connected the URI property with the Heartland property, although historical review did not show a pipe exactly corresponding with these linear anomalies. The discrete anomalies identified on the Heartland property may be indicative of buried rebar or other remnants associated with former MGP operations.

Soil borings advanced in the Heartland property parking lots following the geophysical survey did not identify specific MGP artifacts at the linear or discrete locations identified by the geophysical survey, but did show that bricks, concrete, and other building materials likely associated with the former MGP were present underneath most of the parking lot. The complete geophysical survey report is provided in Attachment H.

3.2.3 Field Artifacts

As described below, artifacts potentially associated with the former MGP were encountered primarily at the Heartland property and in the NP Avenue ROW. A detailed summary of the field artifacts encountered during the investigations is provided in Table 3.4, with approximate locations shown on Figure 2.4.

Soil borings advanced on the Heartland property encountered several concrete obstructions in the footprint of former MGP structures identified from historical plans. Boring B-HLA-02, advanced south of the coal storage building, encountered concrete immediately below the ground surface that may be associated with the former retort building. Boring B-HLA-13, advanced on the east part of the property, encountered a piece of cement at 3 ft bgs, potentially associated with the former garage and service station that was located in the area. The possible bottom of the weak liquor or settling tanks was encountered in the south parking lot at a depth of 6.5 ft bgs by two different borings (B-HLA-16 and B-HLA-17), and test pits identified a vertical concrete wall coinciding with the former tar settling tank wall extending downward from 2 ft bgs to below the bottom of the excavation at 3 ft bgs. Bricks were encountered overlying the concrete. Further to the southeast in that parking lot, boring B-HLA-34, encountered concrete from 3.4-4 ft bgs that may be associated with the former MGP purifiers. Pieces of coal and wood chips were found overlying the concrete. Test pits excavated on the property identified a 3-ft-diameter former manhole with concrete footings and wall segments. Two 12-in cast iron pipes were also identified at multiple locations in the southern parking lot (Pipes 18-21) that connected the former gas holders across 12th Street North (Figure 2.4). The pipes contained water when encountered in the western test pit, and one pipe (Pipe 20) connected with a "T" intersection. A vitrified clay tile pipe (Pipe 22) was also encountered in the western test pit and was observed to contain some residual tar. The portions of the pipes in the test pits were removed, and the remaining portions of the pipes were plugged with cement grout.

In the NP Avenue ROW south of the former MGP, two pipes (Pipes 5 and 6; see Table 3.4) that contained black material were unearthed during excavation. In addition, Pipe 2 contained a petroleum sheen. Pipes that were within the extents of the field excavations shown on Figure 2.4 were removed. Pipes that continued outside the excavation boundaries were capped. Of the 10 pipes potentially associated with the former MGP, 9 were constructed of cast iron and one was constructed of galvanized steel with potential asbestos wrapping. Three pipes were empty.

Three metal drip pots, each 2.5 ft in diameter, were also encountered beneath NP Avenue and were found to be surrounded by stained soil that had an odor. Two of the drip pots were 2.5 ft high and had vent pipes. One of these drip pots was connected to an 8-in pipe, while the other did not appear to be connected to pipes other than the vent. The third drip pot was 3 ft high and was constructed with a "T" shape; the two horizontal ends had previously been plugged.

Just south of the former MGP Site, close to the intersection of NP Avenue and 12th Street North, two old underground wooden tanks were encountered near buried railroad ballast. The eastern tank was oval in shape, approximately 6 ft by 10 ft in dimension, had 4-ft-high sidewalls, did not have a top, and had a bottom constructed of wooden planks. Yellowish-green NAPL was observed in this tank, and impacted soil was removed from beneath the tank until visible impacts were no longer observed. Impacted soil to the north and southeast was not removed. The western tank was circular in shape, approximately 12 ft in diameter, with 4-ft-high sidewalls. It did not have a top and had an earthen clay bottom. The tank contained black, tarry material. Impacted soil was removed beneath the tank, west of the tank, and south of the tank until visual impacts were no longer observed. Impacted soil was removed to the north until the excavation approached a natural gas line, at which point the remaining impacted soil was left in place (Figure 2.4).

Fewer field artifacts were encountered in the other ROW locations. The access way for a drip pot (P-4; Table 3.4) was observed in 11th Street North to the east of the former MGP. To the west, a 6-in steel, asbestos-wrapped pipe (Pipe 12; Figure 2.4) was encountered in 12th Street North, east of the URI building running north-south underneath the sidewalk between the alleys on the north and south sides of the property. The pipe was in good condition, and a hole was drilled in the pipe for observation purposes. The pipe was empty, and exhibited a slight petroleum odor. Two 12-in cast iron bell and spigot pipes (Pipes 13 and 14; Figure 2.4) were encountered about 4 ft bgs in the alley south of the URI property at 12th Street North. Both pipes were full of water, and one-third full of black, moist residue. The pipes exhibited a strong petroleum odor. The pipes were encountered further west (Pipes 16 and 17) and extending north onto the URI property during excavations in the alley. The pipes were removed where encountered in the test pit, drained of 650 gallons of water (which was transported off-Site for waste characterization), and grouted 70 ft to the east under 12th Street North. A shallow, abandoned 4-in pipe (Pipe 15) was separately encountered underneath the sidewalk during the excavation and grouting activities. The pipe was removed where encountered in the excavation.

No former underground structures or piping were encountered at sample locations on the URI property, Culligan property, 1213 NP Avenue property, or the other ROWs (the alley north of the URI property and the alley north of the Heartland property). A potential continuation of one of the pipes encountered in the NP Avenue ROW was found south of the Historic Union building (Pipe 8; Figure 2.4).

3.2.4 NAPL Observations

Oily and/or tarry material present as NAPL was encountered near some former MGP structures and piping systems during the field investigations. These materials are consistent with historic releases of drip oil, petroleum, and MGP tar, respectively. The visual observations of NAPL were categorized into three tiers:

1. **NAPL Sheen:** The presence of a thin coating on soil or a thin NAPL layer on groundwater.
2. **NAPL Blebs:** Isolated, discontinuous NAPL droplets/globules or stringers (thin, continuous ganglia of NAPL).
3. **NAPL:** Present as a liquid saturating the soil matrix.

As described below, NAPL was primarily observed in the footprint of former MGP structures in the Heartland property southern parking lot and one wooden tank and two pipes in the NP Avenue ROW (Figure 3.4a). The thickness of the depth interval over which NAPL was observed decreased with distance from the Heartland property southern parking lot (Figure 3.4e). A detailed summary of the NAPL observations is provided in Table 3.5 and discussed below. The spatial distribution of NAPL observations is shown in Figures 3.4a-d. The total NAPL-impacted soil thickness for each soil boring (excluding sheens) is shown in Figure 3.4e.

NAPL was present at 14 locations on the Heartland property, and at 6 locations, NAPL and/or blebs were present in greater than 10 ft of the soil boring. The most heavily impacted area was in the southern parking lot, coinciding with locations where tar was produced, handled, stored, and likely transferred for off-Site shipment. All of the borings advanced through the former tar well encountered NAPL (Figure 3.4b). The thickness of soil impacted with NAPL and/or blebs was generally highest (greater than 10 ft) in the vicinity of the former retorts and decreased in thickness with distance from the retorts (Figure 3.4e). NAPL and/or blebs extended over a 24-ft-thick interval up to a depth of 32 ft at location B-HLA-14 near the west wing of the apartment complex. Other evidence of NAPL, including the presence of sheens, was observed in the southern parking lot.

In contrast to the southern parking lot area, there were limited NAPL impacts beneath the northern parking lot and in the eastern portion of the Heartland property. In the northern parking lot, NAPL sheens and blebs were present at five locations, within the footprint of the former retort/conveyor room, near the edge of the former propane tank, and the edge of the former oil tank.

On the URI property, trace to light sheens were observed at only two locations (Figure 3.4c). At location B-URI-14, in the southeastern corner of the property, a sheen was observed on the groundwater surface from 6-10 ft bgs. At location B-URI-21, located along the eastern property edge, a sheen was observed in the top 6 ft of soil.

In the City ROWs, NAPL was observed in a tank and two pipes at a depth of 3-7 ft bgs along the northern edge of NP Avenue, nearest to the former MGP operations (Figure 3.4d). One tank (T-1; Figure 3.4d) contained yellowish-green liquid. The other tank (T-2) contained black, tar-like liquid exhibiting a petroleum odor. The NAPL observed from the tanks appears to be separated from the distribution of

NAPL centered on the former MGP retorts. The tanks, observed NAPL, and surrounding impacted soil were removed and properly disposed of as part of the NP Avenue excavation. Two cast iron pipes between the northern rail spur and the southern rail spur (Pipes 5 and 6; Figure 3.4d) contained black, tarry liquid that flowed easily. The location and contents of the pipes indicates that the pipes may have been used to transfer tar for rail shipments. A third cast iron pipe (Pipe 2), running north-south across NP Avenue and then east-west along its southern edge, contained water with a petroleum sheen and odor. The pipes and their contents were removed and properly disposed of as part of the NP Avenue excavation. Sporadic sheens were the only observations in the other ROWs. No NAPL was observed at any of the investigation locations in the alley north of the URI property at 12th Street North.

Some black, moist residue was observed on the Historic Union property in a 12-in pipe running north-south on the north and south sides of the western building. The observed residue was less than 2 in thick and exhibited a slight petroleum odor. The pipes were removed, the ends capped, and the material properly disposed of as part of the excavations.

No NAPL was observed at any of the investigation locations on the Culligan property or at 1213 NP Avenue.

3.2.5 Analytical Results

This section provides a discussion of the analytical results of samples collected during the field investigation activities. The analytical results for soil and groundwater samples showed the detection of metals, such as arsenic, chromium, lead, and manganese, which were largely detected at concentrations that were consistent with background levels in North Dakota (*i.e.*, at levels consistent with the presence of natural and/or anthropogenic sources in the area).[19] USGS and US EPA background levels and levels specific to North Dakota, if available, were used to evaluate the analytical data. A memorandum presenting the list of relevant background levels and the basis for their selection is included as Attachment G.

This discussion is focused on chemical constituents that may be potentially related to former MGP activities ("potential MGP constituents"), noting that many of these same chemicals (*e.g.*, BTEX, PAHs) are not unique to MGPs but are common to many other sources. This list is based on our understanding of former MGP operations, in general and at this Site,[20] as well as based on the available soil and groundwater analytical data and field observations recorded during Site investigations, and an evaluation of background conditions at the Site.[21]

- MAHs – BTEX compounds, alkylated MAHs (*e.g.*, trimethylbenzene), styrene, and cumene
- PAHs – US EPA's 16 Priority Pollutants + 2-methylnaphthalene
- DRO and GRO
- Free[22] and Total Cyanide
- Ammonia

[19] Metals detected at concentrations exceeding background levels were included in the risk evaluation, as discussed in Section 5.
[20] As described in Section 2.1.3 and in the 2015 Historical Review Report (Gradient, 2015b).
[21] Metals were not included as potential MGP constituents because of the high metals content of the native geologic formation and their consistent detection at levels similar to background.
[22] Free cyanide data were not reportable for some samples due to data quality issues with the free cyanide analyses during the 2015 investigations (Barr, 2016o).

Overall, the analytical results for soil, groundwater, and vapor samples showed the detection of organic potential MGP constituents (MAHs, PAHs, DRO, and GRO) in relatively localized locations near former MGP equipment, structures, and certain piping. In order to better understand the magnitude and distribution of potential MGP constituents at the Site and its vicinity, the analytical data were used to calculate values for total PAHs (tPAH), total MAHs (tMAH), and benzo[a]pyrene toxicity equivalent (BaPTEQ) for all samples. The tPAH value was calculated as the sum of the concentrations of the 16 US EPA priority pollutants and 2-methylnaphthalene. The tMAH value was calculated as the sum of BTEX compounds and alkylated MAHs, including trimethylbenzenes, styrene, and cumene. The BaPTEQ value for each sample was computed by multiplying the concentrations of potentially carcinogenic PAHs by the BaPTEQ factors summarized in Table 3.12.

Table 3.12 Benzo[a]pyrene Toxicity Equivalent Factors

Analyte	BaPTEQ Factor
Indeno[1,2,3-cd]pyrene	0.1
Benzo[b]fluoranthene	0.1
Benzo[k]fluoranthene	0.01
Chrysene	0.001
Benzo[a]pyrene	1
Dibenz[a,h]anthracene	1
Benz[a]anthracene	0.1

Notes:
BaPTEQ = Benzo[a]pyrene Toxicity Equivalent.
Source: US EPA (1993).

The estimated values of potential MGP constituents are summarized by media and location in Tables 3.6-3.10 and presented in data post maps in Figures 3.5a-3.8. A complete summary of the analytical results for soil, groundwater, and vapor samples collected during the investigations is presented in Attachment C. A discussion of the analytical results for the former MGP (Heartland and URI properties) and off-Site locations, including the City ROWs, and the Historic Union and Culligan properties, is presented below, with the objective of providing a general overview of the location and relative magnitude of potential MGP impacts encountered during the investigations. The results for each property are grouped into discussions of organic and then inorganic potential MGP constituents.

Subsequent sections of the report provide an interpretative analysis of the results regarding contaminant source, fate, and transport (Section 4), an evaluation of the potential impacts to human health (Section 5), and an analysis of the remedy implications of the results (Section 6).

3.2.5.1 Heartland Apartments

Organics

Soil, groundwater, and soil gas samples with the highest concentrations of organic potential MGP constituents were found in the proximity of NAPL. Impacted soil was encountered in both relatively shallow samples (*e.g.*, B-HLA-23 from 1-1.4 ft bgs with tPAH at 1,175 mg/kg and DRO at 4,700 mg/kg) and deeper samples (*e.g.*, B-HLA-14 from 28-30 ft bgs with DRO at 1,900 mg/kg) in the southern parking lot. High concentrations of MAHs (tMAH up to 3,751 mg/kg and benzene up to 1,200 mg/kg) and PAHs (tPAH up to 87,200 mg/kg and naphthalene up to 28,000 mg/kg) were encountered in subsurface soil at location B-HLA-23 from 4.7-5.8 ft bgs and in other investigated soils within and around the former MGP operational areas in the southern parking lot. B-HLA-23 (4.7-5.7 ft bgs) also had the highest concentrations of DRO and GRO, with DRO at 130,000 mg/kg and GRO at 11,000 mg/kg.

Impacted groundwater was encountered at locations in the vicinity of impacted soil; the highest groundwater impacts were found in the southern parking lot, particularly along the southern edge of Apartment Building A, near former MGP structures. The highest MAHs (tMAH up to 22,653 μg/L and benzene up to 17,000 μg/L), PAHs (tPAH up to 7,990 μg/L and naphthalene up to 11,000 μg/L), DRO 17,000 μg/L), and GRO (42,000 μg/L) were found at MW-HLA-04 (4-19 ft bgs), along former process piping. Organic constituents were not detected in Heartland building sump water (Table 3.9; Figures 3.7a and 3.7b).

The highest concentrations of organics in soil gas were detected in samples collected along the southern building perimeter, particularly at location SG-HLA-18, which is located close to the high soil concentrations at B-HLA-14 and the high groundwater concentrations at MW-HLA-04 (Table 3.8; Figure 3.8). The soil gas sampling results showed the detection of constituents potentially associated with the MGP, including benzene (up to 10,000 $\mu g/m^3$) and naphthalene (up to 160 $\mu g/m^3$) (Table 3.8), as well as constituents not typically associated with MGPs, such as dichlorodifluoromethane (CFC-12). Sub-slab soil gas measurements beneath Building A were orders of magnitude lower in comparison to the soil gas sampling results, with lower level detections of naphthalene (up to 6.6 $\mu g/m^3$) and 1,2,4-trimethylbenzene (up to 80 $\mu g/m^3$) measured in the sub-slab soil gas samples (Table 3.8; Figure 3.8).

Sampling results for the surface soil samples collected on the Heartland property were much lower than the results for the subsurface media sampled during the investigation. The results showed the detection of PAHs (pyrene, benzo[a]pyrene, chrysene), DRO, and GRO, but showed no detection of MAHs, including BTEX compounds (Table 3.6; Figures 3.5a and 3.5b). Soil sample SO-HLA-07 showed the highest detections of PAHs, including pyrene (1.4 mg/kg), fluoranthene (1.3 mg/kg), benzo[a]pyrene (1.1 mg/kg), and naphthalene (0.64 mg/kg). DRO was detected at up to 150 mg/kg at SO-HLA-03B on the far northwest corner of the property, although concentrations in the rest of the property were lower (average detection of 24.5 mg/kg). GRO was not detected at all sampling locations except for SO-HLA-01, where it was detected at 16 mg/kg.

Inorganics

While total cyanide was detected at high concentrations in soil at a few isolated locations (up to 360 mg/kg at B-HLA-33 near the former steel coke trestle from 6-8 ft bgs), the maximum free cyanide detected in any soil sample on the Heartland property was 1.9 mg/kg (in the footprint of the former tar well at B-HLA-17 from 4-6.5 ft bgs). Free cyanide was detected in about half of the groundwater samples, with concentrations up to 66 μg/L encountered at MW-HLA-03, located in the area of the former retorts in the northern parking lot, from 4-19 ft bgs. Samples from the building sump did not show the detection of free cyanide, but did show a detection of total cyanide at 680 μg/L (Table 3.9; Figure 3.7c).

Ammonia was detected in soil across the property at concentrations up to 4,400 mg/kg (at B-HLA-14 from 28-30 ft bgs) and was present in most groundwater samples, with up to 285,000 μg/L found at B-HLA-24 from 5-20 ft bgs.

Most metals (aluminum up to 22,000 mg/kg, chromium up to 42 mg/kg, manganese up to 1,300 mg/kg) were encountered at levels consistent with background soils for Cass County, North Dakota (Attachment G), and in areas that did not show evidence of other MGP impacts. The highest arsenic detection (58 mg/kg at B-HLA-26 from 28-32 ft bgs) was within an order of magnitude of background concentrations and found in a deep soil sample with an absence of MAHs, PAHs, DRO, and GRO. Lead was an exception to this trend, with concentrations up to 620 mg/kg (compared to background levels of less than 20 mg/kg) at B-HLA-23 from 4.7-5.8 ft bgs, the location of many of the other highest MGP-related impacts. This was the only subsurface soil location with lead impacts more than an order of magnitude above background concentrations, however, and the average concentration in subsurface soil on the Heartland property was 22 mg/kg, consistent with background concentrations.

Inorganic sampling results for the surface soil samples collected on the Heartland property were much lower than the results for the subsurface media sampled during the investigation. The results showed the detection of metals, total cyanide, and free cyanide, but showed no detections of ammonia (Table 3.6; Figure 3.5c). Metals, including aluminum, arsenic, chromium, iron, and manganese, were detected at levels consistent with background concentrations in Cass County soils. Total cyanide was detected at SO-HLA-07 at 6.65 mg/kg; however, free cyanide at this location was detected at 0.1 mg/kg. The maximum free cyanide detection in surface soil was 0.16 mg/kg at SO-HLA-05B (Table 3.6; Figure 3.5c). Ammonia was not detected at any of the surface soil sampling locations.

3.2.5.2 United Refrigeration

Organics

The highest concentrations of organic potential MGP constituents on the URI property were in the southeast corner of the property, near former gas holder piping and an observed sheen on the groundwater surface. Several organics, including naphthalene (up to 650 mg/kg), 1,2,4-trimethylbenzene (up to 170 mg/kg), 2-methylnaphthalene (up to 100 mg/kg), DRO (up to 1,200 mg/kg), and GRO (up to 1,800 mg/kg) were detected in soil samples collected from B-URI-13, B-UR1-14, B-UR1-18, B-URI-21, and B-URI-22 on the URI property at depths ranging from 4-20 ft bgs (Table 3.6; Figures 3.6a and 3.6c).

Sampling results for groundwater similarly showed the detection of MAHs (BTEX, trimethylbenzenes), PAHs (naphthalene, 2-methylnaphthalene), DRO, and GRO (Table 3.7; Figures 3.7a, 3.7b, 3.7d, and 3.7e). Groundwater samples collected from a depth of 7-8 ft bgs near the observed sheen on the groundwater surface (*i.e.*, near the highest soil impacts and former gas holder piping) at locations B-URI-13, B-URI-14, and MW-URI-04S showed the highest detections of BTEX (up to 7,900 μg/L), naphthalene (up to 6,300 μg/L), DRO (up to 26,000 μg/L), and GRO (up to 31,000 μg/L), while concentrations at B-URI-12, B-URI-15, B-URI-16, and B-URI-17 were mostly non-detectable. Groundwater results for the deep monitoring well (50-60 ft bgs) installed on the property did not show evidence of MGP-related organic constituents (Table 3.7; Figures 3.7b and 3.7d).

Multiple organic constituents (BTEX, trimethylbenzenes) were detected in building exterior soil gas samples in several locations, with the highest concentrations in the general vicinity of the most impacted groundwater (locations SG-URI-02 and SG-URI-21) (Table 3.8). However, sub-slab soil gas detections from samples collected inside the building (SS-URI-01 to SS-URI-05) were at least an order of magnitude lower than concentrations in soil gas samples collected underneath the parking lot (Table 3.8; Figure 3.8). For example, near the southeast corner of the URI building, SG-URI-02 had a tMAH value of 33,560 $\mu g/m^3$, while the nearest sub-slab soil gas sample at SS-URI-03 had a tMAH value of 42 $\mu g/m^3$, three orders of magnitude lower (Table 3.8; Figure 3.8).

Inorganics

Several metals were detected in soil on the URI property at a depth interval of more than 4 ft bgs, but the detected levels are consistent with background concentrations for Cass County, North Dakota. Arsenic concentrations in many of the samples were similar to naturally occurring background concentrations of arsenic (7.9 mg/kg) in Cass County, North Dakota, soils (Attachment G). Concentrations of chromium were well below the background concentration of 100 mg/kg.

Manganese was detected in one sample (2,800 mg/kg) collected at a depth of 17 ft bgs, but the value is consistent with background concentrations of manganese in shallow (788-3,120 mg/kg) and deep (776-3,100 mg/kg) soils collected across North Dakota (see Attachment G). Ammonia (up to 2,370 mg/kg) was detected in soil collected from 4-8 ft bgs at B-URI-21 (Table 3.6). Total cyanide was detected in both shallow (4-8 ft bgs) and deep[23] (58-60 ft bgs) soil samples at low levels (up to 0.55 mg/kg); free cyanide was only detected in shallow samples at up to 0.21 mg/kg (Figure 3.6e).

Sampling results for groundwater were consistent with the observations in soil and showed detections of metals, ammonia, and total cyanide (Table 3.7; Figure 3.7c). Groundwater samples near the highest soil impacts (locations B-URI-13 and B-URI-14) showed the only detections of ammonia (up to 4,410 µg/L). Total cyanide was detected in all shallow samples (less than 20 ft bgs) on the URI property, with the highest concentration detected at B-URI-17 (485 µg/L; Figure 3.7c). Free cyanide was not detected at any location. Groundwater sampling results for the deep monitoring well (50-60 ft bgs) installed on the property did not show evidence of MGP-related inorganic constituents (Table 3.7; Figure 3.7f).

3.2.5.3 City Rights of Way

Organics

Impacts to soil in the City ROWs were highest underneath NP Avenue, which borders the southern edge of the former MGP operations, and were localized to within the vicinity of potential MGP artifacts, including tanks, piping, and drip pots. Elevated concentrations of organics, including BTEX (up to 540 mg/kg), naphthalene (up to 8,900 mg/kg), phenols (up to 680 mg/kg), and DRO (up to 140,000 mg/kg), were detected at soil sample B-NP09, collected at a depth interval of 5-7 ft bgs, near the two former wooden tanks and an observed sheen (Table 3.6; Figure 3.6b and 3.6d). The impacted soils were removed during the excavation work, and the post-excavation samples collected from this area (203-1 through 203-3 and 203-7 through 203-10) showed low to non-detectable levels of constituents. The highest concentrations of naphthalene (up to 23,300 mg/kg) encountered in the City ROWs were detected from a sample (8" PIPE CONTENTS) collected from the contents of an 8-in pipe located in the NP Avenue ROW near the northwest corner of the Historic Union property (Pipe 1). The pipe and its contents were removed and properly disposed of during the field investigation. Analytical results for soil samples collected in the surrounding area showed lower-level detections (*e.g.*, sample 10B-2 had a concentration of naphthalene of 32.3 mg/kg) (Table 3.6; Figure 3.6b). The highest concentrations of BTEX (up to 948 mg/kg) and GRO (up to 14,800 mg/kg) were detected in a soil sample taken at location 10TP-20, in the southern portion of the NP Avenue ROW near former gas distribution piping leading to the Historic Union property (Table 3.6; Figure 3.6b and 3.6d). Additional samples collected in this area (*e.g.*, DP-2 and B-NP07) also showed detections of potential MGP constituents, but at lower concentrations. Concentrations were found to attenuate to low to non-detectable levels east of 11th Street North (Figure 3.6b and 3.6d).

Sampling results showed that potential MGP-related impacts to groundwater were generally co-located with the elevated impacts to soil. Elevated concentrations of organic constituents in groundwater (up to 140,000 µg/L of naphthalene, 2,300 µg/L of benzene, 40,000 µg/L of 2-methylnaphthalene, 170,000 µg/L DRO, and 35,000 µg/L GRO) were detected in sample B-NP09, collected at a depth interval of 7-12 ft bgs, just below the soil sample from the same location (Table 3.7; Figure 3.7a and 3.7b). Sampling results showed that concentrations of organic constituents attenuated to low to non-detectable levels in groundwater samples collected to the south and east of the samples in the vicinity of the wooden

[23] The lack of detection of other MGP constituents in deep groundwater wells indicates that the detection of total cyanide may be caused by matrix interference.

tanks. Sampling results similarly attenuated quickly in several directions at other locations with co-located impacts, *e.g.*, B-NP07.

Some elevated concentrations of MAHs were detected in soil gas, with the highest concentrations generally observed near the soil and groundwater impacts at location B-NP07, and close to historical piping located immediately north of the Historic Union property (Table 3.8; Figure 3.8). Benzene (6,200 µg/m^3), naphthalene (280 µg/m^3), and 1,2-4-trimethylbenzene (450 µg/m^3), were detected at this location. Follow-up results from sampling efforts on the Historic Union property to the south indicate that the impacts in this area were localized.

Inorganics

The highest concentration of total cyanide (up to 384 mg/kg) encountered in the City ROWs was detected from a sample (8" PIPE CONTENTS) collected from the contents of an 8-in pipe located near the northwest corner of the Historic Union property in NP Avenue. The pipe and its contents were removed and properly disposed of during the field investigation. The highest total cyanide in groundwater (up to 277 µg/L) was detected near the high soil impacts at 8" PIPE CONTENTS. Free cyanide data in groundwater in the City ROWs were not reportable or non-detect at all locations except MW-ROW-03S, where free cyanide was detected at up to 21 µg/L (Table 3.7; Figure 3.7c). The highest concentrations of ammonia (up to 1,380 mg/kg) were observed at B-ROW-01 in 12th Street North, near the southwest corner of the Heartland property, where the former ammonia tank and legacy MGP piping were located (Figures 2.3 and 2.4).

3.2.5.4 Historic Union

Organics

Soil analytical results showed relatively low to non-detectable levels of organic potential MGP constituents in soils sampled around the Historic Union building perimeter, including BTEX (up to 5.5 mg/kg), naphthalene (up to 8.6 mg/kg), phenols (non-detect), DRO (up to 260 mg/kg), and GRO (up to 610 mg/kg) (Table 3.6; Figures 3.6b and 3.6d).

Concentrations of potential MGP constituents in groundwater were localized, with the highest concentrations (up to 370 µg/L of naphthalene, 51 µg/L of benzene, and 455 µg/L of GRO) detected west of the building at sample location B-UB03 at a depth interval of 2-12 ft bgs (Table 3.7; Figures 3.7a and 3.7b). Slightly elevated concentrations (tMAH up to 54.7 µg/L) were also present in permanent monitoring well MW-UB-01, located near the northwest corner of the property (Figure 3.7a), and the highest concentration of DRO was detected in a sub-slab groundwater sample (up to 1,400 µg/L at location SS-UB10; Figure 3.7b).

Soil gas and sub-slab soil gas analytical results showed detections of potential MGP constituents, including BTEX compounds and naphthalene. Sampling results for soil gas samples collected outside the building showed the detection of benzene (up to 590 µg/m^3) and xylenes (up to 1,400 µg/m^3) (Table 3.8; Figure 3.8). Concentrations of potential MGP constituents in sub-slab soil gas samples were generally orders of magnitude lower, with samples showing detections of benzene (up to 7.9 µg/m^3), naphthalene (up to 2.8 µg/m^3), and toluene (up to 39 µg/m^3) (Table 3.8; Figure 3.8).

Inorganics

Total cyanide was non-detect in soils on the Historic Union property (Table 3.6; Figure 3.6f). Total cyanide was detected at up to 115 μg/L in groundwater, but free cyanide in all of the groundwater samples and samples from the building sump was non-detect (Figure 3.7c). Arsenic detections in soil (up to 6.9 mg/kg) were consistent with background levels for Cass County, North Dakota (Attachment G). Ammonia was non-detect in all of the groundwater samples; it was detected in samples from the building sump at up to 1,640 μg/L in November 2015, but non-detect in samples from the elevator sump in May 2016 (Table 3.9).

3.2.5.5 Culligan

Organics

Sampling results from the Culligan property generally did not show impacts from potential MGP constituents. No MAHs, PAHs, DRO, or GRO were detected in soil samples collected around the Culligan building (Figures 3.6b and 3.6d). No MAHs, PAHs, DRO, or GRO were detected in groundwater samples from the Culligan property (Figures 3.7a and 3.7b). MAHs (BTEX and naphthalene) were detected at low levels (tMAH up to 33 $\mu g/m^3$) in sub-slab samples collected from underneath the Culligan building (Table 3.8; Figure 3.8).

Inorganics

No total cyanide or ammonia were detected in soil samples collected around the Culligan building (Figure 3.6f). Total cyanide was detected in groundwater at up to 24 μg/L at B-CUL-01, the sampling point furthest north on the property, but free cyanide results for all samples were non-detect (Figure 3.7c). Metals (chromium, lead, manganese) were detected at concentrations consistent with background levels for Cass County, North Dakota (Attachment G). Arsenic was detected at levels marginally exceeding background at one location (up to 22 mg/kg at B-CUL-01 from 4-6 ft bgs), but detections at other locations were less than background. No ammonia was detected in groundwater samples from the Culligan property.

3.2.5.6 1213 NP Avenue

Organics

Sampling results from the northeastern corner of 1213 NP Avenue generally did not show impacts from potential MGP constituents. No MAHs, PAHs, or GRO were detected in groundwater samples (Figures 3.7a and 3.7b). Given the lack of detected MAHs and PAHs, the DRO that was detected at low levels (up to 220 μg/L) at B-KBP-01 and B-KBP-02 from 5-20 ft bgs is likely from naturally occurring organic material or from prior use of the property as a filling station. MAHs (BTEX) were detected at low levels (tMAH up to 36.7 $\mu g/m^3$) in sub-slab samples collected from underneath the eastern building (Table 3.8; Figure 3.8).

Inorganics

Total cyanide was detected in groundwater at up to 13 μg/L at B-KBP-02, but free cyanide results for all groundwater samples were non-detect (Table 3.7; Figure 3.7c).

4 Site Investigation Results

The results of the field investigations described in Section 3 were evaluated in the context of the Site's operational history to identify the sources of contamination at the MGP Site, and to develop a comprehensive understanding of the nature and extent of potential MGP constituents in soil, groundwater, and vapor at the Site and its vicinity (Section 4.1). The investigation results were also used to assess the environmental fate and transport of potential MGP constituents in the subsurface and to develop a CSM (Section 4.2) that was used to support a risk evaluation (Section 5) and develop remedial strategies (Section 6).

4.1 Sources, Nature, and Extent of Potential MGP Constituents

4.1.1 Sources

The distribution of NAPL relative to the location of former MGP structures shows that there are 4 main source areas at the MGP Site:

1. **Tar production and storage operations**, located in the southern parking lot area at the Heartland property, where NAPL impacts were observed during the field investigations.
2. **Tar transfer areas**, including former rail lines, pipes, and wooden tanks in portions of the City ROWs and on the Heartland property that were likely used to convey tar for off-Site sale.[24] NAPL was found in, beneath, and around these tar transfer areas.
3. **MGP petroleum storage and conveyances**, used for CWG production and located in the northern parking lot area at the Heartland property, where petroleum impacts were observed.
4. **Drip oil sheens**, encountered near the former gas distribution holder at the URI property.

Former MGP piping in close proximity to the former MGP Site may have also acted as preferential pathways for limited historical NAPL migration based on the presence of sheen in and adjacent to those pipes. Each of these source areas is described below.

Tar Production and Storage Operations

NAPL was encountered in 14 of 42 locations in the southern parking lot area at the Heartland property, most frequently at depths from 2-7 ft bgs, with NAPL "stringers" encountered at depths of up to 32 ft bgs (Figures 3.4a and 3.4e). These NAPL observations coincide with the locations of former MGP equipment used for tar production and storage. The soil intervals over which NAPL impacts were encountered were thickest in locations advanced in this area (up to 24 ft), particularly at the former tar well and the former retort area, and the thicknesses attenuated rapidly with distance. Most of the NAPL sheen observed during the investigations surrounded this source area.

[24] As described in the 2015 Historical Review Report (Gradient, 2015b), significant quantities of tar were sold and presumably transported by rail.

Tar Transfer Areas

NAPL was also encountered at and near conveyances (three rail spurs, two pipes, and one wooden tank) that were likely used to transfer tar for rail shipment. Two of the four borings advanced along the north-south rail spur along the western edge of the Heartland property southern parking lot (B-HLA-19 and B-HLA-39) encountered black, high-viscosity NAPL from 2-4 ft bgs (Figure 3.4e). This shallow depth is consistent with a surface or near-surface release in this location. Pipes 5 and 6 (see Figure 3.4a) 3-7 ft bgs contained black, tarry liquid and lead to the southern rail spur. The two former wooden tanks encountered near railroad ballast in the NP Avenue ROW contained black, tar-like liquid (T2) and yellowish-greenish liquid (T1) starting at a depth of 4 ft bgs and ending at 8 ft bgs. The locations of the impacts are shallow and are separated from the larger NAPL presence in the Heartland property southern parking lot (Figure 3.4a), and their location and shallow depth along former rail lines indicates that the impacts may be associated with tar conveyance *via* rail.

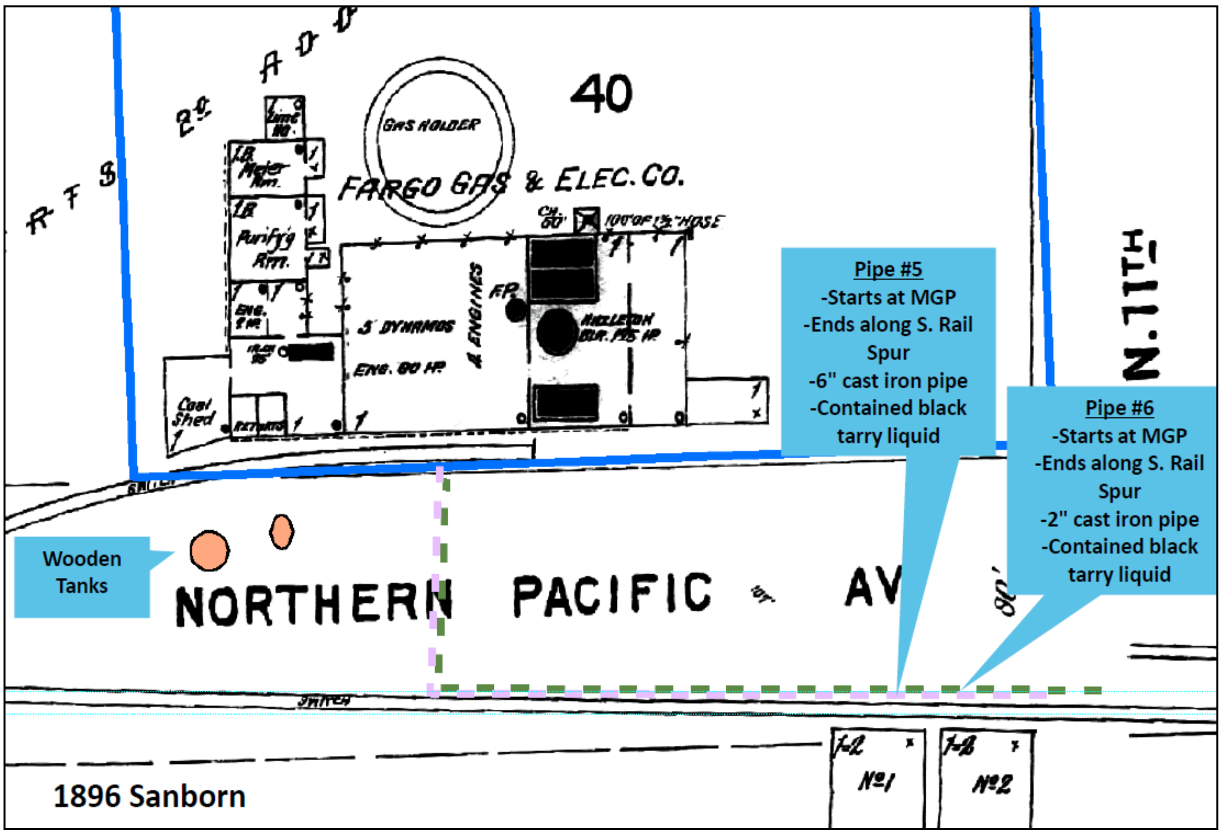


Figure 4.6 Rail Spurs, Wooden Tanks, and Piping Likely Used to Transfer Tar for Rail Shipment. Sources: Carlson McCain (2015a,c); Sanborn Fire Insurance Maps (1896).

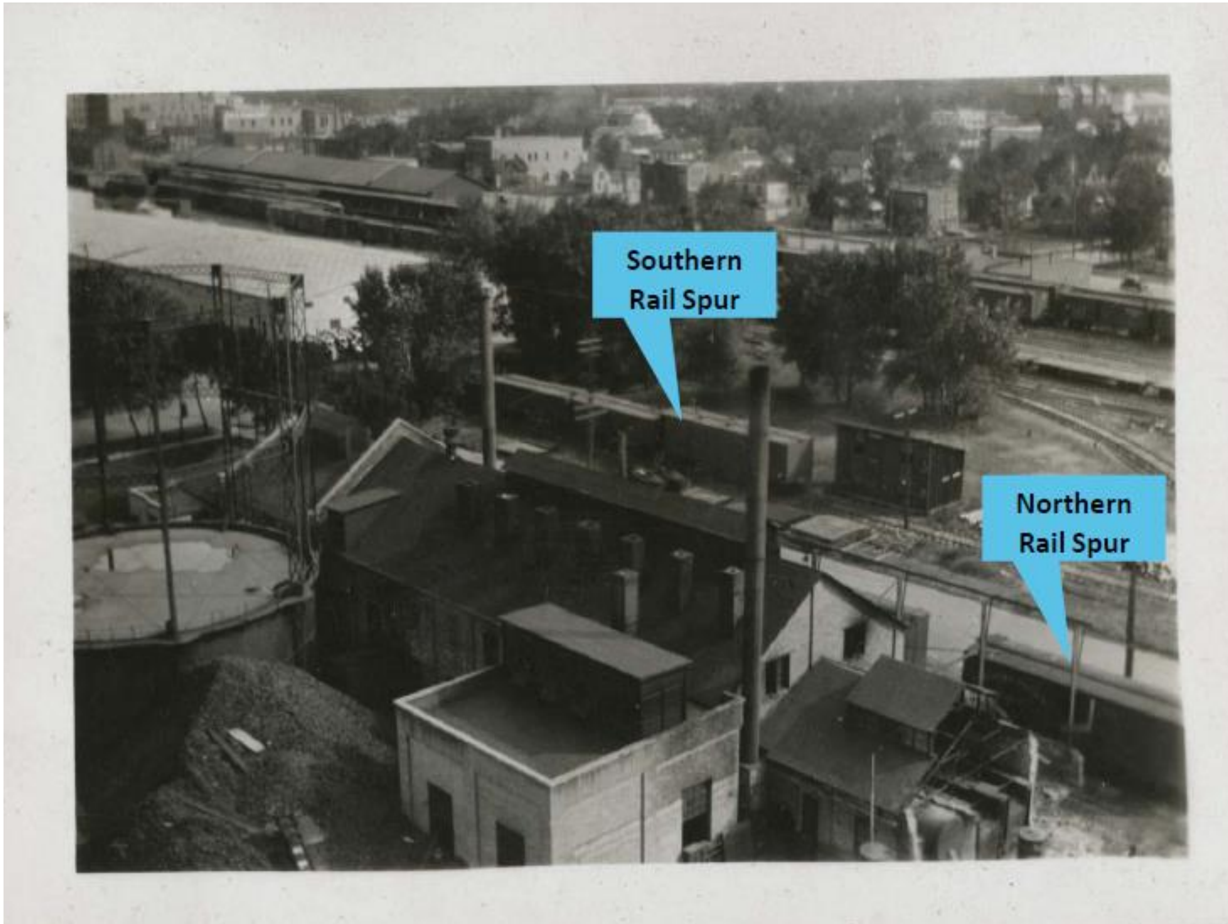


Figure 4.7 Northern and Southern Rail Spurs (Historical Photo, c. 1925). Source: NSP (1925).

MGP Petroleum Storage and Conveyances

Petroleum impacts are a likely source of the impacts observed in the northern parking lot at the Heartland property.[25] A light sheen was observed at B-HLA-09 from 6-8 ft bgs, advanced through the footprint of the former 100,000-gallon oil tank, and at three other shallow (less than 4 ft bgs) locations in the northern parking lot. The proximity to the former oil tank and the shallower depth of the sheens indicates that they may be associated with a petroleum-related source.[26]

Drip Oil Sheens

Drip oil sheen[27] was encountered near the former gas distribution holder at the URI property. A shallow sheen was observed at depths up to 8 ft bgs at borings in the alley south of the URI property and the

[25] The deeper small blebs encountered over a 1- 2-in area at 9 ft bgs at B-HLA-07 may be associated with a different source in the northern parking lot or may be associated with NAPL migration from the tar production and storage area in the southern parking lot.
[26] Fingerprinting analyses (see Attachment I) also indicated that some of the impacts in the southern portion of the 11th Street North ROW and in the alley south of URI may be petroleum-related, but are unlikely to be related to the MGP based on their location.
[27] Samples from the location of this sheen consist primarily of pyrogenic naphthalene, which is consistent with manufactured gas condensate (*i.e.*, drip oil). See Attachment I for further details

southeastern corner of the URI property: B-URI-21 from 0-6 ft bgs, at B-ROW-23 from 4-7 ft bgs, and at B-ROW-27 from 6-8 ft bgs.

Sheen was encountered sporadically in other locations (B-ROW-16 from 0-5 and 20-22 ft bgs, and B-ROW-18 from 0-8 ft bgs) adjacent to piping corridors as well as in a former pipe (Pipe 2 from 5-7 ft bgs). Based on the presence of sheen in and adjacent to those pipes, the former MGP piping in close proximity to the former MGP Site may have also acted as preferential pathways for limited historical NAPL migration.

The four main source areas were delineated by the investigation, which showed that NAPL impacts were limited primarily to soils beneath the former MGP operations to a depth of about 25 ft bgs, as shown in cross-sections depicted in Figures 4.2a, 4.3a, 4.4, and 4.5. The cross-sections in Figures 4.4 and 4.5 also show that the eastern and northern extent of NAPL impacts have been well defined.

The highest concentrations of potential MGP constituents were co-located with NAPL observations and concentrations declined with distance from the identified NAPL, confirming that the NAPL acts as a source of contamination and is sufficiently delineated by the analytical data collected in the investigation. The potential MGP constituents that were detected in soil and groundwater, both on- and off-Site, were MAHs (including BTEX compounds and trimethylbenzenes), PAHs (including naphthalene, 2-methylnaphthalene, pyrene, and fluoranthene), DRO, GRO, and inorganics (ammonia and cyanide) (Tables 3.6-3.10). The MGP-related constituents detected in soil gas samples were BTEX compounds and naphthalene (Table 3.8). As discussed in Section 3, although the analytical results showed the detection of additional analytes (such as CFC-12) in soil gas and metals (such as magnesium) in soil, they are not generally associated with MGPs (1,3-butadiene) and/or were detected at concentrations that were comparable to background levels in Cass County, North Dakota (magnesium). Further, some constituents, such as BTEX and PAHs, may be produced from the many other potential industrial/commercial sources located near the Site (Figure 2.5 and Section 4.1.1.1, below).

4.1.1.1 Forensic Analysis

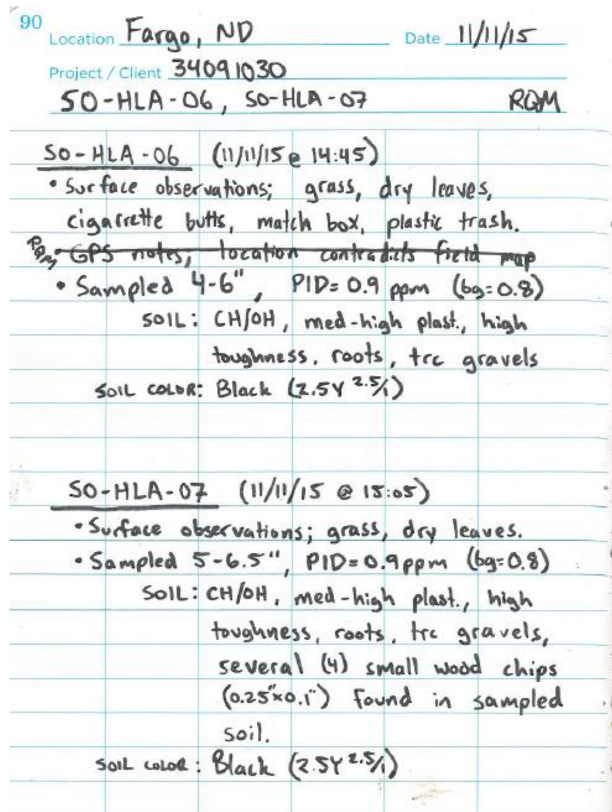
Forensic analyses were performed using fingerprinting data collected during the investigations (Attachment I). The goal of these analyses was to characterize the total petroleum hydrocarbons (TPH), PAH, and MAH fingerprints of former MGP operations and identify potential off-Site contamination sources. The results demonstrate that the predominant source of PAHs at the Site appears to be coal carbonization (CC) tar, which is consistent with historical MGP operations at the Site. NAPL samples from the Heartland property are consistent with a CC tar, as are most of the subsurface soil samples. The surface soils at the Heartland property have low tPAH concentrations (<25 mg/kg) and chromatograms that are consistent with urban background. There are some indications that CWG tar is also present at the Site and in its vicinity. Drip oil (*i.e.*, manufactured gas condensate) appears to be present in and near the former distribution gas holder at the URI property and in locations near drip pots in the portion of NP Avenue in the immediate vicinity of the former MGP. The samples from these locations consist primarily of pyrogenic naphthalene. There is also evidence for some petroleum contribution for individual samples, including B-ROW-28 (4-8 ft bgs), B-ROW-11 (6-8 ft bgs), and B-ROW 27 (4-6 ft bgs) that suggests contributions from off-Site or more recent sources.

4.1.2 Nature and Extent of MGP-related Constituents

This section discusses the nature and extent of potential MGP constituents, by media.

Surface Soil

Overall, the sampling results showed no significant evidence of MGP-related sources or impacts in the surface soil. Fingerprinting results for the surface soil samples collected during the investigation showed results that were consistent with urban background (see Attachment G). The highest concentration of tPAH (12.2 mg/kg) in surface soil was detected at SO-HLA-07 (Figure 3.5a), which is within the range of typical urban background for PAHs (mean of 18 mg/kg). The field log for the sample showed no evidence of MGP residuals at this location (see entries for SO-HLA-06 and SO-HLA-07 in Figure 4.8, at right). While small wood chips were observed, they did not exhibit any sign of the distinctive bright blue staining that characterizes purifier box waste.



90
Location Fargo, ND Date 11/11/15
Project / Client 34091030
SO-HLA-06, SO-HLA-07 RQM

SO-HLA-06 (11/11/15 @ 14:45)
• Surface observations; grass, dry leaves, cigarette butts, match box, plastic trash.
~~GPS notes; location contradicts field map~~
• Sampled 4-6", PID= 0.9 ppm (bg=0.8)
SOIL: CH/OH, med-high plast., high toughness, roots, trc gravels
SOIL COLOR: Black (2.5Y 2.5/1)

SO-HLA-07 (11/11/15 @ 15:05)
• Surface observations; grass, dry leaves.
• Sampled 5-6.5", PID=0.9ppm (bg=0.8)
SOIL: CH/OH, med-high plast., high toughness, roots, trc gravels, several (4) small wood chips (0.25"x0.1") found in sampled soil.
SOIL COLOR: Black (2.5Y 2.5/1)

Figure 4.8 November 2015 Surface Soil Sampling Field Notes for SO-HLA-06 and SO-HLA-07. Source: Barr (2015i).

tPAH values at other surface sampling locations were less than 3 mg/kg and tMAH levels were non-detect in all of the surface soil sampling locations. BaPTEQ values were generally zero, with three low-level detections less than or equal to 0.5 mg/kg. Nine of the fifteen surface soil sampling locations had no detections of either MAHs or PAHs. Two of the fifteen surface soil sampling locations (SO-HLA-04 and SO-HLA-07, on the northeast portion of the Heartland property) showed detections of total cyanide (Table 3.6). Low-level detections of DRO across the Heartland property (detected at up to 220 mg/kg) and GRO at one location (SO-HLA-01 at 16 mg/kg) are likely not related to former MGP operations, given the lack of viable source material identified in the surface soil sampling. Additionally, interferences from unrelated, naturally occurring organic matter may have contributed to a high bias of DRO in samples collected in 2015 without the use of a silica gel extraction step (see Section 3.1.3).

Subsurface Soil

The subsurface soil sampling results showed that elevated levels of tPAH and tMAH were localized to the immediate vicinity of the former MGP operations and MGP-related structures (including piping). The most significant impacts were beneath the Heartland property southern parking lot, near the former distribution gas holder at the URI property, proximate to the underground wooden tanks encountered in the ROW, and at points along former MGP piping beneath the portion of NP Avenue adjacent to the former MGP Site (Figures 4.1a and 4.1b). The highest tPAH concentrations (up to 87,200 mg/kg) were detected in soil samples collected from the center of the source area underneath the Heartland property southern parking lot (at locations B-HLA-23 and B-HLA-21). Highly elevated concentrations were also observed in the vicinity of the wooden tanks (B-NP09 and Large Tank Contents1) and former MGP piping (10TP-20) encountered during the NP Avenue excavation work (Figure 3.6b). The highest levels of tMAH (up to 3,751 mg/kg), BaPTEQ (up to 3,032 mg/kg), DRO (up to 140,000 mg/kg), GRO (up to 14,800 mg/kg), and ammonia (up to 4,400 mg/kg) in soil were typically co-located with the elevated PAH impacts (B-HLA-23, B-HLA-21, Large Tank Contents1, 10TP-20, and B-NP09), indicating that the impacts are typically associated with the NAPL source areas described in Section 4.1.1.

DRO is an exception, for which concentrations greater than 100 mg/kg or µg/L were detected along the boundaries of the sampled area (Figure 4.1c), while tPAH, tMAH, and GRO results were lower (Figures 4.1a, 4.1b, and 4.1d). There are many other potential sources of DRO in the Site vicinity and surrounding areas, however (see discussion in Section 2.2), that may be contributing to higher concentrations around the periphery of the investigation area. Additionally, interferences from unrelated, naturally occurring organic matter may have contributed to a high bias of DRO in samples collected in 2015 without the use of a silica gel extraction step (see Section 3.1.3).

The sampling results showed that the impacts to soil attenuated with distance from the source areas and were delineated to lower concentrations in all directions. Deep soil samples collected from 58-60 ft bgs during the investigation did not show significantly elevated concentrations (>1 mg/kg) of MGP-related constituents at any location. The deepest identifiable impacts in soil were found at B-HLA-14, from 28-30 ft bgs, located at the northern end of the source area along former piping connecting the two gas holders (Figure 4.3b). NAPL observations continued up to the terminal depth of the boring at this location, indicating that soil impacts likely extend deeper than 30 ft bgs. Deeper impacts were not observed in the deeper (58-60 ft bgs) soil sample taken from MW-ROW-02D further north, nor were groundwater impacts related to deeper contamination observed at that location (Tables 3.6 and 3.7; Figures 3.6a, 3.6c, 3.6e; and Figures 3.7d, 3.7e, and 3.7f).

Groundwater

Sampling results showed that impacts to groundwater were localized and co-located with impacts to soil (Figures 4.1a-d), which is consistent with the low hydraulic conductivity and limited contaminant transport potential of the shallow soils at the Site and its vicinity, as discussed in Section 2 and detailed further in Section 4.2.

The highest tPAH concentrations in groundwater were detected at sample location B-NP09 (454,000 µg/L), between the two wooden tanks in the NP Avenue ROW. Although orders of magnitude lower in comparison to B-NP09, elevated tPAH levels were also detected at B-ROW-18 (9,733 µg/L) and at source area monitoring well MW-HLA-04 (7,990 µg/L) (Figure 3.7a). These impacts are consistent with the NAPL observations of a sheen on the groundwater at each sampling location. High levels of ammonia (up to 285,000 µg/L at B-HLA-24), DRO (up to 170,000 µg/L at B-NP09), GRO (up to 42,000 µg/L at MW-HLA-04), and BaPTEQ (up to 12,867 µg/L at B-NP09) were detected near source areas. Free cyanide was detected at up to 66 µg/L (at location MW-HLA-03), but concentrations in most groundwater samples were low to non-detect.

Concentrations of MGP constituents in shallow groundwater around the investigation area periphery in all directions were low to non-detect for tPAH, tMAH, BaPTEQ, and GRO (Figures 3.7a and 3.7b). Permanent groundwater monitoring well MW-ROW-03S in the 11th Street North ROW near NP Avenue and nearby boring B-ROW-08 showed total cyanide detected at up to 1,890 µg/L, free cyanide detected at up to 21 µg/L, and DRO detected at up to 630 µg/L, despite the absence of tPAH, tMAH, or BaPTEQ impacts. DRO was detected at low to mid-range concentrations (100-300 µg/L) at the northern and southern extents of the investigation, consistent with areas of elevated soil concentrations (Figure 3.7b). Given that alternative sources of DRO are present in the area and that most other MGP constituents are low to non-detect at these locations, the periphery detections of DRO are not indicative of an extensive shallow groundwater plume beyond the boundaries of the investigation. The high bias in DRO data collected early in the investigation due to interferences from organic matter may also be contributing to the detections around the investigation periphery.

The intermediate permanent groundwater monitoring well installed in the source area (MW-HLA-04M) showed that impacts to groundwater extended to the screened depth of the well (20-30 ft bgs). tPAH (up to 1,402 μg/L), tMAH (up to 1,343 μg/L), free cyanide (up to 21 μg/L), DRO (up to 3,900 μg/L), and GRO (up to 2,600 μg/L) were detected at this location. No deeper groundwater samples were collected from the area; however, the intermediate and deep permanent groundwater monitoring wells installed near the edges of the former MGP operations showed minimal impacts of MGP-related constituents, with the exception of MW-HLA-05M (Figures 3.7d-f). Samples collected from MW-HLA-05M, located between the former MGP operations and the impacted shallow monitoring well MW-ROW-03S, showed detections of MAHs (tMAH up to 149 μg/L), free cyanide (up to 59 μg/L), DRO (up to 180 μg/L), and GRO (up to 620 μg/L). Samples collected from the shallow groundwater monitoring well (MW-HLA-05) overlying this location did not detect free cyanide or GRO and had a calculated tMAH value of 15 μg/L, which may indicate the proximity of a localized NAPL "stringer." A deep monitoring well located 60 ft to the southeast (MW-HLA-01D) did not show significant impacts from MGP-related constituents. The lack of impacts detected in the deep monitoring well at 60 ft bgs indicates that impacts are highly unlikely to have migrated below the clay layer to the underlying aquifer, which is located more than 100 ft bgs.

Similar to the contaminant distribution pattern observed for soils, concentrations of MAHs and PAHs in shallow groundwater attenuated rapidly with distance from the source area.

Soil Gas and Sub-slab Soil Gas

The sampling results showed the frequent detection of tMAH and some detections of naphthalene, albeit at generally low levels, in soil gas and sub-slab soil gas samples collected on the Heartland property, URI property, City ROWs, Historic Union property, and Culligan property. Elevated detections (greater than 700 $\mu g/m^3$) of tMAH were restricted to soil gas samples collected near the identified sources, such as pipes. The highest concentrations Site-wide included SG-URI-21 (56,500 $\mu g/m^3$) and SG-URI-02 (33,560 $\mu g/m^3$), collected in and around the gas holder footprint on the URI property; SG-HLA-18 (13,073 $\mu g/m^3$), located along piping connecting the former MGP operations; B-NP-09 (882.5 $\mu g/m^3$), collected in the vicinity of the wooden tank on NP Avenue; B-NP07 (13,950 $\mu g/m^3$), collected adjacent to gas distribution piping on the border of NP Avenue and the Historic Union building; and B-UB01 (3,785 $\mu g/m^3$), collected from a pipe running south from the Historic Union building (Table 3.8; Figure 3.8).

Importantly, analytical results for sub-slab soil gas samples collected on the Heartland property, URI property, Historic Union property, and Culligan property showed that concentrations of MAHs were orders of magnitude lower in comparison to the soil gas samples collected around the exteriors of the buildings. The URI property had the highest sub-slab soil gas tMAH concentration (up to 607.8 $\mu g/m^3$, driven by high BTEX concentrations) while the Heartland Apartments building had the highest sub-slab soil gas naphthalene concentration (up to 6.6 $\mu g/m^3$). Sub-slab soil gas concentrations at the Culligan building, 1213 NP Avenue eastern building, and Historic Union buildings were low (tMAH less than 50 $\mu g/m^3$; naphthalene less than or equal to 2.8 $\mu g/m^3$).

4.2 Fate and Transport

The overall distribution of potential MGP constituents in the environment, as depicted in Figures 4.1a-d and cross-sections (Figures 4.2a-4.5), was evaluated in conjunction with potential sources and physical and chemical properties of the constituents to develop a better understanding of their fate and transport in the environment. The distribution shows that NAPL serves as a source of soil contamination, groundwater impacts are generally localized to areas with high soil concentrations, and soil gas impacts are localized to areas with high soil and groundwater concentrations. NAPL is the primary source of organic contaminants at the Site, and its transport away from the identified sources is limited by the low conductivity of the native silts and clays at the Site. Although full vertical delineation of soil impacts was not complete at all locations (*e.g.*, B-HLA-14), the low conductivity of the clays controls vertical migration. Deep monitoring wells screened from 50-60 ft bgs at the Site and its vicinity did not show detections of MGP constituents[28] (Figures 3.7d-f). Thus, even though vertical delineation of impacts in the source area is not complete, it is highly unlikely that NAPL has migrated to the deep aquifer, which is located at a depth of more than 100 ft bgs.

Potential MGP constituents were detected in surface soil at much lower concentrations than in subsurface soils, with most surface soil sampling locations showing non-detectable levels of tPAH, tMAH, and BaPTEQ (Figures 3.5a-c). These findings are consistent with the lack of field observation of MGP-related waste and residuals in surface soils. The distribution of potential MGP constituents in subsurface soils, as shown in Figures 4.1a-d, does not show widespread contamination, but rather is more consistent with the presence of source material in isolated locations associated with tar production and storage operations; tar transfer areas, petroleum impacts, the gas distribution holder, or along the MGP piping/bedding and drip pots in close proximity to the MGP Site. For example, the highest concentration of GRO in groundwater, after the high detections at the former wooden tanks (B-NP09; 35,000 μg/L) and the piping intersection near NP Avenue and 11th Street North (B-NP07; 13,000 μg/L), was 530 μg/L at B-NP10, more than an order of magnitude lower than either of the samples with higher concentrations.

The similarity of the distribution of organic constituents in soil and groundwater (Figures 4.1a-d) is consistent with the low hydraulic conductivity and transport potential of the shallow clays at the Site. Given the horizontal hydraulic conductivity of the clays underlying the Site (geometric mean of 5×10^{-8} cm/s; see Attachment C), migration of groundwater through the bulk clay is likely on the order of millimeters per year,[29] at most. Significant bulk migration of MGP constituents in groundwater is thus not likely. The collocation of the soil and groundwater impacts (*e.g.*, B-HLA-28 and B-ROW-18; Figures 4.1a and 4.1b) and general attenuation with distance from the source areas indicates that little NAPL and/or dissolved phase migration has occurred away from source material. The contaminant distribution patterns show that off-Site impacts to soil and shallow groundwater (*i.e.*, away from the identified source areas) may be attributable to transport *via* preferential pathways, such as piping that is in contact with NAPL or impacted groundwater, as evident from the corridor of elevated detections of MGP-related constituents (*i.e.*, greater than 100 mg/kg tMAH and tPAH) along the former MGP piping beneath portions of NP Avenue in proximity to the MGP Site (Figures 4.1a-d).

[28] Laboratory-reported detection of total cyanide in deep monitoring well MW-HLA-01D is likely due to interference from turbidity in the sample.

[29] 5×10^{-8} cm/s is equivalent to 16 mm/year; this value would be multiplied by the value of the hydraulic gradient (typically 0.005-0.1) to determine the actual groundwater migration rate.

The soil gas sampling results showed more widespread detection of MGP-related constituents (MAHs and naphthalene) in comparison to soil and groundwater (*e.g.*, the northwest corner of the Heartland property in Figure 4.1b). This may be due to the higher rate of contaminant diffusion and transport through soil vapor in comparison to groundwater, as shown in the Table 4.1, and may be attributable to transport *via* preferential pathways, such as piping.

Table 4.1 Diffusion Coefficients of Benzene and Naphthalene

Constituent	Diffusion Coefficient in Water (cm^2/s)	Diffusion Coefficient in Air (cm^2/s)
Benzene	9.80E-06	8.80E-02
Naphthalene	7.50E-06	5.90E-02

Note:
Data Source: New Jersey Department of Environmental Protection (NJDEP, 2008).

However, similar to soil and groundwater, contaminant distribution patterns for soil gas showed that the highest MAH concentrations were localized in areas close to identified sources (*e.g.*, gas holder piping on the URI property and gas distribution piping north and south of the Historic Union building) and attenuated with distance from the source areas (Figure 4.1b). Further, sub-slab sampling results for the Heartland, URI, and Historic Union properties generally showed lower concentrations in sub-slab samples underneath the buildings than at soil gas locations in the surrounding areas (*e.g.*, tMAH for sample SS-URI-03 was 42 $\mu g/m^3$, while tMAH for nearby SG-URI-02 was 33,560 $\mu g/m^3$; see Figure 3.8), which provides further evidence of vapor attenuation with distance from a subsurface source.

Given the low vertical hydraulic conductivity of the shallow clays at the Site (geometric mean of 2×10^{-8} cm/s; see Attachment C), the gravity drainage of groundwater through the shallow clays would occur at a rate of less than 1 cm/year. Constituent transport would occur at even slower rates, due to retardation associated with sorption to the soil column. Specifically, the retardation rates of benzene and naphthalene and the corresponding downward vertical migration rate under gravity drainage in the clay are presented in Table 4.2.

Table 4.2 Constituent Transport Rates

Constituent	Organic Carbon-Water Partition Coefficient (L/kg)	Retardation Factor (-)	Vertical Migration Rate (cm/year)
Benzene	58.9	1.6	0.4
Naphthalene	2,000	20	0.03

Notes:
Data Source: New Jersey Department of Environmental Protection (NJDEP, 2008).
Calculation of the retardation factor used the physical parameter data in Attachment C to determine Site-specific bulk density (1.29 g/cm^3), porosity (0.5), and fraction of organic carbon (0.04%).

Given the hydrogeological conditions described above, the downward vertical migration of MGP-related constituents is expected to be limited and unlikely to impact the deeper aquifer, which is presumably located at a depth of more than 100 ft bgs, as discussed in Section 2.

4.2.1 Conceptual Site Model

The CSM for the Fargo MGP describes the origin, current extent, and future potential migration of MGP constituents at the Site using all of the information about the Site and its vicinity gathered to-date. The Fargo MGP operated from 1885-1960, producing predominantly coal gas and also CWG at various times. The manufactured gas was distributed to Fargo through an underground piping network, and tar was likely transferred *via* three railroad spurs identified on or near the Site. MGP materials, such as tars and oils, were produced and stored in various MGP structures (tar wells, gas holder bottoms), as shown in Figure 2.3, until the MGP ceased operations in 1960. The potential MGP constituents associated with MGP materials at the Site are MAHs (including BTEX compounds), PAHs, DRO, GRO, ammonia, and cyanide.

Releases of MGP materials to the environment may have occurred through several different mechanisms. Accidental spills of oil and/or tar during transfer to and loading of tanker cars may have occurred and may have resulted in shallow impacts. Unexpected leaks of NAPLs (tar and drip oil) from former MGP structures (*e.g.*, tar wells, drip pots) may have occurred and may have resulted in subsurface impacts. It appears that NAPL may have migrated in the form of stringers to locations where it is now trapped as residual. Additional factors (*e.g.*, high temperature) that may have enhanced tar mobility during and shortly after the release are significantly different now, further limiting the mobility of the heavily weathered tar. During the 1962 demolition of the MGP, portions of some of the subsurface structures, such as concrete foundations, were left in place.

MGP residuals, such as drip oils and tars, in the subsurface as NAPL impacted the surrounding soil. The more soluble and volatile NAPL constituents (*e.g.*, BTEX and naphthalene) leached into groundwater and volatilized into the soil vapor phase. Buried piping in contact with source material may have acted as preferential pathways for vapor and groundwater migration.

The Site is locally underlain by fill material for up to 7 ft bgs, under which tight clays are present to a depth of at least 36 ft bgs and likely up to 100 ft bgs (Attachment F). There is no evidence of continuous vertical breaches of this confining layer.[30] Although shallow groundwater is present in isolated regions within the clay, the depth of the regional groundwater table is less than 10 ft bgs. Due to the very low hydraulic conductivity of the clays, migration of the shallow groundwater is extremely limited both horizontally and vertically (less than 1 cm per year). Site data from coal carbonization tar (present as NAPL) showed that it is immobile in the subsurface.[31] The flow patterns of the shallow groundwater vary and are likely influenced by the presence of local features, such as sumps and preferential flow pathways in the subsurface.

The surface soils on the MGP Site showed no evidence of source material or significant MGP-related contamination. Contamination from MGP-related impacts was observed in subsurface soils, groundwater and soil gas, with the highest concentrations of MAHs and PAHs detected in the immediate vicinity of on- and off-Site source material related to former MGP structures. Source material was mainly found in four areas: tar production and storage operations (*e.g.*, the tar well and former retort area on the Heartland property); tar transfer areas (*i.e.*, the pipes connecting various rail lines and near the two buried tanks in NP Avenue); areas associated with petroleum impacts (*i.e.*, the oil tank in the Heartland property northern parking lot); and drip oil sheens encountered near former structures (*e.g.*, drip pots).

A review of the vertical distribution of MGP impacts, as shown in the cross-sections in Figures 4.2a-4.5, confirmed that the impacts to soil and groundwater were mostly associated with source material (*e.g.*, B-HLA-14), with concentrations attenuating with lateral and vertical distance from the source area. For example, cross-section B-B' (Figures 4.3a and 4.3b) shows the impacts to soil, groundwater, and soil gas north-south through the Heartland property southern parking lot, including at boring B-HLA-14. However, the results for the deep samples collected from the north (B-HLA-45) and south (B-HLA-29) showed no NAPL observations and low to non-detect impacts at depth.

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[30] However, as described in Attachment F, there are discontinuous vertical fractures in the clay.
[31] The dynamic viscosity of NAPL collected from the Site was determined to be 117,000 centipoise at 70°F, relative to the dynamic viscosity of groundwater, which is approximately 1 centipoise at 70°F (Attachment C).

Consistent with the hydrogeological setting of the Site and the observations during the field investigations, the transport of MGP-related constituents in the subsurface is expected to be limited except along preferential pathways. The lateral off-Site extent of MGP-related impacts to soil and groundwater has been sufficiently delineated in all directions, and the limited subsurface migration potential of the contamination is evident from the rapid attenuation of MGP constituents, particularly in groundwater, with distance from the source material. Vertical delineation of impacts is not complete in all areas of the Site, but it is unlikely that contaminants would have migrated to depths approaching the groundwater aquifer located more than 100 ft bgs, given the lack of impacts observed in the investigation at depths of 50-60 ft bgs. The extent of the impacts are well-defined and located only in the subsurface above the groundwater aquifer (*i.e.*, in areas that are not generally accessible to the public).

5 Risk Evaluation Overview

This section provides an overview of the human health risk evaluation that was performed as part of the Site investigation. This risk evaluation was performed using well-established, conservative (*i.e.*, protective) US EPA guidance and protocols. Based on the results of this risk evaluation, there are no unacceptable risks to human health based on current conditions, as determined by the current dataset. There are, however, elevated risks associated with future potential exposures for a Utility Worker at the Heartland property and a Construction Worker at the Heartland, URI, City ROWs, and Historic Union properties. Consistent with the results of the April 2016 Preliminary Evaluation of the Vapor Intrusion Pathway and Comparative Analysis of Alternatives (Gradient, 2016), pre-emptive mitigation is still the preferred alternative to address the vapor intrusion pathway at the Heartland property. Supporting details, including detailed risk calculation methodologies, are provided in Attachment D.

5.1 Scope

The scope of the risk evaluation included all the properties that were investigated, except for the 1213 NP Avenue property, because MGP impacts were not identified at this property. The risk evaluation characterized priority[32] exposure pathways to evaluate whether these pathways present a risk to human health under current conditions. Priority pathways include:

- Exposure to surface soil for a current Resident at the Heartland property.
- Exposure to soil vapors potentially infiltrating residential and commercial buildings at the Heartland, URI, Historic Union, and Culligan properties.
- Exposure to shallow groundwater infiltrating basements at the Heartland property, for a Resident, and the Historic Union property, for a Maintenance Worker.

In addition, the risk evaluation characterized non-priority[33] exposure pathways for which data were collected during the Site investigation. These pathways include:

- Potential exposure to shallow soil (0-15 ft bgs) for a future Utility Worker and Construction Worker at the Heartland, URI, City ROWs, Historic Union, and Culligan properties.
- Potential exposure to groundwater (0-15 ft bgs) during future subsurface excavation for a future Utility Worker and Construction Worker at the Heartland, URI, City ROWs, Historic Union, and Culligan properties.

The exposure pathways evaluated as part of this risk evaluation are summarized in Table 5.1.

[32] Priority exposure pathways were defined as potentially complete exposure pathways for current property occupants.
[33] Non-priority exposure pathways consisted of potentially complete exposure pathways under reasonably foreseeable future use of the properties.

5.2 Methodology

The methodology used to characterize human health risks is consistent with US EPA guidance (*e.g.*, US EPA, 2014, 2004 Risk Assessment Guidance for Superfund [RAGS] Dermal Guidance); additional citations to specific and applicable US EPA guidance documents are provided throughout Attachment D).[34] Although much of this RI/FFS Report focuses specifically on potential MGP constituents (including DRO, GRO, PAHs, MAHs, cyanide), the risk evaluation characterizes potential exposures and human health risks associated with <u>any</u> contaminant that exceeds the screening criteria discussed below (*i.e.*, risk-based screening levels and background). It is therefore conservative in that it includes non-MGP constituents that were detected. The risk evaluation process used in this report is depicted in Figure 5.1.

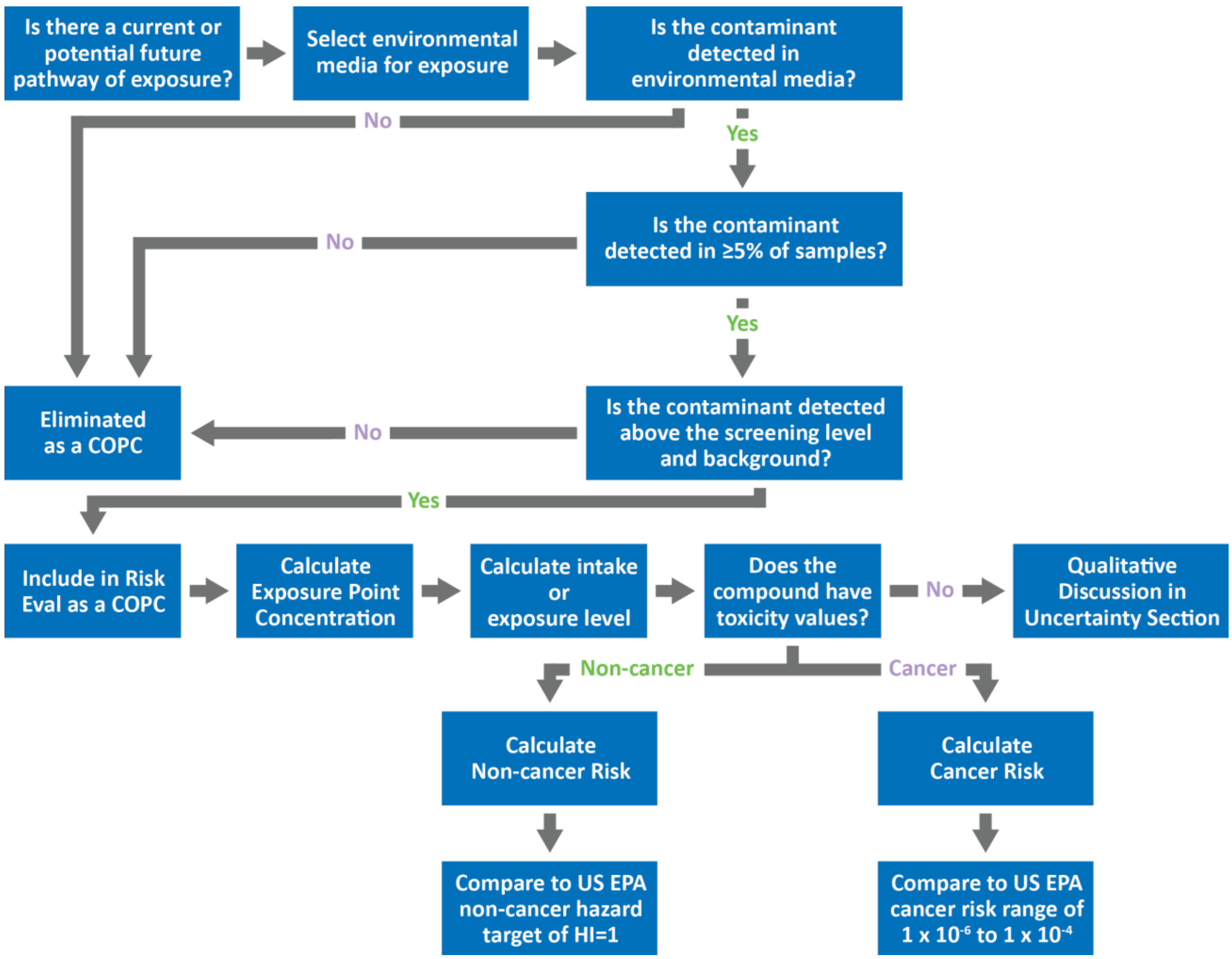

Figure 5.1 Risk Evaluation Decision Process

[34] It is common practice to use US EPA guidance and regulations absent state-equivalent guidance and regulations.

5.2.1 Data Management and Selection of Contaminants of Potential Concern

Data were selected for use in the risk evaluation with the objectives of being representative of current conditions and ensuring a complete and robust risk evaluation. Accordingly, the data used in the risk evaluation included all soil, sub-slab soil gas, exterior soil gas (where sub-slab soil gas were not available), groundwater data, and sump water, as appropriate, except when data were not included due to data quality or other issues as follows.

- Some surface soil data for the Heartland property collected in November 2015 and analyzed for cyanide were excluded from the risk evaluation due to analytical issues. Concentrations of total cyanide in the surface soils were non-detectable, which is consistent with the lack of field observation of oxide box waste during the investigation. However, free cyanide was unexpectedly detected in the absence of total cyanide detections in most soil samples, indicating laboratory analytical issues and non-cyanide interferences causing false positive results. Therefore, re-sampling and re-analysis was conducted in May 2016 to obtain valid free cyanide data for the Heartland property. Free cyanide data from these re-sampled surface soil locations were included in the risk evaluation.
- Surface soil data for the Heartland property collected in November 2015 for DRO C10-28 and TPH were also excluded from the current risk evaluation. Review of the correlations between TPH concentrations and tPAH concentrations indicates likely analytical interferences from non-hydrocarbon organic matter that was present in these samples. Therefore, these surface soil locations were re-sampled and re-analyzed using an SI method. A silica gel cleanup column was used to remove non-hydrocarbons prior to analysis. This step removes much of the biological oils that would add to the DRO, if they were not removed by the silica gel cleanup. The DRO with silica gel extraction cleanup method (DROSI) data were used in the risk evaluation.
- Four samples collected from shallow monitoring wells (MW-ROW-01S, MW-ROW-02S, MW-ROW-03S, and MW-ROW-04) in the City ROWs on June 28, 2016, were not included in the risk evaluation, because the data were not available at the time the risk evaluation was produced. These data are available in the Barr (2016g) Technical Memorandum. Each of these wells was previously sampled on November 12, 2015, and February 2, 2016. A review of the preliminary data for these four samples indicates that exclusion of the June 28, 2016, data would not result in the addition of any contaminants of potential concern (COPCs) or change the conclusions of the risk evaluation for any receptor in the City ROWs.
- Several VOCs were detected in six sub-slab soil gas samples collected from beneath the slab within the Storage and Former Pool Buildings of the Heartland property. Access to these buildings is limited. Due to the limited access, sub-slab soil gas data were compared to US EPA Vapor Intrusion Screening Levels (VISLs) that are appropriate for commercial exposure scenarios (US EPA, 2015). PCE (920 $\mu g/m^3$) detected in one sub-slab soil vapor sample from beneath the Former Pool Building (SS-HLA07) exceeded the US EPA VISL (520 $\mu g/m^3$). PCE is a non-MGP constituent and has not been detected in any shallow (0-15 ft bgs) soil samples on the Heartland property. The source of the PCE is unknown, but may be attributable to material stored in the pool area or contaminated fill used to backfill the former pool.

All other usable data were compared to risk-based screening levels and geographically appropriate background concentrations[35] to identify COPCs that required further investigation. Compounds with maximum concentrations above the risk-based screening levels and background were retained as COPCs

[35] Further details provided in Attachment G.

for the risk evaluation. However, compounds with a detection frequency of less than 5% were not retained as COPCs (US EPA, 1989a). If a measured concentration is below applicable screening levels, there is a negligible risk of adverse health effects; exceedance of a relevant screening level indicates that more analysis or investigation may be warranted, not that there is an unacceptable risk. The screening levels applicable to each medium, depth, and exposure scenario are discussed in the risk evaluation (Attachment D) and the screening level selection memorandum (Attachment E). These screening levels were presented previously in the Barr Technical Memoranda (Barr, 2015c-h; Barr, 2016g-l). Detailed summary statistics and screening results by exposure area and medium are presented in Tables 5.12a-5.16c.

Certain data were given special consideration in the COPC selection process, as follows.

- **Cyanide:** Cyanide associated with MGP sites is generally tightly bound as ferrocyanide complexes that generally do not release free cyanide. Therefore, the free cyanide analyses better represent the toxicologically available cyanide, and these were carried through the risk evaluation (Beck *et al.*, 2006). Free cyanide was not detected above screening levels in soil at the Heartland, URI, City ROWs, or Culligan properties.[36] Free cyanide was not detected above screening levels in groundwater at the Heartland, URI, City ROWs, or Culligan properties. Free cyanide was detected above screening levels in sump groundwater at the Historic Union property.
- **Petroleum Hydrocarbons:** Petroleum hydrocarbons in soil and groundwater were analyzed as DRO C10-28, GRO C6-C10, and TPH at all five properties. The DRO and GRO fractions, rather than TPH, were carried through the risk evaluation.
- **DRO:** The DRO dataset consists of a mixture of results from samples analyzed using a DRO analysis and samples analyzed using a DROSI method to remove non-hydrocarbons. A detailed discussion of the treatment of DRO data is provided in Section 5.2.3.

5.2.2 Quantification of Exposure

In a risk evaluation, an exposure point concentration (EPC) represents the concentration of a chemical in an environmental medium to which an individual may be exposed. Consistent with US EPA guidance, EPCs at each property comprising the former MGP Site were calculated for each COPC and represent the lower of either the 95% upper confidence limit on the mean (UCLM) (calculated using US EPA's ProUCL software) or the maximum detected concentration within the exposure area.

Exposure assumptions used to estimate exposure frequency (EF), duration, and intensity are consistent with current US EPA guidance. When appropriate, exposure parameters were based on property-specific considerations and professional judgment. The following assumptions for EF and exposure duration were applied to receptors evaluated in this risk assessment.

- The Utility Worker at all five properties was assumed to contact soil and groundwater for 10 days per year while performing maintenance or repair of subsurface utilities. The exposure duration for the Utility Worker was 25 years, which is an upper-bound estimate of time spent in one job (US EPA, 2014).
- The Construction Worker at all five properties was assumed to contact soil and groundwater during subsurface excavation for 250 days per year for 1 year. These values represent the estimated duration of a construction project.

[36] In soil samples collected from Historic Union, total cyanide was not detected and free cyanide was not analyzed.

- The child and adult Resident at the Heartland and Historic Union[37] properties were assumed to contact surface soil and indoor air for 350 days per year, accounting for 15 days spent away from the home. The residential exposure scenario assumes that the Resident will live in the Heartland Apartments or Historic Union residential buildings for 15 years (6 years as a child and 9 years as an adult). The exposure duration for the child Resident was 6 years, and the exposure duration for the adult Resident was 9 years, which are central tendency estimates for time spent at one residence (US EPA, 2004).
- At the Heartland property, the child and adult Resident were also assumed to contact groundwater infiltrating into the basement of Building A, where the common laundry room is located. It was assumed that groundwater infiltration would occur once per month; therefore the EF was 12 days per year.
- The Maintenance Worker at the Historic Union property and Office Worker at the URI, Historic Union, and Culligan properties was assumed to be exposed to indoor air for 250 days per year, assuming a 5-day work week for 50 weeks per year. The exposure duration was assumed to be 25 years, representing the duration of time spent in one job (US EPA, 2014).
- At the Historic Union property, the Maintenance Worker was also assumed to contact groundwater infiltrating into the building's basement while maintaining the sump pump. It was assumed that groundwater infiltration would occur once per month; therefore the EF was 12 days per year.

In addition to the above, US EPA-recommended values for soil ingestion rate (IR), inhalation rate, and skin surface area were used to estimate exposure intensity. These exposure assumptions were combined with the EPCs to calculate human intake levels. The primary source for the exposure equations used in the risk evaluation is the US EPA's RAGS (US EPA, 2014, 1989a).

5.2.3 Risk Calculations

The human intake levels, as presented above, were then combined with toxicity values to estimate cancer risk and non-cancer hazard. The toxicity values used were consistent with those used in the derivation of US EPA Regional Screening Levels (RSLs).

Cancer risks are characterized as the incremental probability that an individual will develop cancer during his or her lifetime due to chemical exposure to contaminants at the site under the specific exposure scenarios evaluated. The risks are calculated with the inputs for the exposure parameters that are described in Attachment D of this report. Cancer risks are expressed as a unitless probability (*e.g.*, 1 in 1 million, or 1×10^{-6}) of an individual developing cancer over a lifetime, above background risk, as a result of site-related exposures. US EPA has established a target cancer risk range of 1×10^{-6} to 1×10^{-4}; this is often referred to as an acceptable cancer risk range.

Risks from non-carcinogenic effects are expressed as hazard quotients (HQs) rather than probabilities. An HQ compares the calculated human intakes to toxicity values derived by US EPA. HQs were calculated for each receptor, exposure pathway, and COPC according to US EPA guidance (US EPA, 1989a). For each exposure route, HQs were summed across all COPCs to calculate a hazard index (HI). As per US EPA guidance, HIs were rounded to one significant figure, and HIs for the individual exposure pathways were rounded to two significant figures.

[37] The Resident at Historic Union is not expected to contact surface soil, because a minimum of 6 in of clean fill was assumed to be used for re-vegetation and landscaping during redevelopment of the Historic Union building.

US EPA considers an HI greater than 1 to exceed the target risk threshold. Because an HQ is simply a ratio of site exposures to reference exposure levels (reference doses [RfDs], reference concentrations [RfCs], *etc.*), HIs do not represent the probability that an adverse health effect will occur. An HI less than 1 suggests that exposures are likely to be without an appreciable risk of non-cancer effects during a lifetime. An HI greater than 1 indicates only that a potential may exist for adverse health effects. Unlike cancer risks, non-cancer HIs are not additive across different age groups for a Resident.

Detailed risk calculations for each of the five properties are presented in Attachment D.

5.2.4 Evaluation of Diesel Range Organics in Soil

The DRO dataset used in the risk evaluation consists of a combination of DRO data and DROSI data. As discussed earlier, DRO analysis with a silica gel cleanup method was used for soil samples collected in 2015 to remove non-hydrocarbons or biological oils. For the Heartland property, DROSI soil data were used in the risk evaluation. DROSI data collected at the Heartland property in November 2015 were replaced with DROSI data collected in May 2016, due to the analytical issues discussed earlier in this section. For the URI and City ROWs properties, data collected in 2015 were not analyzed with the SI method, while 2016 data were analyzed with the SI method. For the URI and City ROWs properties, both DRO and DROSI data are used in the risk evaluation. For the Historic Union property, data collected in 2015 were not analyzed with the SI method; therefore, only DRO data were used in the risk evaluation. For the Culligan property, data collected in 2016 were only analyzed with the SI method; therefore DROSI data were used in the risk evaluation.

For consistency, COPC screening was performed using screening levels associated with medium-range aliphatic hydrocarbons. Prior to performing the risk calculations, Gradient reviewed the laboratory chromatograms for DRO data in soil to identify the most appropriate toxicological surrogate to use at each of the five properties.

- Chromatograms from surface soil at the Heartland property in the 0-7 in depth interval were consistent with low PAH, urban background concentrations and aliphatic-like residuals; therefore, toxicity values associated with high aliphatic hydrocarbons were used in the risk evaluation.
- Chromatograms from soil collected in the 0-15 ft depth interval at the Heartland and URI properties were consistent with coal tar in the C10-18 range; therefore, toxicity values associated with medium-range aromatic hydrocarbons were used in the risk evaluation.
- Chromatograms from soil collected at the City ROWs, Historic Union, and Culligan properties were consistent with medium-range aliphatic hydrocarbons, therefore toxicity values associated with this range were used in the risk evaluation.

Table 5.2 summarizes the data and toxicity information used to evaluate risk from DRO at each of the five properties.

Table 5.2 Summary of Diesel Range Organic Analytic Data and Toxicity Information Used in the Risk Evaluation

Property	DRO	DROSI	Toxicity Surrogate Used in Soil Risk Calculations
Heartland (0-7 in bgs)		✔	Total Petroleum Hydrocarbon – Aliphatic High
Heartland (0-15 ft bgs)		✔	Total Petroleum Hydrocarbon – Aromatic Medium
URI	✔	✔	Total Petroleum Hydrocarbon – Aromatic Medium
City ROWs	✔	✔	Total Petroleum Hydrocarbon – Aliphatic Medium
Historic Union	✔		Total Petroleum Hydrocarbon – Aliphatic Medium
Culligan		✔	Total Petroleum Hydrocarbon – Aliphatic Medium

Notes:
DRO = Diesel Range Organics; DROSI = Diesel Range Organics with Silica Gel Extraction Cleanup; ft bgs = Feet Below Ground Surface; ROW = Right of Way; URI = United Refrigeration, Inc.

Gradient's review of chromatograms indicated that many samples analyzed for DRO and DROSI contained concentrations of PAHs that are also evaluated separately in the risk evaluation. To avoid double-counting the same detected constituents within the risk evaluation, the concentrations of these PAHs (2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene) were subtracted from the DRO and DROSI data to yield the "DRO-PAH" EPC for use in the risk evaluation. These PAHs were then evaluated as individual analytes. The resultant concentrations were then used to calculate soil EPCs at each property, using the methodology described in Section 5.2.2.

5.3 Results (by Property)

Table 5.3 summarizes the cancer risks and non-cancer hazards for all properties. Results are presented for each of the five properties individually below.

5.3.1 Heartland Apartments

Cancer risks and non-cancer hazards were assessed for the adult and child Resident[38] living in each of the three buildings at the Heartland property, as well as for the potential future Utility Worker and Construction Worker at the property. Pathways evaluated for the adult and child Resident included soil exposures, dermal contact with water from the sump located in the communal laundry room,[39] and inhalation of indoor air based on sub-slab or exterior soil gas. Pathways evaluated for the Utility and Construction Workers included soil exposures and dermal contact with shallow groundwater.

A preliminary evaluation[40] of the vapor intrusion pathway for the adult and child Resident at the Heartland property was submitted and accepted by NDDH in April 2016 and concluded that there are no unacceptable risks to human health based on current conditions (Gradient, 2016). Consistent with the results of the April 2016 Preliminary Evaluation of the Vapor Intrusion Pathway and Comparative Analysis of Alternatives (Gradient, 2016), pre-emptive mitigation is still the preferred alternative to address the vapor intrusion pathway at the Heartland property.

[38] Receptor populations (Resident, Construction Worker, Utility Worker, *etc*.) are capitalized as proper nouns, because they refer to the hypothetical receptor evaluated according to US EPA exposure scenarios.
[39] The sump is located in the laundry room in Apartment Building A, but the room is accessible to residents of all three buildings.
[40] This risk evaluation was considered preliminary because it was based on a limited dataset consisting of 16 samples from 14 locations. Completing the vapor intrusion evaluation in accordance with US EPA guidance would require the collection of additional soil gas samples (spatially and temporally).

The current risk evaluation confirms that the cancer risk and non-cancer hazard for the current adult and child Resident at the property are within US EPA's target risk range. Risks for the future Utility and Construction Worker at the property exceed US EPA's target risk range. Cancer risks and non-cancer hazards are summarized as follows.

Heartland Apartments Building A

Cancer risk for the Resident at Heartland Apartments Building A was 1×10^{-6}, which is within US EPA's target risk range of 10^{-6} to 10^{-4}. Non-cancer hazard for the adult and child Resident was 0.5, which is below US EPA's target HI of 1.

Table 5.4 Heartland Apartments Building A Resident Risk Summary

Receptor/Exposure Pathway	Adult Non-cancer Hazard	Child Non-cancer Hazard	Cancer Risk	Major Contributors
Incidental Ingestion of Soil	1.7E-05	1.8E-04	---	Diesel Range Organics, C10-C28
Dermal Contact with Soil	---	---	---	---
Inhalation of Particulates	---	---	---	---
Dermal Contact with Sump Water	---	---	---	---
Inhalation of Indoor Air (Sub-slab Soil Gas)[a]	4.6E-01	4.6E-01	1.4E-06	1,2,4-Trimethylbenzene; Naphthalene
Total Hazard or Risk:	**5E-01**	**5E-01**	**1E-06**	

Note:
(a) Sub-slab samples better represent the vapor intrusion pathway and were therefore used when available to evaluate risk (*i.e.*, Building A).

Heartland Apartments Building B

Cancer risk for the Resident at Heartland Apartments Building B was 2×10^{-5}, which is within US EPA's target risk range of 10^{-6} to 10^{-4}. Non-cancer hazard for the adult and child Resident was 0.9, which is below US EPA's target HI of 1.

Table 5.5 Heartland Apartments Building B Resident Risk Summary

Receptor/Exposure Pathway	Adult Non-cancer Hazard	Child Non-cancer Hazard	Cancer Risk	Major Contributors
Incidental Ingestion of Soil	1.7E-05	1.8E-04	---	Diesel Range Organics, C10-C28
Dermal Contact with Soil	---	---	---	---
Inhalation of Particulates	---	---	---	---
Dermal Contact with Sump Water	---	---	---	---
Inhalation of Indoor Air (Exterior Soil Gas)	9.0E-01	9.0E-01	1.7E-05	1,3-Butadiene
Total Hazard or Risk:	**9E-01**	**9E-01**	**2E-05**	

Heartland Apartments Building C

Cancer risk for the Resident at Heartland Apartments Building C was 1×10^{-6}, which is within US EPA's target risk range of 10^{-6} to 10^{-4}. Non-cancer hazard for the adult Resident was 0.09, which is below US EPA's target HI of 1.

Table 5.6 Heartland Apartments Building C Resident Risk Summary

Receptor/Exposure Pathway	Adult Non-cancer Hazard	Child Non-cancer Hazard	Cancer Risk	Major Contributors
Incidental Ingestion of Soil	1.7E-05	1.8E-04	---	Diesel Range Organics, C10-C28
Dermal Contact with Soil	---	---	---	---
Inhalation of Particulates	---	---	---	---
Dermal Contact with Sump Water	---	---	---	---
Inhalation of Indoor Air (Exterior Soil Gas)[a]	9.1E-02	9.1E-02	1.2E-06	1,3-Butadiene
Total Hazard or Risk:	**9E-02**	**9E-02**	**1E-06**	

Note:
(a) The non-cancer hazard index (HI = 0.089) was slightly lower in the preliminary risk evaluation than in the present risk evaluation (HI = 0.091) due an update of US EPA's ProUCL software, which was used to calculate the soil gas exposure point concentrations (Gradient, 2016). The HIs calculated in the preliminary and the present risk evaluation are both well below US EPA's target HI of 1.

Workers at Heartland Apartments

For a potential future Utility Worker at the Heartland property, cancer risk is 1.04×10^{-4}, which is slightly above US EPA's target risk range of 10^{-6} to 10^{-4}. The primary risk-driver for cancer risk for the Utility Worker is benzo[a]pyrene. Non-cancer hazard for the Utility Worker is 1.2, which is slightly above US EPA's target HI of 1. The primary contributor to non-cancer hazard is DRO. Elevated concentrations of DRO are generally concentrated in the southern parking lot area of the property (see Figure 3.6c).

For a potential future Construction Worker conducting subsurface excavation at the Heartland property, cancer risk is 1.04×10^{-4}, which is slightly above US EPA's target risk range of 10^{-6} to 10^{-4}. The primary risk-driver for cancer risk for the Construction Worker is benzo[a]pyrene. Non-cancer hazard for the Construction Worker is 30, which exceeds US EPA's target HI of 1. The primary contributors to non-cancer hazard are DRO, GRO, naphthalene, 2-methylnaphthalene, dibenzofuran, and benzene.

Table 5.7 Heartland Apartments Worker Risk Summary

Receptor/Exposure Pathway	Non-cancer Hazard	Cancer Risk	Major Contributors
Utility Worker			
Incidental Ingestion of Soil	3.7E-01	6.4E-05	Diesel Range Organics, C10-C28; Benzo[a]pyrene
Dermal Contact with Soil	5.7E-02	2.6E-05	2-Methylnaphthalene; Benzo[a]pyrene
Inhalation of Particulates	5.9E-01	8.9E-06	Diesel Range Organics, C10-C28; Naphthalene
Dermal Contact with Groundwater	1.8E-01	4.5E-06	Gasoline Range Organics, C6-C10; Benzene
Total Hazard or Risk:	**1E+00**	**1E-04**	
Construction Worker			
Incidental Ingestion of Soil	9.2E+00	6.4E-05	Diesel Range Organics, C10-C28; Benzo[a]pyrene
Dermal Contact with Soil	1.4E-00	2.6E-05	2-Methylnaphthalene; Benzo[a]pyrene
Inhalation of Particulates	1.5E+01	8.9E-06	Diesel Range Organics, C10-C28; Naphthalene
Dermal Contact with Groundwater	4.5E+00	4.5E-06	Gasoline Range Organics, C6-C10; Benzene
Total Hazard or Risk:	**3E+01**	**1E-04**	

5.3.2 United Refrigeration

Cancer risks and non-cancer hazards were assessed for the Utility Worker, Construction Worker, and Office Worker at the URI property. The risk evaluation indicates that there are no unacceptable risks for the Utility or Office Workers at this property.

For a potential future Construction Worker conducting subsurface excavation at the URI property, cancer risks are within US EPA's target risk range of 10^{-6} to 10^{-4}. Non-cancer hazard for the Construction Worker was 7, which is above the US EPA's target HI of 1. The primary contributors to the non-cancer hazard were DRO and GRO in soil, and GRO and benzene in groundwater. The highest concentrations of GRO were detected in samples from the southeastern corner of the URI property (see Figure 3.6c).

Table 5.8 United Refrigeration Risk Summary

Receptor/Exposure Pathway	Non-cancer Hazard	Cancer Risk	Major Contributors
Utility Worker			
Incidental Ingestion of Soil	3.4E-02	6.1E-07	Gasoline Range Organics, C6-C10; Arsenic
Dermal Contact with Soil	1.1E-03	9.8E-08	Arsenic
Inhalation of Particulates	8.0E-02	4.4E-07	Gasoline Range Organics, C6-C10; Naphthalene
Dermal Contact with Groundwater	1.8E-01	2.5E-06	Gasoline Range Organics, C6-C10; Benzene
Total Hazard or Risk:	**3E-01**	**4E-06**	
Construction Worker			
Incidental Ingestion of Soil	8.5E-01	6.1E-07	Gasoline Range Organics, C6-C10; Arsenic
Dermal Contact with Soil	2.9E-02	9.8E-08	Arsenic
Inhalation of Particulates	2.0E+00	4.4E-07	Gasoline Range Organics, C6-C10; Naphthalene
Dermal Contact with Groundwater	4.6E+00	2.5E-06	Gasoline Range Organics, C6-C10; Benzene
Total Hazard or Risk:	**7E+00**	**4E-06**	
Office Worker			
Inhalation of Indoor Air (Sub-slab Soil Gas)	1.9E-01	---[a]	1,2,4-Trimethylbenzene
Total Hazard or Risk:	**2E-01**	**---[a]**	

Note:

(a) The contaminants of potential concern (COPCs) that exceeded screening levels in sub-slab soil gas have non-cancer toxicity values, but no carcinogenic toxicity values available from US EPA (2016). Therefore, only non-cancer hazard was calculated for the Office Worker at the United Refrigeration, Inc. (URI) property.

5.3.3 City Rights of Way

Cancer risks and non-cancer hazards were assessed for the Utility Worker and Construction Worker conducting subsurface activities within the City ROWs. The risk evaluation indicates that there are no unacceptable risks for the Utility Worker in the City ROWs.

For a potential future Construction Worker conducting subsurface excavation in the City ROWs, cancer risks are within US EPA's target risk range of 10^{-6} to 10^{-4}. Non-cancer hazard for the Construction Worker was 6, which is above US EPA's target HI of 1. Primary contributors to the non-cancer hazard were GRO and naphthalene in soil and GRO in groundwater.

Table 5.9 City Rights of Way Risk Summary

Receptor/Exposure Pathway	Non-cancer Hazard	Cancer Risk	Major Contributors
Utility Worker			
Incidental Ingestion of Soil	4.6E-02	5.0E-05	Gasoline Range Organics, C6-C10; Benzo[a]pyrene
Dermal Contact with Soil	7.2E-03	2.1E-05	Naphthalene; Benzo[a]pyrene
Inhalation of Particulates	1.7E-01	2.3E-06	Diesel Range Organics, C10-C28; Naphthalene
Dermal Contact with Groundwater	5.5E-02	3.2E-07	Gasoline Range Organics, C6-C10; Ethylbenzene
Total Hazard or Risk:	**3E-01**	**7E-05**	
Construction Worker			
Incidental Ingestion of Soil	1.2E+00	5.0E-05	Gasoline Range Organics, C6-C10; Benzo[a]pyrene
Dermal Contact with Soil	1.8E-01	2.1E-05	Naphthalene; Benzo[a]pyrene
Inhalation of Particulates	4.3E+00	2.3E-06	Diesel Range Organics, C10-C28; Naphthalene
Dermal Contact with Groundwater	1.4E+00	3.2E-07	Gasoline Range Organics, C6-C10; Ethylbenzene
Total Hazard or Risk:	**7E+00**	**7E-05**	

5.3.4 Historic Union

Cancer risks and non-cancer hazards were assessed for the Utility Worker, Construction Worker, Office Worker, Maintenance Worker, and Resident at the Historic Union property. The risk evaluation indicates that there are no unacceptable risks for the Utility Worker, Office Worker, Maintenance Worker, or Resident at the Historic Union property.

For a potential future Construction Worker conducting subsurface excavation at the Historic Union property, cancer risks are within US EPA's target risk range of 10^{-6} to 10^{-4}. Non-cancer hazard for the Construction Worker was 2, which is above US EPA's target HI of 1. The primary contributor to the non-cancer hazard was GRO in soil. Elevated GRO in soil is primarily associated with two soil samples (B-UB03 and B-UB04) collected along the western border of the Historic Union property, near relic gas distribution piping (see Figure 3.6d).

Table 5.10 Historic Union Risk Summary

Receptor/Exposure Pathway	Non-cancer Hazard	Cancer Risk	Major Contributor
Utility Worker			
Incidental Ingestion of Soil	2.1E-02	2.9E-06	Gasoline Range Organics, C6-C10; Benzo[a]pyrene
Dermal Contact with Soil	5.7E-04	1.2E-06	Naphthalene; Benzo[a]pyrene
Inhalation of Particulates	7.3E-02	4.7E-7	Gasoline Range Organics, C6-C10; Naphthalene
Dermal Contact with Groundwater	2.6E-03	9.3E-09	Gasoline Range Organics, C6-C10; Benzene
Total Hazard or Risk:	**1E-01**	**5E-06**	
Construction Worker			
Incidental Ingestion of Soil	5.4E-01	2.9E-06	Gasoline Range Organics, C6-C10; Benzo[a]pyrene
Dermal Contact with Soil	1.4E-02	1.2E-06	Naphthalene; Benzo[a]pyrene
Inhalation of Particulates	1.8E+00	4.7E-07	Gasoline Range Organics, C6-C10; Naphthalene
Dermal Contact with Groundwater	6.5E-02	9.3E-09	Gasoline Range Organics, C6-C10; Benzene
Total Hazard:	**2E+00**	**5E-06**	
Office Worker			
Inhalation of Indoor Air	8.4E-04	8.0E-07	Chloroform
Total Hazard:	**8E-04**	**8E-07**	
Maintenance Worker			
Inhalation of Indoor Air	8.4E-04	8.0E-07	Chloroform
Dermal Contact with Groundwater	4.8E-03	2.6E-10	Manganese; Chloroform
Total Hazard:	**6E-03**	**8E-07**	
Resident			
Inhalation of Indoor Air (Sub-slab)	2.3E-01 (Adult) 2.3E-01 (Child)	4.8E-05	Isopropyl Alcohol; Chloroform
Total Hazard:	**2E-01**	**5E-05**	

5.3.5 Culligan

Cancer risks and non-cancer hazards were assessed for the Utility Worker, Construction Worker, and Office Worker at the Culligan property. The risk evaluation indicates that there are no unacceptable risks for any of the three receptors at the Culligan property.

Table 5.11 Culligan Risk Summary

Receptor/Exposure Pathway	Non-cancer Hazard	Cancer Risk	Major Contributors
Utility Worker			
Incidental Ingestion of Soil	5.0E-03	8.0E-07	Arsenic
Dermal Contact with Soil	8.0E-04	1.3E-07	Arsenic
Inhalation of Particulates	9.0E-06	2.1E-10	Arsenic
Dermal Contact with Groundwater	---	---	---
Total Hazard or Risk:	**6E-03**	**9E-07**	
Construction Worker			
Incidental Ingestion of Soil	1.2E-01	8.0E-07	Arsenic
Dermal Contact with Soil	2.0E-02	1.3E-07	Arsenic
Inhalation of Particulates	2.3E-04	2.1E-10	Arsenic
Dermal Contact with Groundwater	---	---	---
Total Hazard or Risk:	**1E-01**	**9E-07**	
Office Worker			
Inhalation of Indoor Air	3.6E-03	2.9E-06	Chloroform
Total Hazard or Risk:	**4E-03**	**3E-06**	

5.4 Uncertainties Associated with Risk Evaluation

The risk evaluation process involves multiple steps and assumptions, which contribute inherent uncertainties that affect the final risk estimates. Uncertainties may exist in numerous areas, including sample collection, laboratory analysis, derivation of toxicity values, and estimation of potential site exposures. The most important contributors to uncertainty in this risk assessment are discussed below. In light of these uncertainties, US EPA risk assessment methods promote a systemic bias towards overestimation of risk in order to be conservative.

Exposure Pathways

Several pathways are incomplete and were not quantitatively evaluated in the risk evaluation. Construction and Utility Workers were assumed to be exposed to groundwater *via* dermal contact only. Any incidental ingestion of groundwater while working in the subsurface would be expected to be very small and thus would have a negligible contribution to risk. Workers were not evaluated for inhalation of volatiles from groundwater, because volatiles are likely to disperse into ambient air and would have a negligible contribution to risk. Therefore, the exclusion of this pathway is not expected to change the overall conclusions of the risk evaluation.

COPC Selection

Chemicals were eliminated as COPCs during the screening evaluation (Attachment D, Table 2 series for each property). Maximum detected concentrations were compared against generic health-based screening criteria (*e.g.*, RSLs). Chemicals with concentrations below their respective screening criterion do not warrant further evaluation. US EPA (1989a) uses a screening evaluation to reduce the number of COPCs carried through the risk assessment, because in many cases, risks are driven by a handful of chemicals. Chemicals that were not identified as COPCs are not expected to be major contributors to risk, and the exclusion of these chemicals is not anticipated to change the conclusions of the risk assessment.

Exposure Frequency and Duration

Residents were assumed to be exposed to soil for 350 days per year. This EF does not account for grass, leaf, and snow covering (during the colder months), which would likely limit soil exposures in the Fargo, North Dakota, climate. Therefore, the risks may be lower than those estimated in this report.

For the Utility Worker, the exposure duration was 25 years, based on the 95th percentile duration that an individual stays at any one workplace (US EPA, 1991, 2014). This assumption overestimates exposures for most workers, because the median occupational tenure of the working population has been estimated to be 7.9 years for men and 5.4 years for women (US EPA, 2011).

The residential exposure scenario assumes that the Resident will live in a given exposure area for 15 years, including 6 years as a child and 9 years as an adult. It assumes that the Resident will ingest or touch soil and inhale dust from soil for 350 days per year, regardless of weather conditions, for 15 years. The use of these assumptions for each pathway may overestimate risk for a typical Resident.

Soil Ingestion Rates

The exposure factors used in the risk assessment generally represent high-end "upper percentile" (*e.g.*, 90th or 95th percentile) exposure factors. High-end IRs (100 and 200 mg/day, the 90th percentile) were applied for year-round exposure (350 days/year); however, soil IRs will likely be lower in winter months, when people spend less time outdoors. Data analyzed by US EPA indicates that soil intake decreases by 6-55% on poor weather days, when children are more likely to stay inside, compared with good weather days (US EPA, 1994). Data regarding hand-to-mouth events, which are a primary mechanism by which soil is ingested, indicates that hand-to-mouth frequency is significantly greater indoors than outdoors (US EPA, 2012). Therefore, risks evaluated with the high-end soil IRs for year-round exposure may overestimate risks. For example, a recent reanalysis of previous soil ingestion studies estimated a mean of 26 mg/day for children, with an estimated 95th percentile of 79 mg/day (Stanek *et al*., 2012a,b).

Construction and Utility Workers were assumed to incidentally ingest 330 mg of soil per day. US EPA recommended the IR of 330 mg/day for a Construction Worker for their soil screening level guidance (US EPA, 2002b), based on a study by Stanek *et al*. (1997), who noted that the 95th percentile soil IR of 330 mg/day is substantially uncertain. The most current Exposure Factors Handbook (US EPA, 2011) did not acknowledge this study as a key or secondary study for soil and dust IRs. Therefore, using this high-end IR may overestimate risks for Construction and Utility Workers.

Compounds Not Assessed in the Risk Evaluation

Cancer risks and non-cancer hazards were not calculated for ethyl alcohol due to a lack of published toxicity values. Ethyl alcohol was detected at concentrations ranging from 3.5-240 $\mu g/m^3$ in exterior and sub-slab soil vapor at the Heartland, URI, Historic Union, and Culligan properties.

Risks from inhalation of trichlorofluoromethane were not evaluated because US EPA no longer provides an inhalation RfC for this compound (US EPA, 2016). Trichlorofluoromethane was detected at concentrations ranging from 2.5-23,000 $\mu g/m^3$ in sub-slab soil vapor at the Heartland, URI, Historic Union, and Culligan properties.

If these unevaluated compounds and/or pathways contribute to risk, then the risks presented in the risk evaluation could be underestimated.

Dermal Absorption

For organic compounds in water, US EPA uses a mathematical model to predict absorption from exposures to water. Compounds for which there are sufficient data to predict dermal absorption with acceptable confidence are said to be within the model's effective predictive domain (EPD). There is significant uncertainty associated with the evaluation of dermal absorption for highly lipophilic chemicals that fall outside the EPD. Therefore, dermal risks were not calculated for COPCs in groundwater that are outside the EPD based on US EPA's mathematical model for calculating absorbed dose; these COPCs generally include DRO and several PAHs. US EPA (2004a) noted that chemicals outside the EPD may not be absorbed before desquamation (or shedding) of the skin. Dermal risks contribute a relatively small proportion of the overall risk compared to soil exposures. Therefore, although addition of dermal risk for chemicals outside the EPD would result in a small increase in risk, but this is not expected to change the overall conclusions of the risk evaluation.

6 Focused Feasibility Study

6.1 Remedial Action Objectives

The purpose of remedial action at the Fargo MGP Site is to protect human health and the environment from exposure to potential MGP constituents, which may be present as NAPL, and in soil, groundwater, and soil gas at the MGP Site and in its vicinity. Remedial Action Objectives (RAOs) are medium-specific goals that guide the remedy evaluation and selection process to specific endpoints that ensure protectiveness.[41] RAOs for the Fargo MGP Site have been developed based on relevant US EPA and NDDH guidance (*e.g.*, US EPA, 1988, 1989b, 1995) and Site-specific factors based on the results of the comprehensive Site investigation and human health risk evaluation for the media of concern – source material (NAPL and impacted soils), surface and subsurface soil, groundwater, and soil gas.

Overall, the Site investigation and risk assessment results show that MGP impacts are well defined and that there are relatively few human health exposure pathways of concern based on current or reasonably anticipated land and water use. The Site-specific factors relevant to the RAOs are described in Table 6.1.

Accordingly, the RAOs for the Fargo MGP Site are as follows.

- **Surface Soil, Subsurface Soil, and Groundwater:** Control the potential for direct exposure to impacted soil and/or impacted groundwater at levels that may pose unacceptable human health risks to current and future potential receptors based on reasonably anticipated land use (*i.e.*, prevent exposure to chemicals posing an HI of >1 and a lifetime excess cancer risk of $>1 \times 10^{-6}$ for individual carcinogens or $>1 \times 10^{-5}$ for multiple carcinogens).
- **Source Material (NAPL and Heavily Impacted Soil):** Reduce the mass, volume, and/or mobility through treatment or removal and off-Site disposal, as practicable based on property-specific conditions. This will, in turn, help achieve attenuation and stability of the groundwater and soil gas impacts (see below). Achieve attenuation and stability of subsurface NAPL.
- **Groundwater:** Achieve attenuation and stability of impacted groundwater associated with MGP source material.
- **Soil Gas:** As necessary, protect potential receptors from exposure to potential MGP constituents that may pose human health risk *via* the vapor intrusion pathway. Achieve attenuation and stability of impacted soil gas associated with potential MGP source material and impacted groundwater.

In turn, risk-based CUGs and Not to Exceed values (NTE) have been established for each property that has been investigated (Heartland, URI, City ROWs, Historic Union, Culligan, discussed in Section 6.2). In accordance with the RAOs, these risk-based goals, the presence of NAPL, and the presence of heavily impacted soil (*i.e.*, with concentrations exceeding 10,000 mg/kg) were the criteria used to identify locations to target for remediation, as shown in Figure 6.1. Other factors, such as current and future

[41] "Remedial action objectives consist of medium-specific or operable unit-specific goals for protecting human health and the environment. The objectives should be as specific as possible but not so specific that the range of [remedial] alternatives that can be developed is unduly limited" (US EPA, 1988).

property use, and logistical constraints (*e.g.*, the location and integrity of buildings and urban infrastructure; receptor proximity) also guided remedy selection at each property.

Table 6.1 Site-specific Factors for RAO Determination

Site-specific Factor	Description
Nature of Release	It appears that the releases may have occurred as subsurface leaks and/or spills of NAPLs (tar and drip oil). Weathering has reduced potential NAPL mobility.
Nature and Extent of Contamination	There is focalized source material (NAPL and impacted soil) at shallow depths in certain areas (primarily in and around former MGP units in the southern parking lot at the Heartland property), stringers of residual NAPL at intermediate depths, and the presence of more soluble and volatile constituents in water and soil vapor, respectively, from the NAPL. These impacts are located at the MGP Site and at some off-Site properties.
Hydrogeological Features	Subsurface geology within the impacted area is dominated by low-permeability silts/clays with limited horizontal and vertical transport potential. The low transmissivity of the silts and clays precludes potable water use, limits fluid migration (vapor, water, and NAPL), and also limits the potential for certain remediation alternatives that rely on distribution or recovery of fluid through interconnected pore space (*e.g.*, groundwater extraction, *in situ* chemical oxidation).
Current and Reasonably Anticipated Land Use[a]	The MGP Site and its vicinity consists of an urban area occupied by a mixture of commercial, residential, and transportation uses (*i.e.*, parking lots, sidewalks, and roads). While land use within the areas is not anticipated to change, there are several redevelopment initiatives in the area that will likely involve earthworking activities. Current physical attributes, such as the structural stability of existing buildings and the presence of underground infrastructure (*e.g.*, piping), as well as the potential for short-term community exposures to chemical vapors and dust could pose significant implementation challenges for certain remediation alternatives, such as full source removal.
Groundwater Use	There is no potable water use within the impacted area. The low transmissivity of the shallow silts and clays precludes potable water use and the results of a well search show that the deeper aquifer in this area is not used as a potable water source.
Exposure Pathways	The primary human exposure pathways consist of: ▪ Direct contact with exposed surface soil (current and future use). ▪ Direct contact with NAPL, impacted soil, and/or groundwater during construction and maintenance activities (future use). ▪ Vapor intrusion into buildings overlying source material and/or impacted media (current and future use).

Notes:
MGP = Manufactured Gas Plant; NAPL = Non-aqueous Phase Liquid; RAO = Remedial Action Objective.
(a) "Remedial action objectives developed during the RI/FS should reflect the reasonably anticipated future land use or uses" and "Future land use assumptions allow the baseline risk assessment and the feasibility study to be focused on developing practicable and cost effective remedial alternatives" (US EPA, 1995).

6.2 Risk-based Cleanup Goals

In risk-based cleanups, the clean-up goal (CUG) is the post-remediation target concentration that will achieve risks within US EPA's target risk range (HI of 1 or cancer risk of 10^{-6} to 10^{-4}). For the Fargo MGP Site, CUGs were calculated for risk-drivers at each property that comprises the MGP Site and its vicinity. Risk-drivers were defined as any compound that contributed significantly (*i.e.*, individual HI of >0.5 or cancer risk of >10^{-5}) to an exceedance of the US EPA target risk range for a particular receptor and exposure pathway. The primary risk-drivers for the Fargo MGP Site are DRO, GRO, PAHs

(2-methylnaphthalene, naphthalene, benzo[a]pyrene), benzene, and dibenzofuran, as listed by exposure area in Table 6.2a. For each risk-driver, a post-remediation target 95% UCLM concentration was identified that would achieve an individual compound HI of <0.5 and a cancer risk of $\leq 10^{-6}$. This target 95% UCLM is the CUG that is to be achieved on average.

Because of the underlying risk assessment assumptions of human exposure to contamination, the CUG for each contaminant represents an average over the area of concern. Sampling data for each property comprising the Site and its vicinity shows that there is a distribution of many different concentrations of each contaminant (*i.e.*, a "data distribution"). If the central tendency of this data distribution (*e.g.*, the 95% UCLM concentration of a contaminant) is higher than the target concentration (the CUG), then remedial action is warranted.

To ensure that the CUG is met on average, a Not to Exceed (NTE) value can also be determined for each risk-driving chemical. These NTE values represent upper-end values of the data distribution that will satisfy the requirement that CUGs are met on average. These NTE values are used to define target remediation areas by comparing the NTE value to individual sampling results (which cannot be done using a CUG that is based on some type of average).[42] The NTE approach and applicability for remediation has been accepted by US EPA as consistent with US EPA guidance and policy to ensure protectiveness at many sites.[43]

Preliminary NTE values for each risk-driving chemical were calculated using Gradient's Confidence Response Goal (CRG) software tool[44] for each primary risk-driver identified in the risk evaluation. These NTEs were further evaluated by removing data points exceeding the NTEs and recalculating the 95% UCLM to determine compliance with the CUG. In cases in which the preliminary NTE was not sufficient to achieve the CUG, additional data points were removed from the dataset, in order from highest to lowest, until the calculated 95% UCLM was less than the CUG. These final NTE values are presented in Table 6.2b.

The available soil and groundwater data[45] for each property were compared to the calculated NTE values to identify locations to target for remediation (Figure 6.1). In accordance with the RAOs, the presence of NAPL and heavily impacted soil were the other main criteria used to define locations to target for remediation (Figure 6.1).

6.3 Preliminary Screening of Remedial Technologies

A preliminary screening of a robust set of remedial technologies and process options was performed to identify the remedial technologies that were retained for the development of remediation alternatives for the properties that comprise the MGP Site and its vicinity. Table 6.3 presents the preliminary screening matrix for each of the media of concern: exposed surface soil, source material (NAPL and heavily impacted soil), groundwater, and soil gas. The matrix includes a list of viable remedial technologies and process options, a description of each remedial technology, and the rationale for selecting or rejecting the same. The factors that influenced the selection of remedial technologies, as discussed in the screening matrix, included the nature of contamination (MGP tar and related contaminants of concern [COCs]), the

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[42] If all values above a CUG were targeted for remediation, the new, post-remediation average would be significantly lower than the CUG. This is because the remaining data distribution would have no data above the CUG and many data below it, thus leading to a new average that must necessarily be below the CUG.
[43] For example, the Fields Brook Superfund Site, Lower Fox River and Green Bay Superfund Site (WDNR, 2002; US EPA, 1997; US EPA Region V, 2010).
[44] Refer to Bowers *et al*. (1996) for further details regarding this software tool and the underlying statistical approach.
[45] Excluding samples that have already been removed (*e.g.*, within the excavation limits depicted on Figure 3.1a).

depth and extent of impacts, current and future land use, aquifer properties, logistical considerations, such as the presence of buildings and underground debris/structures, and the RAOs for the Site. Each remedial technology was evaluated in the context of these various factors and either retained or rejected for the development of remediation alternatives.

6.3.1 Exposed Surface Soil

The remedial technologies that were considered for the remediation of source material at the MGP Site belonged to the following general response categories: no further action, removal action, physical containment, and institutional controls. One process or technology for each category (*e.g.*, for physical containment, placement of a low-permeability cap) was retained for its implementability, ability to eliminate or control direct exposure to contaminated soil, and to limit the contaminant flux from surface soil to other media (Table 6.3).

6.3.2 Source Material

The remedial technologies that were considered for the remediation of source material at the MGP Site belonged to the following general response categories: no further action, removal action, physical containment, *in situ* treatment, and institutional controls.

Based on the results of the preliminary screening analysis (Table 6.3), remedial technologies such as excavation and off-Site disposal/treatment, placement of low-permeability cap, and institutional controls were retained for their implementability, their ability to eliminate or control direct exposure to source material, and their ability to limit the contaminant flux from the source material to groundwater and soil gas. Some technologies, such as NAPL recovery and *in situ* solidification and stabilization (ISS), were retained for further consideration as viable options because of their potential to achieve RAOs, but with an acknowledgment that there are implementability issues that could hinder their effectiveness.

6.3.3 Groundwater

The remedial technologies that were considered for the remediation of groundwater at the MGP Site belonged to the following general response categories: no further action, monitored natural attenuation (MNA), groundwater extraction and treatment, *in situ* treatment, and institutional controls (Table 6.3).

Given that the low permeability of the native soils limits lateral and vertical migration of impacted groundwater, the zone of influence of a groundwater extraction system will also be limited. The low permeability of the native soils would also preclude the effective delivery and distribution of amendments that is critical to the success of *in situ* technologies, such as *in situ* chemical oxidation (ISCO) and enhanced bioremediation. Thus, groundwater extraction and treatment and *in situ* technologies were not retained for further consideration. In comparison, MNA and institutional controls were retained for development of remediation alternatives, because they would, if used in concert with each other, enable long-term monitoring of contaminant stability and attenuation, while also controlling the potential for direct exposure to impacted groundwater.

6.3.4 Soil Gas

The remedial technologies that were considered for the remediation of soil gas at the MGP Site belonged to the following general response categories: no further action, MNA, *in situ* treatment, and institutional controls (Table 6.3).

Based on the results of the preliminary screening analysis, no further action was retained for properties where no significant risks associated with the vapor intrusion pathway were identified. Of the *in situ* treatment technologies, soil vapor extraction (SVE) was rejected because of the challenges associated with the low permeability and heterogeneities of the formation, while vapor mitigation was retained because it would effectively eliminate the vapor intrusion pathway at properties where it poses a potential risk to human health. Further, MNA and institutional controls were retained for the development of remediation alternatives because they would, if used in concert with each other, enable long-term monitoring of contaminant stability and attenuation, while also controlling the potential for direct exposure to impacted soil gas.

As described in the Preliminary Evaluation of the Vapor Intrusion Pathway and Comparative Analysis of Alternatives (Gradient, 2016), submitted to NDDH on April 1, 2016, preemptive mitigation is the preferred alternative to address the vapor intrusion pathway at the Heartland property because it: provides the highest level of certainty regarding human health protection, is readily implementable using existing technology, is less disruptive and faster to implement than repeated vapor sampling in multiple tenant units, provides the most certain outcome, and is similar in cost to the further vapor sampling with contingent mitigation alternative.

Table 6.3 Preliminary Screening of Remedial Technologies

Medium	General Response Category	Process/Technology	Description	Retained as Viable Option	Rationale	Notes
Exposed Surface Soil	No Further Action	N/A	Provides a baseline for comparison.	Yes	May be effective in achieving RAOs at certain properties.	N/A
	Removal Action	Excavation and Off-Site Disposal/ Treatment	Removal and off-Site disposal/treatment of exposed surface soil.	Yes	Eliminates direct contact exposure pathway.	N/A
	Physical Containment	Low Permeability Cap	Placement of a low permeability (*e.g.* , asphalt) cap over exposed surface soil.	Yes	Mitigates direct contact-related risks and reduces contaminant mass flux associated with leaching into the groundwater.	Institutional controls will likely be required to ensure long-term protectiveness.
	Institutional Controls	N/A	Administrative/legal controls that help minimize the potential for exposure to contamination	Yes	Minimizes exposure to contamination and protects the integrity of a response action.	N/A
Source Material (NAPL and Heavily Impacted Soil)	No Further Action	N/A	Provides a baseline for comparison.	Yes	May be effective in achieving RAOs at certain properties.	N/A
	Removal Action	Excavation and Off-Site Disposal/ Treatment	Removal and off-Site disposal/treatment of NAPL and impacted soil in potential MGP source areas.	Yes	Mitigates direct contact-related risks and stabilizes MGP-related groundwater and vapor impacts.	This approach has implementability challenges (*e.g.* , presence of buildings and active parking lots, NAPL mixed with debris) and short-term impacts (*e.g.* , odors, increased traffic).
		NAPL Recovery	Targeted extraction of NAPL *via* extraction well(s) or collection trench/drain, and *ex situ* treatment and/or disposal of extracted NAPL.	Yes	This approach would allow removal of source material from the subsurface if performed in a targeted manner.	Implementation is likely to be challenging due to the presence of buildings and subsurface structures. Furthermore, the low permeability of the formation and presence of debris with the NAPL will likely limit the NAPL recovery zone and result in short-circuiting, especially considering the low viscosity of NAPL. A small-scale pilot study could evaluate viability
		Surfactant/Solvent Flushing	Enhanced NAPL removal is achieved by flushing the source zone with chemical additives, such as surfactants and cosolvents. The injected chemicals enhance NAPL mobility by either increasing dissolution (solvents) or reducing viscosity (surfactants). The mobilized NAPL is recovered *via* an active recovery system.	No	The need to deliver and cycle fluids through a target zone in a low permeability formation in a reasonable period of time and the potential for induced migration of NAPL greatly limits the application of this technology at the MGP Site.	N/A
	Physical Containment	Shallow Soil Removal and Restoration	Replace upper soil column (*e.g.* , upper 2 ft of soil) in potential MGP source areas and restore surface cover (*e.g.* , repave parking lot).	Yes	Mitigates potential for future exposure *via* direct contact.	Institutional controls will likely be required to ensure long-term protectiveness.
		Subsurface Barrier	Containment of potential MGP source areas *via* a subsurface barrier (*e.g.* , slurry wall) with potential NAPL/groundwater extraction within the containment zone.	No	The implementation of this technology will be highly challenging and cost-prohibitive, given the presence of buildings and subsurface structures on-Site. Site soils are low-permeability, so this remedy is not well suited to the Site regardless of other complications. Further, the configuration and location of off-Site source areas (pipe at Historic Union and gas holder at United Refrigeration building) would not be compatible with the use of this remedy technology.	N/A
	In Situ Treatment	*In Situ* Chemical Oxidation (ISCO)	Delivery and distribution of chemical oxidants, such as hydrogen peroxide, sodium permanganate, ozone, *etc.* to chemically transform MGP related constituents into innocuous end products.	No	ISCO may be able to destroy some of the MGP-related constituents, but a treatability study would be needed to determine the strength and type of oxidants that would be effective at the Site. Further, effective delivery and distribution of the oxidants will be severely impeded by the low permeability clay in the Site formation and the presence of debris mixed with the NAPL. The presence of buildings, active parking lots, and subsurface structures in the source areas could pose additional implementation challenges.	N/A
		In-Situ Solidification/ Stabilization (ISS)	*In situ* blending of treatment reagents, such as cement and polymers, to immobilize source material and mitigate the leaching of MGP constituents into groundwater.	Yes	ISS is a viable source treatment remedy that could encapsulate mobile NAPL in the subsurface and reduce contaminant mass flux from the source area; however, the implementability challenges associated with the presence of buildings, active parking lots, subsurface structures, and NAPL mixed with debris would apply to this remediation option as well. Further, a treatability study would be needed prior to field-scale implementation.	Institutional controls will likely be required to ensure long-term protectiveness. Could provide structural support for future redevelopment (if any).
		Enhanced *In Situ* Bioremediation (EISB)	Promoting conditions in the subsurface by delivering electron donors, electron acceptors, nutrients, and/or microbes to enhance the microbial degradation of COCs to innocuous end products. Aerobic bioremediation would be the appropriate approach to treat tar-related COCs.	No	EISB is not an effective source treatment technology, because elevated source concentrations would inhibit microbial growth.	N/A
		Soil Vapor Extraction (SVE)	Application of vacuum to the vadose zone in the source area to facilitate volatilization and recovery of the volatile contaminants in the subsurface.	No	SVE is not a viable source treatment option because the low permeability of the Site formation could greatly limit the radius of influence of the SVE wells and likely result in short-circuiting. Furthermore, SVE will not address the numerous low volatility constituents of MGP tar (*e.g.* , PAHs).	N/A
		Thermal Treatment	Application of thermal energy to source material or contaminated soil through a variety of techniques to destroy, volatilize and/or mobilize contaminant mass. Contaminant vapors and mobilized NAPL would have to be effectively captured and treated.	No	Thermal treatment is a viable destruction method for MGP tar and impacted soils; however, if not properly captured, mobilized NAPL could migrate to unimpacted areas and exacerbate conditions. Furthermore, clay subsidence could be a detrimental side effect of thermal treatment, and regional climate factors could result in high energy costs.	N/A
	Institutional Controls	N/A	Administrative/legal controls that help minimize the potential for exposure to contamination	Yes	Minimizes exposure to contamination and protects the integrity of a response action.	N/A

Table 6.3 Preliminary Screening of Remedial Technologies

Medium	General Response Category	Process/Technology	Description	Retained as Viable Option	Rationale	Notes
Groundwater	No Further Action	N/A	Provides a baseline for comparison.	Yes	May be effective in achieving RAOs at certain properties.	N/A
	Monitored Natural Attenuation (MNA)	Sampling and Chemical Analysis	Monitoring and quantitative documentation of the attenuation of dissolved phase contamination due to naturally occurring processes, such as degradation, dilution, dispersion, and advection.	Yes	MNA is an effective way to monitor the long-term stability and attenuation of groundwater impacts.	Institutional controls that limit exposure to groundwater may be required to ensure long-term protectiveness.
	Groundwater Extraction and Treatment	Pump and Treat (P&T)	Pumping of groundwater to induce flow to an extraction well or collection trench/drain and *ex situ* treatment and disposal of extracted groundwater.	No	P&T is not a viable groundwater remediation option, mainly because the low permeability of the formation could greatly limit the radius of influence of the extraction wells and likely result in short-circuiting. Furthermore, the timeframe needed to achieve RAOs in such a formation would be only marginally shorter, if at all, in comparison to MNA and would not justify the higher cost and O&M requirements associated with a P&T system.	N/A
	In Situ Treatment	*In Situ* Chemical Oxidation (ISCO)	Delivery and distribution of chemical oxidants, such as hydrogen peroxide, sodium permanganate, and ozone, to facilitate the chemical oxidation of COCs to innocuous end products, such as carbon dioxide and water.	No	Although ISCO is capable of destroying some of the MGP-related constituents, it will not be considered as a remedial option for the groundwater impacts, because effective delivery and distribution of the oxidants will be severely impeded by the low permeability clay in the Site formation. The presence of buildings, active parking lots, and subsurface structures in the source areas could pose additional implementation challenges.	N/A
		Multi-Phase Extraction (MPE)	MPE is the combined extraction of liquid and soil vapor from the vadose and saturated zones using a variety of configurations that combine liquid extraction and vacuum application	No	MPE is not a viable remediation option because the low permeability and heterogeneities of the Site formation will greatly limit the radius of influence of the extraction system and likely result in short-circuiting.	N/A
		Enhanced *In Situ* Bioremediation (EISB)	Promoting conditions in the subsurface by delivering electron donors, electron acceptors, nutrients, and/or microbes to enhance the microbial degradation of COCs to innocuous end products. Aerobic bioremediation would be the appropriate approach to treat the tar-related COCs.	No	Although some of the key MGP-related constituents, such as benzene and naphthalene, are amenable to aerobic biodegradation, the challenges associated with the effective delivery and distribution of EISB amendments in a low permeability formation would impede the effectiveness of this technology.	N/A
		Thermal Treatment	A variety of techniques can be used to apply heat to source material or contaminated soil to destroy, volatilize, and/or mobilize contaminant mass. Contaminant vapors and mobilized NAPL would have to be effectively captured and treated.	No	Thermal treatment is a viable option for the destruction of MGP constituents in groundwater. However, factors, such as the high temperature needed to destroy non-volatile constituents of MGP tar (*e.g.* , PAHs), the potential for NAPL mobilization to unimpacted areas, high energy costs associated with regional climate factors, and the potential for clay subsidence make this technology a poor remediation option.	N/A
	Institutional Controls	N/A	Administrative/legal controls that help minimize the potential for exposure to contamination	Yes	Minimizes exposure to contamination and protects the integrity of a response action.	N/A
Soil Gas	No Further Action	N/A	Provides a baseline for comparison.	Yes	May be effective in achieving RAOs at certain properties.	N/A
	Monitored Natural Attenuation (MNA)	Sampling and Chemical Analysis	Monitoring and quantitative documentation of the attenuation of vapor phase contamination due to naturally occurring processes, such as degradation, dilution, dispersion, and advection.	Yes	Particularly in conjunction with a source control remedy, MNA is an effective way to monitor the long-term stability of the soil gas impacts, which is limited in extent and attenuates with distance from the source.	Institutional controls may be required to ensure long-term protectiveness.
	In Situ Treatment	Soil Vapor Extraction (SVE)	Application of vacuum to the vadose zone to facilitate volatilization and recovery of the volatile contaminants in the subsurface.	No	Not likely to be effective at preventing exposure *via* the vapor intrusion pathway due to the distributed nature of the source material and low permeability and heterogeneities of the Site formation.	N/A
		Vapor Mitigation System	Sub-slab or sub-membrane depressurization system designed to lower air pressure under relative to indoor air pressure and prevent migration of soil vapors into the building.	Yes	This is a widely used and effective vapor intrusion mitigation strategy that can reduce risks by eliminating the exposure pathway.	N/A
	Institutional Controls	N/A	Administrative/legal controls that help minimize potential for exposure to contamination.	Yes	Minimizes exposure to contamination and protects the integrity of a response action.	N/A

Notes:
COC = Contaminant of Concern; MGP = Manufactured Gas Plant; N/A = Not Applicable; NAPL = Non-Aqueous Phase Liquid; O&M = Operations and Maintenance; PAH = Polycyclic Aromatic Hydrocarbon; RAO = Remedial Action Objective.

6.4 Development of Remediation Alternatives

Remediation alternatives were developed for each of the five properties that comprise the MGP Site and its vicinity using a combination of remedial technologies that were retained in the preliminary remedial screening matrix. The key components (*e.g.*, source removal, NAPL extraction, removal/grouting of piping) of the remediation alternatives for each property were selected mainly based on the nature, magnitude, and extent of contamination encountered during the two phases of environmental investigations and the potential risks to human health identified for each property in the risk assessment. Other factors, including property access, the potential for future redevelopment, and logistical constraints (such as the presence of occupied buildings and active parking lots) also influenced the development of the remediation alternatives and dictated the need for and type of engineering and institutional controls.

The remedial alternative matrices developed for each of properties are presented in Tables 6.4a-e. The range of remediation alternatives for each property generally included a baseline option of no further action; source removal options for source material and surface soil (as applicable) remediation; piping removal/grouting to eliminate preferential pathways; MNA or no further action for groundwater impacts; vapor mitigation, MNA, or no further action for soil gas impacts; and engineering and institutional controls to limit exposures and manage residual risks. Due to the relative abundance of NAPL and heavily impacted media on the Heartland property in comparison to the other properties evaluated, additional source remediation options such as NAPL extraction and ISS were included in the range of remediation alternatives for the Heartland property.

The range of remediation alternatives for each property is presented as follows. Remediation depths will be further refined in the remedial design phase and will be based on actual conditions encountered in the field.

Heartland Apartments

The remediation alternatives for the Heartland property (Table 6.4a) include source removal of identified impacts and structures/debris up to 15 ft bgs, targeted source removal of source material and structures/debris to the extent possible up to 12 ft bgs, targeted extraction and off-Site treatment or disposal of NAPL, ISS of source material up to 12 ft bgs, excavation and off-Site disposal of the upper 2 ft of soil in the parking lots, institutional/engineering controls, and the baseline option of no further action.

Other components of the remediation alternatives, as summarized in Table 6.4a, include piping removal/grouting to eliminate preferential pathways, MNA or no further action for groundwater impacts, vapor mitigation or no further action for soil gas impacts, and engineering and institutional controls to limit exposures and manage residual risks. The remediation alternatives were developed based on the current property configuration. If the existing buildings were removed, the overall remedial approach would remain similar, but additional excavation underneath the buildings' footprints would be undertaken. A vapor mitigation system would be required for a future occupied building, unless otherwise approved by NDDH, and the other components of the remediation alternative would remain the same. This remedial scenario was not carried forward in the alternatives analysis, however, because the analysis is based on existing uses of the property.

United Refrigeration

The remediation alternatives for the URI property (Table 6.4b) include removal of all identified source material up to 10 ft bgs, targeted removal of source material up to 5 ft bgs, institutional/engineering controls, and the baseline option of no further action.

Other components of the remediation alternatives, as summarized in Table 6.4b, include piping removal/grouting to eliminate preferential pathways, MNA or no further action for groundwater impacts, no further action for soil gas impacts (since no significant risk was identified), and engineering and institutional controls to limit exposures and manage residual risks.

City Rights of Way

The remediation alternatives for the City ROWs (Table 6.4c) include removal of all identified source material up to 15 ft bgs, targeted removal of source material up to 8 ft bgs, institutional/engineering controls, and the baseline option of no further action.

Other components of the remediation alternatives, as summarized in Table 6.4c, include piping removal/grouting to eliminate preferential pathways, MNA or no further action for groundwater impacts, and engineering and institutional controls to limit exposures and manage residual risks. No remedial options were developed for soil vapor treatment, because vapor intrusion is not a pathway of concern in the City ROWs.

Historic Union

The remediation alternatives for the Historic Union property (Table 6.4d) include removal of all identified source material up to 10 ft bgs on the property and the area at the northern property boundary, targeted removal of source material in the vicinity of piping along the western property boundary up to 8 ft bgs, institutional/engineering controls, and the baseline option of no further action.

Other components of the remediation alternatives, as summarized in Table 6.4d, include piping removal/grouting to eliminate preferential pathways, MNA or no further action for groundwater impacts, no further action for soil gas impacts (because no significant risk was identified), and engineering and institutional controls to limit exposures and manage residual risks.

Culligan

The remediation alternatives for the Culligan property (Table 6.4e) include targeted removal of source material in the vicinity of piping along the eastern property boundary up to 8 ft bgs, institutional/ engineering controls, and the baseline option of no further action.

Other components of the remediation alternatives, as summarized in Table 6.4e, include piping removal/grouting to eliminate preferential pathways, MNA or no further action for groundwater impacts, additional confirmatory sampling or no further action for soil gas impacts, and engineering and institutional controls to limit exposures and manage residual risks.

Table 6.4a Remediation Alternatives Matrix, Heartland Apartments Property

Media	1 (Source Removal)	2 (Targeted Source Removal)	3 (NAPL Extraction)	4 (*In Situ* Stabilization)	5 (Institutional/Engineering Controls Only)	6 (Vapor Mitigation Only)	7 (Baseline)
Source Material (NAPL and Heavily Impacted Soil)	Excavation and off-Site disposal/treatment of all currently identified impacts, including NAPL, impacted soil, and structures/debris (to the extent possible) at depths up to 15 ft bgs.	Excavation and off-Site disposal/treatment of NAPL, impacted soil, and structures/debris (to the extent possible) at depths up to 12 ft bgs.	Excavation and off-Site disposal of structures/upper 2 ft of soil beneath the south and north parking lots. Targeted extraction of NAPL and *ex situ* treatment and/or disposal of extracted NAPL. If viable based on pilot test.	Excavate and off-Site disposal of upper 2 ft of soil beneath the south and north parking lots. ISS of source material at depths up to 12 ft bgs to immobilize NAPL and reduce contaminant flux from the source area.	Excavate and off-Site disposal of upper 2 ft of soil beneath the south and north parking lots.	–	
Preferential Pathways	Removal and/or grouting of piping to eliminate preferential pathways and prevent off-Site migration.					–	
Engineering Controls	Replace upper soil column (*e.g.*, upper 2 ft of soil) in south and/or north parking lot and restore surface cover (*e.g.*, repave parking lot). Marker layer at base of excavation.					Continued use of asphalt parking lot reduces exposure to underlying soil.	
Institutional Controls	Soil, groundwater, and soil vapor management plan.						–
Exposed Surface Soil	Replace upper 1 ft of soil on portions of eastern lawns with clean topsoil and revegetate.					–	
Groundwater	Monitored natural attenuation to ensure stability/attenuation.					– (no significant risk identified based on current use of property and shallow groundwater)	
Soil Gas	Vapor mitigation system to eliminate vapor intrusion into the Heartland Apartments building. [a]						–

Notes:

ft bgs = Feet Below Ground Surface; ISS = *In Situ* Stabilization; NAPL = Non-aqueous Phase Liquid.

– = No Further Action.

Assumption: Current residential apartment building remains in place.

(a) Refer to Gradient (2016), "Preliminary Evaluation of the Vapor Intrusion Pathway and Comparative Analysis of Alternatives, Heartland Apartments Property, Fargo Former MGP Site, Fargo, Cass County, North Dakota" for further details.

Table 6.4b Remediation Alternatives Matrix, United Refrigeration, Inc. Property

Media	1 (Source Removal)	2 (Targeted Source Removal)	3 (Institutional/Engineering Controls Only)	4 (Baseline)
Source Material (NAPL and Heavily Impacted Soil)	Removal of all currently identified source material on the United Refrigeration property (depths of up to 10 ft bgs) and off-Site disposal/treatment.	Targeted source removal (at depths up to 5 ft bgs) and off-Site disposal/treatment.	–	
Preferential Pathways	Removal and/or grouting of MGP pipes that may serve as preferential pathways.		–	
Engineering Controls	Replace upper soil column (*e.g.* , upper 2 ft of soil) in parking lot. Marker layer at base of excavation.	Replace upper soil column (*e.g.* , upper 2 ft of soil) in parking lot. Marker layer at base of excavation.	Continued use as asphalt parking lot reduces infiltration and reduces dermal contact with soil.	Continued use as asphalt parking lot reduces infiltration and reduces dermal contact with soil.
Institutional Controls	Soil and groundwater management plan (zones not remediated); soil vapor management plan.			–
Exposed Surface Soil	N/A (no exposed surface soil)			
Groundwater	Monitored natural attenuation to ensure stability/attenuation.		–	
Soil Gas	– (no significant risk identified based on the current use of the property)			

Notes:

ft bgs = Feet Below Ground Surface; MGP = Manufactured Gas Plant; N/A = Not Applicable; NAPL = Non-aqueous Phase Liquid.

– = No Further Action.

Table 6.4c Remediation Alternatives Matrix, City ROWs

Media	1 (Source Removal)	2 (Targeted Source Removal)	3 (Institutional/Engineering Controls Only)	4 (Baseline)
Source Material (NAPL and Heavily Impacted Soil)	Removal of all currently identified source material (depths up to 15 ft bgs) and off-Site disposal/treatment.	Targeted source removal (at depths up to 8 ft bgs) and off-Site disposal/treatment.	–	
Preferential Pathways	Removal and/or grouting of pipes that may serve as preferential pathways.		–	
Engineering Controls	Continued use as paved road and concrete sidewalk limits exposure potential and reduces infiltration.			
Institutional Controls	Institutional controls, such as deed restriction, or soil and groundwater management plan.			–
Exposed Surface Soil	N/A			
Groundwater	Monitored natural attenuation to ensure stability/attenuation.		–	
Soil Gas	N/A			

Notes:

ft bgs = Feet Below Ground Surface; MGP = Manufactured Gas Plant; N/A = Not Applicable; NAPL = Non-aqueous Phase Liquid; ROWs = Rights of Way.

– = No Further Action.

Table 6.4d Remediation Alternatives Matrix, Historic Union Property

Media	1 (Source Removal)	2 (Targeted Source Removal)	3 (Institutional/Engineering Controls Only)	4 (Baseline)
Source Material (NAPL and Heavily Impacted Soil)	Removal of all currently identified source material on the Historic Union property and the area at the northern property boundary with exceedances of risk-based cleanup goals (depths of up to 10 ft bgs) and off-Site disposal/treatment.	Targeted source removal in the vicinity of piping along the western property boundary (at depths up to 8 ft bgs) and off-Site disposal/treatment.	–	
Preferential Pathways	Removal and/or grouting of MGP pipes that may serve as preferential pathways.		–	
Engineering Controls	Marker layer at base of excavation.		–	
Institutional Controls	Institutional controls, such as deed restriction, or soil, groundwater and soil vapor management plan.			–
Exposed Surface Soil	– (redevelopment has included a minimum of 6 in of clean fill for revegetation and landscaping in previously exposed areas)			
Groundwater	Monitored natural attenuation to ensure stability/attenuation.		–	
Soil Gas	– (no significant risk identified based on the current use of the property)			

Notes:

ft bgs = Feet Below Ground Surface; MGP = Manufactured Gas Plant; NAPL = Non-aqueous Phase Liquid.

– = No Further Action.

Assumptions:

– Continued commercial (west) and residential (east) use of property.

– Active exhaust ventilation is performed in the residential garage.

– Redevelopment has included a minimum of 6 inches (in) of clean fill for revegetation and landscaping in previously exposed areas.

– Shallow groundwater is not used for potable or irrigation purposes.

Table 6.4e Remediation Alternatives Matrix, Culligan Property

<table>
<tr><th>Media</th><th>1 (Targeted Source Removal)</th><th>2 (Institutional/Engineering Controls Only)</th><th>3 (Baseline)</th></tr>
<tr><td>Source Material (NAPL and Heavily Impacted Soil)</td><td>Targeted source removal in the vicinity of piping along the eastern property boundary (at depths up to 8 ft bgs).</td><td colspan="2">–</td></tr>
<tr><td>Preferential Pathways</td><td>Removal and/or grouting of MGP piping along the eastern property boundary to eliminate preferential pathways and prevent off-Site migration.</td><td colspan="2">–</td></tr>
<tr><td>Engineering Controls</td><td>Marker layer at base of excavation.</td><td colspan="2">Continued use as asphalt parking lot reduces infiltration and reduces dermal contact with soil.</td></tr>
<tr><td>Institutional Controls</td><td colspan="2">Institutional controls, such as deed restriction, or soil, groundwater and soil vapor management plan.</td><td>–</td></tr>
<tr><td>Exposed Surface Soil</td><td colspan="3">N/A
(no exposed surface soil)</td></tr>
<tr><td>Groundwater</td><td>Monitored natural attenuation to ensure stability/attenuation.</td><td colspan="2">–
(no significant risk identified based on current use of the property)</td></tr>
<tr><td>Soil Gas</td><td>Perform two rounds of confirmatory sampling.</td><td colspan="2">–</td></tr>
</table>

Notes:

ft bgs = Feet Below Ground Surface; MGP = Manufactured Gas Plant; N/A = Not Applicable; NAPL = Non-aqueous Phase Liquid.

– = No Further Action.

6.5 Evaluation Criteria

In accordance with US EPA guidance (US EPA, 1988, 1989b), the following criteria[46] were used to evaluate the remediation alternatives that were developed for each of the properties (Table 6.4a-e). The evaluation criteria are defined as follows.

- **Overall Protection of Human Health and the Environment:** This criterion is used to evaluate whether and how the alternative as a whole achieves and maintains the protection of human health and the environment. In particular, this criterion was used to evaluate the ability of the alternative to achieve the RAOs developed for the MGP Site.
- **Long-term Effectiveness and Permanence:** This criterion includes an evaluation of the magnitude of human health and ecological risk from untreated contaminated materials or treatment residuals remaining after remedial action has been concluded (known as residual risk), and the adequacy and reliability of controls to manage that residual risk.
- **Reduction of Toxicity, Mobility, and Volume Through Treatment:** This criterion refers to the evaluation of whether treatment processes can be used to address the source material, the amount of hazardous material treated, including the principal threat that can be addressed, and the degree of expected reduction in the toxicity, mobility, and volume of source material.
- **Short-term Effectiveness:** This criterion includes an evaluation of the effects of the alternative during the construction and implementation phase, until remedial objectives are met. This criterion includes an evaluation of the protection of the community and workers during the remedial action and the short-term environmental impacts of implementing the remedial action.
- **Implementability:** This criterion is used to evaluate the technical feasibility of the alternative, including construction and operation, reliability, monitoring, and the ease of undertaking remedial action in the context of any logistical constraints at the Site. It also considers the administrative feasibility of activities needed to coordinate with other third parties (*e.g.*, the property owners, regulatory agencies), such as for obtaining property access, obtaining permits, and the availability of services and materials necessary to the alternative, such as disposal facilities and qualified contractors.
- **Cost:**[47] This criterion includes an evaluation of direct and indirect capital costs, including the costs of treatment and disposal; the annual costs of operating, maintaining, and monitoring the alternative; and the total present worth of these costs.
- **Regulatory Approval and Community Acceptance:** This criterion is used to evaluate the expected level of approval from the regulatory agency and acceptance from community stakeholders.

[46] Compliance with Applicable or Relevant and Appropriate Requirements (ARARs) was not used as a separate evaluation criterion for this FFS because it is assumed that the NDDH will evaluate the remediation alternatives in the context of State regulations and highlight the need for compliance with additional requirements, if any.
[47] Given that this is a *focused* FS (*i.e.*, a streamlined FS), a qualitative rather than a quantitative approach was used for the comparative evaluation of the cost of the various remediation alternatives. This included an assessment of the level of uncertainty associated with remedy implementation and other potential logistical and administrative issues.

6.6 Evaluation of Remediation Alternatives

For each of the properties that comprise the MGP and its vicinity, a detailed assessment of the remediation alternatives against each of the criteria listed above is presented in the remediation evaluation matrices (Tables 6.5a-e).

The results of the comparative analysis demonstrates that the Targeted Source Removal alternative is the preferred remedial approach for all five properties, assuming regulatory approval and cooperation from the property owners, because it provides long-term effectiveness and protectiveness with a higher level of certainty in comparison to other alternatives, while also being cost-effective, implementable, and more likely to receive regulatory approval. Through the removal of source material and elimination of preferential pathways (pipes), the targeted source removal alternative limits direct exposure to impacted media, while also promoting the long-term stability and attenuation of associated groundwater and soil gas impacts. This alternative is implementable and cost-effective, and short-term impacts and logistical challenges associated with its implementation can be managed through the use of safety measures and engineering controls. The use of institutional and engineering controls, a critical component of this alternative, will allow for the long-term management of any residual risks, such as those associated with source material and impacted media left in place outside the remediation zones. Further, a monitoring program will be implemented at permanent groundwater and soil gas monitoring points to evaluate the MNA of impacts to both media.

A comparative analysis of the remediation alternatives for each property and the rationale for the selection of the preferred approach is provided in Tables 6.5a-e and discussed in the sub-sections below.

6.6.1 Heartland Apartments

The evaluation of remediation alternatives for the Heartland property is presented in Table 6.5a. The preferred remedial approach for the Heartland property is Alternative 2 (Targeted Source Removal), for the following reasons.

- Through the removal of source material, the elimination of preferential pathways (pipes), and the use of institutional/engineering controls, Alternative 2 (Targeted Source Removal) would provide a higher level of protectiveness and long-term effectiveness in comparison to all the other alternatives, except Alternative 1. Alternative 1 (Source Removal) would remove more contaminant mass than Alternative 2, but Alternative 2 is adequately protective because it targets the more likely exposure zone. Engineering controls, such as placing a marker layer at the base of the excavation, would further promote protectiveness by limiting direct contact with source material. Further, Alternative 1 would be costly, is less implementable, and poses greater short-term impacts, as discussed below. Alternatives 3 (NAPL Extraction) and 4 (ISS) would be moderately protective by removing and immobilizing source material, respectively, and thus reducing the contaminant flux to other media; however, implementation challenges associated with both alternatives, as discussed below, would limit their effectiveness as viable alternatives. Alternatives 5 (Institutional/Engineering Controls Only), 6 (Vapor Mitigation Only), and 7 (Baseline) were rejected because they would allow NAPL and highly impacted soils to be left in place at depth (>2 ft bgs) and would not achieve the mass reduction- or risk reduction-related RAOs for the Site.
- Of the alternatives that are protective, Alternative 2 is the most readily implementable, and the challenges associated with property access, worker/public safety, disruptions to the community (*e.g.*, truck traffic), and disruption to apartment building occupants, while significant, can be

managed and are lesser for Alternative 2 than for Alternative 1. Alternatives 3 and 4 would pose significant implementation challenges associated with the presence of buried structures and debris. Further, the low-permeability clays in the formation would greatly reduce the yield of the NAPL extraction system (Alternative 3) and impede the uniform *in situ* mixing of soils with a stabilizing additive needed for ISS (Alternative 4). Alternative 1 was eliminated in comparison to Alternative 2 based on its inferior implementability (*e.g.*, deeper excavation could pose structural stability issues for existing building), greater cost, and greater short-term impacts (*e.g.*, greater duration leads to more truck traffic; greater impact on property tenants; air/odor issues).

- Of the alternatives that are protective, Alternative 2 is moderately cost-effective in comparison to Alternative 1 and has moderate cost uncertainty associated with it. Although the capital costs associated with Alternative 3 may be lower, there is a high level of uncertainty because of implementation challenges and the long-term operation and maintenance (O&M) requirements of a NAPL extraction system. Alternative 4 would be moderately cost-effective but have greater cost uncertainty due to debris management requirements and the lack of ISS contractors in the area.
- Both Alternatives 1 and 2 are likely to receive regulatory approval because of their protectiveness, effectiveness, and implementability. Community acceptance and property access may be challenging for both alternatives, because they would both be disruptive to property occupants. However, as discussed above, Alternative 2 was selected over Alternative 1 because it would be the more cost-effective and implementable option and would have lesser short-term impacts.

The preferred remedial approach is based on the current use of the property and is contingent upon obtaining access to the property and regulatory approval.

Table 6.5a Evaluation of Remediation Alternatives, Heartland Apartments Property

Evaluation Criteria	1 (Source Removal)	2 (Targeted Source Removal)	3 (NAPL Extraction)	4 (*In Situ* Stabilization)	5 (Institutional/Engineering Controls Only)	6 (Vapor Mitigation Only)	7 (Baseline)
Overall Protection of Human Health/ Environment	**– High** – Removing all identified source material in the parking lots and surface soil in the eastern lawns would effectively mitigate the human health risk associated with direct exposure to impacted media. – Removal of source material would decrease the MGP contaminant flux to groundwater and soil vapors over time, thus enhancing the long-term attenuation and stability of impacts to both media and decreasing long-term risks associated with exposure to MGP constituents. – Vapor mitigation system would offer a high level of protection from exposure to MGP impacts *via* vapor intrusion into the buildings. – Institutional controls (and potentially additional remediation) would be needed to protect receptors from exposure to impacted media in zones that are not remediated and other zones (*e.g.* , beneath the apartment building, soils at depth) in the event of future redevelopment.	**– High** – This alternative would offer a high level of protectiveness, because targeted source removal would effectively mitigate the human health risk associated with direct exposure to impacted media by removing source material in the parking lots and surface soil in the eastern lawns. Replacing the upper soil column (*e.g.* , upper 2 ft of soil) in the south and/or north parking lot and restoring surface cover (*e.g.* , repave parking lot) would limit exposure potential. – Removal of source material would decrease the MGP contaminant flux to groundwater and soil vapors over time, thus enhancing the long-term attenuation and stability of impacts to both media and decreasing long-term risks associated with exposure to MGP constituents. – Vapor mitigation system would offer a high level of protection from exposure to MGP impacts *via* vapor intrusion into the buildings. – Institutional controls (and potentially additional remediation) would be needed to protect receptors from exposure to impacted media in zones that are not remediated and other zones (*e.g.* , beneath the apartment building, soils at depth) in the event of future redevelopment.	**– Moderate** – This alternative would offer a moderate level of protectiveness because removing soil from the upper 2 ft of the parking lots would mitigate some of the human health risk associated with direct exposure to impacted media; however, soil with concentrations in exceedance of risk-based cleanup goals would be left in place at depth (>2 ft bgs). – Extraction of NAPL may decrease the MGP contaminant flux to groundwater and soil vapors over time, thus enhancing the long-term attenuation and stability of impacts to both media to some extent; however, the impacted soils left in place at depth would continue to serve as a potential source of contamination to groundwater and soil vapor. – Vapor mitigation system would offer a high level of protection from exposure to MGP impacts *via* vapor intrusion into the buildings. – Institutional controls (and potentially additional remediation) would be needed to protect receptors from exposure to impacted media in zones that are not remediated and other zones (*e.g.* , beneath the apartment building, impacted soils below 2 ft bgs) in the event of future redevelopment.	**– Moderate** – This alternative would offer a moderate level of protectiveness because source removal from the upper 2 ft of the parking lots would mitigate some of the human health risk associated with direct exposure to impacted media; however, NAPL and soil with concentrations in exceedance of risk-based cleanup goals would be left in place at depth (>2 ft bgs). – ISS would stabilize/immobilize source material and decrease the MGP contaminant flux to groundwater and soil vapors over time, thus enhancing the long-term attenuation and stability of impacts to both media and decreasing the long-term risks associated with exposure to MGP constituents. – Vapor mitigation system would offer a high level of protection from exposure to MGP impacts *via* vapor intrusion (if any) into the buildings. – Institutional controls (and potentially additional remediation) would be needed to protect receptors from exposure to impacted media in zones that are not remediated and other zones (*e.g.* , beneath the apartment building, soils at depth greater than the remediation depth) in the event of future redevelopment.	**– Low** – This alternative would offer a low level of protectiveness because source removal from the upper 2 ft of the parking lots would mitigate some of the human health risk associated with direct exposure to impacted media; however, NAPL and soil with concentrations in exceedance of risk-based cleanup goals would be left in place at depth (>2 ft bgs). – Institutional controls (and potentially additional remediation) would be needed to protect receptors from exposure to impacted media in zones that are not remediated (*e.g.* , beneath the apartment building, soils at depth greater than the remediation depth) in the event of future redevelopment. – This alternative would not be as protective of human health and the environment in the long term as the active remediation alternatives (1, 2, 3, and 4).	**– Low** – This alternative would offer a low level of protectiveness because the use of institutional/engineering controls would limit direct exposure to impacted soil and groundwater. – Vapor mitigation system would offer a high level of protection from potential exposure to MGP impacts *via* vapor intrusion into the buildings.	**– Low** – The baseline alternative would not achieve RAOs.
Long-term Effectiveness/ Permanence	**– High** – Source removal would permanently and effectively limit the long-term potential for direct contact with impacted media. – Removal and grouting of MGP pipes in combination with source removal would effectively mitigate off-Site migration of MGP constituents *via* groundwater and soil vapor, thus promoting long-term attenuation and stability of impacts to both media. – Vapor mitigation system would effectively mitigate long-term exposure to impacted soil vapors *via* vapor intrusion. – Institutional/engineering controls and potential additional remediation would be needed in zones that are not remediated and other zones (*i.e.* , soils at depth) to ensure long-term effectiveness/permanence in the event of future redevelopment. Reconstruction of the parking lots would further promote long-term attenuation and stability of the contaminant plume by reducing infiltration and contaminant flux from deeper impacts in the subsurface.	**– High** – Targeted source removal would permanently and effectively limit the long-term potential for direct contact with impacted media. – Removal and grouting of MGP pipes in combination with source removal would effectively mitigate off-Site migration of MGP constituents *via* groundwater and soil vapor, thus promoting long-term attenuation and stability of impacts to both media. – Vapor mitigation system would effectively mitigate long-term exposure to impacted soil vapors *via* vapor intrusion. – Institutional controls and potential additional remediation would be needed in zones that are not remediated and other zones (*e.g.* , beneath the apartment building, soils at depth) to ensure long-term effectiveness/permanence in the event of future redevelopment. Reconstruction of the parking lots would further promote long-term attenuation and stability of the contaminant plume by reducing infiltration and contaminant flux from any residual source material in the subsurface.	**– Moderate** – NAPL extraction and shallow soil removal would, in combination with institutional/engineering controls, effectively limit the long-term potential for direct contact with impacted media. – Removal and/or grouting of MGP pipes in combination with NAPL extraction would mitigate off-Site migration of MGP constituents *via* groundwater and soil vapor, thus promoting long-term attenuation and stability of impacts to both media. However, impacted soils left in place at depth would continue to be an ongoing source of contamination to other media and limit the long-term effectiveness/permanence of this alternative. – Vapor mitigation system would effectively mitigate long-term exposure to impacted soil vapors *via* vapor intrusion. – Institutional/engineering controls and potential additional remediation would be needed in zones that are not remediated and other zones (*e.g.* , beneath the apartment building, impacted soils left in place) to ensure long-term effectiveness/permanence in the event of future redevelopment.	**– High** – Shallow soil removal (up to 2 ft bgs) in combination with institutional/engineering controls for source material at depth would effectively limit the long-term potential for direct contact with impacted media. – ISS in combination with removal/regrouting of pipes would effectively mitigate off-Site migration of MGP constituents *via* groundwater and soil vapor, thus promoting long-term attenuation and stability of impacts to both media. – Institutional/engineering controls and potential additional remediation would be needed in zones that are not remediated and other zones (*e.g.* , beneath the apartment building, soils at depths greater than the remediation depth) to ensure long-term effectiveness/permanence in the event of future redevelopment.	**– Low** – Source material would be left in place and continue to impact soil, groundwater, and soil vapor. – Institutional/engineering controls and potential additional remediation would be needed in zones that are not remediated and other zones (*e.g.* , beneath the apartment building, soils at depths greater than the remediation depth) to ensure long-term effectiveness/permanence in the event of future redevelopment.	**– Low** – No assurance of long-term effectiveness because source material would be left in place and continue to impact soil, groundwater, and soil vapor; however, the vapor mitigation system would effectively mitigate long-term exposure to impacted soil vapors *via* vapor intrusion..	**– Low** – No assurance of long-term effectiveness because source material would be left in place and continue to impact soil, groundwater, and soil vapor.
Reduction of Toxicity, Mobility, Volume (TMV) Through Treatment	**– High** – Source removal would permanently reduce the TMV of source material.	**– High** – Targeted source removal would permanently reduce the TMV of source material.	**– High** – NAPL extraction and shallow soil removal would permanently reduce the TMV of source material in remediation zones.	**– Moderate** – ISS would not affect the toxicity or volume, but would significantly reduce the mobility of source material in remediation zones.	**– Low** – Limited reduction in TMV of source material.	**– Low** – No reduction in TMV of source material.	**– Low** – No reduction in TMV of source material.
Short-term Effectiveness	**– Low** – Construction activities associated with source/surface soil removal, piping removal/grouting, and parking lot reconstruction could create short-term risks to workers (construction, outdoor, office) related to heavy equipment use, open excavation, fugitive dust and emissions, and/or stockpiled soils. These risks can be mitigated through the use of PPE, resident relocation, and/or engineering controls. – There will also be greater short-term impacts, disruptiveness, and inconvenience to surrounding properties associated with noise, emissions, dust, truck traffic, and equipment use during construction activities in comparison to Alternative 2, due to greater remedy duration.	**– Moderate** – Construction activities associated with source/surface soil removal, piping removal/grouting and parking lot reconstruction could create short-term risks to apartment building residents and/or to workers (construction, outdoor, office) related to heavy equipment use, open excavation, fugitive dust and emissions, and/or stockpiled soils. These risks can be mitigated through the use of PPE, resident relocation, and/or engineering controls. – There will also be short-term impacts, disruptiveness, and inconvenience associated with noise, emissions, dust, truck traffic, equipment, and restricted access to certain areas during construction activities.	**– Moderate** – Although considerably less so than Alternatives 1 and 2, construction activities associated with shallow soil removal, NAPL extraction system installation, piping removal/grouting, and parking lot reconstruction would create short-term risks to apartment building residents and/or to workers (construction, outdoor, office) related to heavy equipment use, open excavation, fugitive dust and emissions, and/or stockpiled soils. These risks can be mitigated through the use of PPE, resident relocation, and/or engineering controls. – Although considerably less than Alternative 1, there will also be short-term impacts, disruptiveness, and inconvenience associated with noise, emissions, dust, equipment, and restricted access to certain areas during construction activities. However, there would be significantly less truck traffic in comparison to Alternatives 1 and 2.	**– Moderate** – Construction activities associated with ISS, surface soil removal, piping removal/grouting, and parking lot reconstruction could create short-term risks to apartment building residents and/or to workers (construction, outdoor, office) related to heavy equipment use, open excavation, fugitive dust and emissions, and/or stockpiled soils. These risks can be mitigated through the use of PPE, resident relocation, and/or engineering controls. – There will also be short-term impacts and disruptiveness associated with noise, emissions, dust, and equipment during construction activities. However, there would be significantly less truck traffic in comparison to Alternatives 1 and 2.	**– High** – Construction activities associated with surface soil removal, piping removal/grouting and parking lot reconstruction would create short-term risks to apartment building residents and/or to workers (construction, outdoor, office) related to heavy equipment use, open excavation, fugitive dust and emissions, and/or stockpiled soils. These risks can be mitigated through the use of PPE, resident relocation, and/or engineering controls. – There will also be short-term impacts and disruptiveness associated with noise, emissions, dust, and equipment during construction activities. However, there would be significantly less truck traffic in comparison to Alternatives 1, 2, and 4.	**– High** – There will be some short-term impacts and disruptiveness associated with the installation of the vapor mitigation system. However, there would be significantly less disruption in comparison to Alternatives 1, 2, 3, 4, and 5.	**– High** – The baseline alternative would pose no significant short-term "remedy risks" to residents or workers at the Heartland property and would not be intrusive.

Table 6.5a Evaluation of Remediation Alternatives, Heartland Apartments Property

Evaluation Criteria	1 (Source Removal)	2 (Targeted Source Removal)	3 (NAPL Extraction)	4 (*In Situ* Stabilization)	5 (Institutional/Engineering Controls Only)	6 (Vapor Mitigation Only)	7 (Baseline)
Implementability	**– Moderate** – Excavation is a reliable technology with a proven track record. – Equipment and contractors are available. – Implementation challenges include procuring access to the property for the duration of the remedy, the potential for undercutting the building, engineering controls needed to ensure resident/worker/public safety during excavation, measures needed to minimize disruption to surrounding areas, and logistics associated with trucking material to the nearest landfill. – Less implementable than Alternative 2 because of the greater volume and depth of soil to be excavated.	**– High** – Excavation is a reliable technology with a proven track record. – Equipment and contractors are available. – Implementation challenges include procuring access to the property for the duration of the remedy, the potential for undercutting the building, engineering controls needed to ensure resident/worker/public safety during excavation, measures needed to minimize disruption to apartment building occupants, and logistics associated with trucking material to the nearest landfill. – More implementable than Alternative 1 because of the lesser volume and depth of soil to be excavated.	**– Moderate** – Implementation of NAPL recovery at the Heartland property would be challenging because clay soils at the Site and the low viscosity of the NAPL may significantly reduce the yield of the NAPL extraction system. Pilot testing would be warranted. – NAPL may not be easily accessible due to debris presence. – Equipment and contractors are available. – Other implementation challenges include procuring access to the property for the duration of the remedy, engineering controls needed to ensure resident/worker/public safety during implementation, measures needed to minimize disruption to apartment building occupants, and logistics associated with the disposal of extracted material.	**– Low** – Implementation of ISS at the Heartland property would pose significant challenges. The presence of buried structures and debris could impede the uniform *in situ* mixing of soils with an additive needed for the remedy to be effective. The presence of clay could also limit the uniform distribution of the additive in the native formation. – Limited local availability of reliable ISS contractors could also pose an implementation challenge. – Other implementation challenges include procuring access to property for the duration of the remedy, engineering controls needed to ensure resident/ worker/public safety during implementation, measures needed to minimize disruption to apartment building occupants, and logistics associated with the disposal of extracted material.	**– High** – Institutional and engineering controls are implementable.	**– High** – Institutional and engineering controls are implementable. – Vapor mitigation system is a reliable technology, and equipment/contractors are available. Implementation challenges include procuring access to the property and measures needed to minimize disruption to apartment building occupants.	N/A
Cost	High cost due to greater volume and depth of soil to be excavated relative to Alternative 2. Moderate uncertainty due to design contingency based on actual field conditions and logistical constraints encountered.	Moderate cost due to lesser volume and depth of soil to be excavated relative to Alternative 1. Moderate uncertainty due to design contingency based on actual field conditions and logistical constraints encountered.	Low-to-moderate capital cost, but potentially high O&M costs. High uncertainty due to challenges posed by the presence of subsurface structures/debris and clayey Site soils; a pre-design pilot test would be required to evaluate the feasibility of NAPL extraction. There is additional uncertainty in the design due to contingency based on the actual field conditions and logistical constraints encountered.	Moderate Cost. High uncertainty due to the presence of buried structures and debris. There is additional uncertainty in the design due to contingency based on the actual field conditions and logistical constraints encountered.	Low cost. Low level of uncertainty because no active remediation technologies are employed.	Low cost (relative to other alternatives). Low level of uncertainty.	N/A
Community Acceptance/ Regulatory Approval	– Regulatory approval is likely due to the protectiveness, effectiveness, and implementability of this approach. – Community acceptance and property access may be challenging because third party access is required and the remedy would be disruptive to tenants.	– Regulatory approval is likely due to the protectiveness, effectiveness, and implementability of this approach. – Community acceptance and property access may be challenging because third party access is required and the remedy would be disruptive to tenants.	– Regulatory approval may be limited due to the potential risks posed by impacted soils left in place and the implementability challenges of a NAPL extraction system. – Community acceptance may be higher because the overall approach is less intrusive than that of Alternatives 1, 2, and 4.	– Regulatory approval may be limited due to the potential risks posed by source material (albeit stabilized) left in place and the significant implementability challenges associated with ISS. – Community acceptance and property access may be challenging because third party access is required and the remedy would be intrusive and disruptive.	– Regulatory approval may be limited due to the potential risks posed by source material left in place and the low degree of overall protectiveness. – Community acceptance may be moderate due to perceived risk issues associated with leaving source material in place.	– Regulatory approval may be limited due to the potential risks posed by source material left in place. – Community acceptance may be moderate due to perceived risk issues associated with leaving source material in place.	Regulatory approval is not expected because of the low degree of protectiveness and the long-term potential risks to human health and the environment.
Conclusion	This alternative was not selected because of the high cost, implementability challenges, and greater short-term impacts associated with excavation to 15 ft bgs.	This alternative was selected because it offers a high level of effectiveness and protectiveness while also being implementable, particularly in comparison to Alternatives 3 and 4, and is cost-effective. It is also likely to receive regulatory approval.	This alternative was not selected because the implementation challenges associated with NAPL recovery would impede its effectiveness and protectiveness and result in high costs.	This alternative was not selected because implementation challenges associated with ISS would impede its effectiveness and protectiveness and result in high costs.	This alternative was not selected because it offers a less-significant reduction in contaminant mass relative to Alternatives 1, 2, 3, and 4, and there are associated long-term effectiveness and protectiveness concerns.	This alternative was not selected because it does not reduce contaminant mass and there are associated long-term effectiveness and protectiveness concerns.	This alternative was not selected because the remedy offers a low level of overall protectiveness and is not likely to receive regulatory approval.

Notes:

ft bgs = Feet Below Ground Surface; ISS = *In Situ* Stabilization; MGP = Manufactured Gas Plant; N/A = Not Applicable; NAPL = Non-aqueous Phase Liquid; O&M = Operations and Maintenance; PPE = Personal Protective Equipment; RAO = Remedial Action Objective.

The shaded cells highlight the selected remedial alternative.

6.6.2 United Refrigeration

The evaluation of remediation alternatives for the URI property is presented in Table 6.5b. The preferred remedial approach for the URI property is Alternative 2 (Targeted Source Removal), for the following reasons.

- Through the removal of source material, the elimination of preferential pathways (pipes), and the use of institutional/engineering controls, Alternative 2 (Targeted Source Removal) would provide a higher level of protectiveness and long-term effectiveness in comparison to Alternative 3 (Baseline). Alternative 1 (Source Removal) would remove more contaminant mass than Alternative 2, but Alternative 2 is adequately protective because it targets the more likely exposure zone. Engineering controls, such as placing a marker layer at the base of the excavation, would further promote protectiveness by limiting direct contact with source material. Further, Alternative 1 would be costly, is less implementable, and poses greater short-term impacts, as discussed below. Alternative 3 was rejected because it would not remove or treat the impacted media at the property, and, thus, would not achieve the mass reduction- or risk reduction-related RAOs for the Site.
- Of the alternatives that are protective, Alternative 2 is the most readily implementable, and the challenges associated with property access, worker/public safety, disruptions to the community (*e.g.*, truck traffic), and disruption to building occupants can be managed and are lesser for Alternative 2 than for Alternative 1. Alternative 1 was eliminated in comparison to Alternative 2 based on its inferior implementability (*e.g.*, deeper excavation could pose structural stability issues for existing building), greater cost, and greater short-term impacts (*e.g.*, greater duration leads to more truck traffic; greater impact on property tenants; potential air quality/odor issues).
- Of the alternatives that are protective, Alternative 2 is moderately cost-effective in comparison to Alternative 1 and has moderate cost uncertainty associated with it.
- Both Alternatives 1 and 2 are likely to receive regulatory approval because of their protectiveness, effectiveness, and implementability. Community acceptance and property access may be challenging for both alternatives, because they would both be disruptive to property occupants. However, as discussed above, Alternative 2 was selected over Alternative 1 because it would be the more cost-effective and implementable option and would have lesser short-term impacts.

The preferred remedial approach is based on the current use of the property and is contingent upon obtaining access to the property and regulatory approval.

Table 6.5b Evaluation of Remediation Alternatives, United Refrigeration, Inc. Property

Evaluation Criteria	1 (Source Removal)	2 (Targeted Source Removal)	3 (Institutional/Engineering Controls Only)	4 (Baseline)
Overall Protection of Human Health/ Environment	**– High** – The source removal alternative would effectively mitigate the human health risk associated with direct exposure to impacted media by removing all source material currently identified on the URI property. – Removal of source material would decrease the MGP contaminant flux to groundwater and soil vapors over time, thus enhancing the long-term attenuation and stability of impacts to both media and decreasing the long-term risks associated with exposure to MGP constituents. – Institutional controls (and potentially additional remediation) would be needed to protect receptors from exposure to impacted media in zones that are not remediated and other zones (*e.g.* , beneath the URI building, soils at depth) in the event of future redevelopment.	**– High** – The targeted source removal alternative would effectively mitigate the human health risk associated with direct exposure to impacted media by removing source material in the southeastern corner of the URI property. – Removal of source material would decrease the MGP contaminant flux to groundwater and soil vapors over time, thus enhancing the long-term attenuation and stability of impacts to both media and decreasing the long-term risks associated with exposure to MGP constituents. – Institutional controls (and potentially additional remediation) would be needed to protect receptors from exposure to impacted media in zones that are not remediated and other zones (*e.g.* , beneath the URI building, soils at depth) in the event of future redevelopment.	**– Low** – This alternative would offer a low level of protectiveness because the use of institutional/engineering controls would limit direct exposure to impacted soil and groundwater. .	**– Low** – The baseline alternative would not achieve RAOs and risk-based goals.
Long-term Effectiveness/ Permanence	**– High** – Source removal would permanently and effectively limit the long-term potential for direct contact with impacted media. – Removal and grouting of MGP pipes in combination with source removal would effectively mitigate off-Site migration of MGP constituents *via* groundwater and soil vapor, thus promoting long-term attenuation and stability of impacts to both media. – Institutional controls and potential additional remediation would be needed in zones that are not remediated and other zones (*e.g.* , beneath the URI building, soils at depth) to ensure long-term effectiveness/permanence in the event of future redevelopment.	**– High** – Targeted source removal would permanently and effectively limit the long-term potential for direct contact with impacted media. – Removal and grouting of MGP pipes in combination with source removal would effectively mitigate off-Site migration of MGP constituents *via* groundwater and soil vapor, thus promoting long-term attenuation and stability of impacts to both media. – Institutional controls and potential additional remediation would be needed in zones that are not remediated and other zones (*e.g.* , beneath the URI building, soils at depth) to ensure long-term effectiveness/permanence in the event of future redevelopment.	**– Low** – No assurance of long-term effectiveness because source material would be left in place and continue to impact soil, groundwater, and soil vapor.	**– Low** – No assurance of long-term effectiveness because source material would be left in-place and continue to impact soil, groundwater, and soil vapor.
Reduction of Toxicity, Mobility, Volume (TMV) Through Treatment	**– High** – Source removal would permanently reduce the TMV of source material.	**– High** – Targeted source removal would permanently reduce the TMV of source material.	**– Low** – No reduction in TMV of source material.	**– Low** – No reduction in TMV of source material.
Short-term Effectiveness	**– Low** – Construction activities associated with source removal and piping removal/grouting could create short-term risks to workers (construction, outdoor, office) related to heavy equipment use, open excavation, fugitive dust and emissions, and/or stockpiled soils. – There will also be greater short-term impacts, disruptiveness, and inconvenience to surrounding properties associated with noise, emissions, dust, truck traffic, and equipment use during construction activities in comparison to Alternative 2 due to greater remedy duration.	**– Moderate** – Construction activities associated with source removal and piping removal/grouting could create short-term risks to workers (construction, outdoor, office) related to heavy equipment use, open excavation, fugitive dust and emissions, and/or stockpiled soils. – There will also be short-term impacts, disruptiveness, and inconvenience associated with noise, emissions, dust, truck traffic, equipment, and restricted access to certain areas during construction activities.	**– High** –– This alternative would pose no significant short-term risks to workers at the URI property and would not be intrusive.	**– High** – Baseline alternative would pose no significant short-term risks to workers at the URI property and would not be intrusive.
Implementability	**– Moderate** – Excavation is a reliable technology with a proven track record. – Equipment and contractors are available. – Implementation challenges include procuring access to the property for the duration of the remedy, the potential for undercutting the building, engineering controls needed to ensure resident/worker/public safety during excavation, measures needed to minimize disruption to surrounding areas, and logistics associated with trucking material to the nearest landfill. – Less implementable than Alternative 2 because of the greater volume and depth of soil to be excavated.	**– High** – Excavation is a reliable technology with a proven track record. – Equipment and contractors are available. – Implementation challenges include procuring access to the property for the duration of the remedy, the potential for undercutting the building, engineering controls needed to ensure resident/worker/public safety during excavation, measures needed to minimize disruption to surrounding areas, and logistics associated with trucking material to the nearest landfill. – More implementable than Alternative 1 because of the lesser volume and depth of soil to be excavated.	**– High** – Institutional and engineering controls are implementable.	N/A

Table 6.5b Evaluation of Remediation Alternatives, United Refrigeration, Inc. Property

Evaluation Criteria	1 (Source Removal)	2 (Targeted Source Removal)	3 (Institutional/Engineering Controls Only)	4 (Baseline)
Cost	High cost due to greater volume and depth of soil to be excavated relative to Alternative 2. Moderate uncertainty due to design contingency based on actual field conditions and logistical constraints encountered.	Moderate cost due to lesser volume and depth of soil to be excavated relative to Alternative 1. Moderate uncertainty due to design contingency based on actual field conditions and logistical constraints encountered.	Low cost (relative to other alternatives). Low level of uncertainty.	N/A
Community Acceptance/ Regulatory Approval	– Regulatory approval is likely due to the protectiveness, effectiveness, and implementability of this approach. – Community acceptance and property access may be challenging because third party access is required and because the remedy would be more intrusive and longer in duration in comparison to the baseline alternative and Alternative 2.	– Regulatory approval is likely due to the protectiveness, effectiveness, and implementability of this approach. – Community acceptance and property access would be less challenging than Alternative 1 due to the shorter duration of this alternative.	– Regulatory approval may be limited due to the potential risks posed by source material left in place. – Community acceptance may be moderate due to perceived risk issues associated with leaving source material in place. Property access will not be required for this alternative.	Regulatory approval is not expected because of the low degree of protectiveness and the long-term potential risks to human health and the environment.
Conclusion	This alternative was not selected because of the high cost, implementability challenges, and greater short-term impacts associated with the excavation to 10 ft bgs.	This alternative was selected because it offers a high level of effectiveness and protectiveness while also being implementable and cost-effective. It is also most likely to receive regulatory approval.	This alternative was not selected because it does not reduce contaminant mass and there are associated long-term effectiveness and protectiveness concerns.	This alternative was not selected because the remedy offers a low level of overall protectiveness and is not likely to receive regulatory approval.

Notes:
ft bgs = Feet Below Ground Surface; MGP = Manufactured Gas Plant; N/A = Not Applicable; RAO = Remedial Action Objective; URI = United Refrigeration, Inc.
The shaded cells highlight the selected remedial alternative.

6.6.3 City Rights of Way

The evaluation of remediation alternatives for the City ROWs is presented in Table 6.5c. The preferred remedial approach for the City ROWs is Alternative 2 (Targeted Source Removal), for the following reasons.

- Through the removal of source material, the elimination of preferential pathways (pipes), and the use of institutional/engineering controls, Alternative 2 (Targeted Source Removal) would provide a significantly higher level of protectiveness and long-term effectiveness in comparison to Alternative 3 (Baseline). Alternative 1 (Source Removal) would remove more contaminant mass than Alternative 2, but Alternative 2 is adequately protective because it targets the more likely exposure zone. Engineering controls (*i.e.*, continued use of the paved road and concrete sidewalk) would promote protectiveness by limiting exposure potential and reducing infiltration. Further, Alternative 1 would be costly, is less implementable, and poses greater short-term impacts, as discussed below. Alternative 3 was rejected because it would not remove or treat the impacted media in the City ROWs, and, thus would not achieve the mass reduction- or risk reduction-related RAOs for the Site vicinity.
- Of the alternatives that are protective, Alternative 2 is readily implementable, and any challenges associated with property access, worker/public safety, disruptions to the community (*e.g.*, truck traffic), and disruption to the public, while significant, can be managed and are lesser for Alternative 2 than for Alternative 1. Alternative 1 was eliminated in comparison to Alternative 2 based on its inferior implementability (*e.g.*, deeper excavation could pose structural stability and safety issues), greater cost, and greater short-term impacts (*e.g.*, greater duration leads to more truck traffic; greater impact on property tenants and general public; air/odor issues).
- Of the alternatives that are protective, Alternative 2 is moderately cost-effective in comparison to Alternative 1 and has moderate cost uncertainty associated with it.
- Both Alternatives 1 and 2 are likely to receive regulatory approval because of their protectiveness, effectiveness, and implementability. Community acceptance and property access may be challenging for both alternatives, because they would both be disruptive to the public. However, as discussed above, Alternative 2 was selected over Alternative 1 because it would be the more cost-effective and implementable option and would have lesser short-term impacts.

The preferred remedial approach is based on the current use of the property and is contingent upon obtaining access to the property and regulatory approval.

Table 6.5c Evaluation of Remediation Alternatives, City ROWs

Evaluation Criteria	1 (Source Removal)	2 (Targeted Source Removal)	3 (Institutional/Engineering Controls Only)	4 (Baseline)
Overall Protection of Human Health/ Environment	**– High** – The source removal alternative would effectively mitigate the human health risk associated with direct exposure to impacted media by removing all identified source material. – Removal of source material would decrease the MGP contaminant flux to groundwater and soil vapors over time, thus enhancing the long-term attenuation and stability of impacts to both media and decreasing long-term risks associated with exposure to MGP constituents. – Institutional controls (and potentially additional remediation) would be needed to protect receptors from exposure to impacted media below the remediation depth and other zones in the event of future redevelopment.	**– High** – The targeted source removal alternative would effectively mitigate the human health risk associated with direct exposure to impacted media by removing source material. – Removal of source material would decrease the MGP contaminant flux to groundwater and soil vapors over time, thus enhancing the long-term attenuation and the stability of impacts to both media and decreasing long-term risks associated with exposure to MGP constituents. – Institutional controls (and potentially additional remediation) would be needed to protect receptors from exposure to impacted media in zones that are not remediated and other zones (*e.g.* , soils at depth) in the event of future redevelopment.	**– Low** – This alternative would offer a low level of protectiveness because the use of institutional/engineering controls would limit direct exposure to impacted soil and groundwater. .	**– Low** – The baseline alternative would not achieve RAOs and risk-based goals.
Long-term Effectiveness/ Permanence	**– High** – Source removal would permanently and effectively limit the long-term potential for direct contact to impacted media. – Removal and grouting of MGP pipes in combination with source removal would effectively mitigate off-Site migration of MGP constituents *via* groundwater and soil vapor, thus promoting long-term attenuation and stability of impacts to both media. – Institutional controls and potential additional remediation would be needed below the remediation depth and other zones to ensure long-term effectiveness/permanence in the event of future redevelopment.	**– High** – Targeted source removal would permanently and effectively limit the long-term potential for direct contact with impacted media. – Removal and grouting of MGP pipes in combination with source removal would effectively mitigate off-Site migration of MGP constituents *via* groundwater and soil vapor, thus promoting long-term attenuation and stability of impacts to both media. – Institutional controls and potential additional remediation would be needed in zones that are not remediated and other zones (*e.g.* , zones outside the excavation limits, soils at depth) to ensure long-term effectiveness/permanence in the event of future earthworking activities.	**– Low** – No assurance of long-term effectiveness because source material would be left in place and continue to impact soil, groundwater, and soil vapor.	**– Low** – No assurance of long-term effectiveness because source material would be left in place and continue to impact soil, groundwater, and soil vapor.
Reduction of Toxicity, Mobility, Volume (TMV) Through Treatment	**– High** – Source removal would permanently reduce the TMV of source material.	**– High** – Targeted source removal would permanently reduce the TMV of source material.	**– Low** – No reduction in TMV of source material.	**– Low** – No reduction in TMV of source material.
Short-term Effectiveness	**– Low** – Construction activities associated with source removal and piping removal/grouting could create short-term risks to apartment building residents and/or to workers (construction, outdoor, office) in the surrounding areas related to heavy equipment use, open excavation, fugitive dust and emissions, and/or stockpiled soils. – There will also be greater short-term impacts, disruptiveness, and inconvenience to surrounding properties associated with noise, emissions, dust, truck traffic, and equipment use during construction activities in comparison to Alternative 2 due to greater remedy duration. – The ROWs will not be usable during construction activities, creating potentially significant disruption.	**– Moderate** – Construction activities associated with source removal and piping removal/grouting could create short-term risks to apartment building residents and/or to workers (construction, outdoor, office) related to heavy equipment use, open excavation, fugitive dust and emissions, and/or stockpiled soils. – There will also be short-term impacts associated with noise, emissions, dust, truck traffic, and equipment during construction activities. – The ROWs may not be usable during construction activities, but work can be timed to coincide with City construction activities (*e.g.* , road paving, sewer work) to minimize disruption.	**– High** –– This alternative would pose no significant short-term risks to residents/workers and would not be intrusive.	**– High** – The baseline alternative would pose no significant short-term risks to workers and would not be intrusive.

Table 6.5c Evaluation of Remediation Alternatives, City ROWs

Evaluation Criteria	1 (Source Removal)	2 (Targeted Source Removal)	3 (Institutional/Engineering Controls Only)	4 (Baseline)
Implementability	**– Moderate** – Excavation is a reliable technology with a proven track record. – Equipment and contractors are available. – Obtaining access and permission to temporarily relocate utilities to remove all of the subsurface material beneath the ROWs is not likely. – Implementation challenges include procuring access to the property for the duration of the remedy, engineering controls needed to ensure worker/public safety during excavation, measures needed to minimize disruption to surrounding areas, and logistics associated with trucking material to the nearest landfill. – Less implementable than Alternative 2 because of the greater volume and depth of soil to be excavated.	**– High** – Excavation is a reliable technology with a proven track record. – Equipment and contractors are available. – Implementation challenges include procuring access to the property for the duration of the remedy, engineering controls needed to ensure worker/public safety during excavation, measures needed to minimize disruption to surrounding areas, and logistics associated with trucking material to the nearest landfill. – More implementable than Alternative 1 because of the lesser volume and depth of soil to be excavated.	**– High** – Institutional and engineering controls are implementable.	N/A
Cost	High cost due to greater volume and depth of soil to be excavated relative to Alternative 2. High uncertainty due to the extended duration of the required access agreement and the disruption caused to surrounding areas.	Moderate cost due to lesser volume and depth of soil to be excavated relative to Alternative 1. Moderate uncertainty due to design contingency based on the actual field conditions and logistical constraints encountered.	Low cost (relative to other alternatives). Low level of uncertainty.	N/A
Community Acceptance/ Regulatory Approval	Regulatory approval, community acceptance, and property access are unlikely due to the significant disruption caused by the approach.	– Regulatory approval is likely due to the protectiveness, effectiveness, and implementability of this approach. – Community acceptance and property access are likely given the prior success of this approach in Northern Pacific Avenue and in the alley south of United Refrigeration.	– Regulatory approval may be limited due to the potential risks posed by source material left in place. – Community acceptance may be moderate due to perceived risk issues associated with leaving source material in place. Property access will not be required for this alternative.	Regulatory approval is not expected because of the low degree of protectiveness and long-term potential risks to human health and the environment.
Conclusion	This alternative was not selected because of high cost, implementability challenges, and greater short-term impacts.	This alternative was selected because it offers a high level of effectiveness and protectiveness while also being implementable and cost-effective. It is also likely to receive regulatory approval.	This alternative was not selected because it does not reduce contaminant mass and there are associated long-term effectiveness and protectiveness concerns.	This alternative was not selected because the remedy offers a low level of overall protectiveness and is not likely to receive regulatory approval.

Notes:

MGP = Manufactured Gas Plant; N/A = Not Applicable; RAO = Remedial Action Objective; ROWs = Rights of Way.

The shaded cells highlight the selected remedial alternative.

6.6.4 Historic Union

The evaluation of remediation alternatives for the Historic Union property is presented in Table 6.5d. The preferred remedial approach for the Historic Union property is Alternative 2 (Targeted Source Removal), for the following reasons.

- Through the removal of source material, the elimination of preferential pathways (pipes), and the use of institutional/engineering controls, Alternative 2 (Targeted Source Removal) would provide a higher level of protectiveness and long-term effectiveness in comparison to Alternative 3 (Baseline). Alternative 1 (Source Removal) would remove more contaminant mass than Alternative 2, but Alternative 2 is adequately protective because it targets the more likely exposure zone. Engineering controls, such as placing a marker layer at the base of the excavation, would further promote protectiveness by controlling potential exposure to source material. Further, Alternative 1 would be costly, is less implementable, and poses greater short-term impacts, as discussed below. Alternative 3 was rejected because it would not remove or treat the impacted media at the property, and, thus, would not achieve the mass reduction- or risk reduction-related RAOs for the Site vicinity.
- Of the alternatives that are protective, Alternative 2 is the most readily implementable, and the challenges associated with property access, worker/public safety, disruptions to the community (*e.g.*, truck traffic), and disruption to building occupants and the public, while significant, can be managed and are lesser for Alternative 2 than for Alternative 1. Alternative 1 was eliminated in comparison to Alternative 2 based on its inferior implementability (*e.g.*, deeper excavation could pose structural stability issues for existing building), greater cost, and greater short-term impacts (*e.g.*, greater duration leads to more truck traffic; greater impact on property tenants and general public; air/odor issues).
- Of the alternatives that are protective, Alternative 2 is moderately cost-effective in comparison to Alternative 1 and has moderate cost uncertainty associated with it.
- Both Alternatives 1 and 2 are likely to receive regulatory approval because of their protectiveness, effectiveness, and implementability. Community acceptance and property access may be challenging for both alternatives, because they would both be disruptive to property occupants. However, as discussed above, Alternative 2 was selected over Alternative 1 because it would be the more cost-effective and implementable option and would have lesser short-term impacts.

The preferred remedial approach is based on the current use of the property and is contingent upon obtaining access to the property and regulatory approval.

Table 6.5d Evaluation of Remediation Alternatives, Historic Union Property

Evaluation Criteria	1 (Source Removal)	2 (Targeted Source Removal)	3 (Institutional/Engineering Controls Only)	4 (Baseline)
Overall Protection of Human Health/ Environment	**– High** – The source removal alternative would effectively mitigate the human health risk associated with direct exposure to impacted media by removing all source material currently identified on the Historic Union property. – Removal of source material would decrease the MGP contaminant flux to groundwater and soil vapors over time, thus enhancing the long-term attenuation and stability of impacts to both media and decreasing the long-term risks associated with exposure to MGP constituents. – Institutional controls (and potentially additional remediation) would be needed to protect receptors from exposure to impacted media in zones not remediated and other zones (*e.g.* , beneath the Historic Union building, soils at depth) in the event of future redevelopment.	**– High** – The targeted source removal alternative would effectively mitigate the human health risk associated with direct exposure to impacted media by removing source material in the vicinity of the piping along the western property boundary of the Historic Union property. – Removal of source material would decrease the MGP contaminant flux to groundwater and soil vapors over time, thus enhancing the long-term attenuation and stability of impacts to both media and decreasing the long-term risks associated with exposure to MGP constituents. – Institutional controls (and potentially additional remediation) would be needed to protect receptors from exposure to impacted media in zones not remediated and other zones (*e.g.* , beneath the Historic Union building, soils at depth) in the event of future redevelopment.	**– Low** – This alternative would offer a low level of protectiveness because the use of institutional/ engineering controls would limit direct exposure to impacted soil and groundwater.	**– Low** – The baseline alternative would not achieve RAOs and risk-based goals.
Long-term Effectiveness/ Permanence	**– High** – Source removal would permanently and effectively limit the long-term potential for direct contact with impacted media. – Removal and grouting of MGP pipes in combination with source removal would effectively mitigate off-Site migration of MGP constituents *via* groundwater and soil vapor, thus promoting long-term attenuation and stability of impacts to both media. – Institutional/engineering controls and potential additional remediation would be needed in zones that are not remediated and other zones (*e.g.* , beneath the Historic Union building, soils at depth) to ensure long-term effectiveness/permanence in the event of future redevelopment.	**– High** – Targeted source removal would permanently and effectively limit the long-term potential for direct contact to impacted media. – Removal and grouting of MGP pipes in combination with source removal would effectively mitigate off-Site migration of MGP constituents *via* groundwater and soil vapor, thus promoting long-term attenuation and stability of impacts to both media. – Institutional/engineering controls and potential additional remediation would be needed in zones that are not remediated and other zones (*e.g.* , beneath the Historic Union building, soils at depth) to ensure long-term effectiveness/permanence in the event of future redevelopment.	**– Low** – No assurance of long-term effectiveness because source material would be left in place and continue to impact soil, groundwater, and soil vapor.	**– Low** – No assurance of long-term effectiveness because source material would be left in place and continue to impact soil, groundwater, and soil vapor.
Reduction of Toxicity, Mobility, Volume (TMV) Through Treatment	**– High** – Source removal would permanently reduce the TMV of source material.	**– High** – Targeted source removal would permanently reduce the TMV of source material.	**– Low** – No reduction in TMV of source material.	**– Low** – No reduction in TMV of source material.
Short-term Effectiveness	**– Low** – Construction activities associated with source removal and piping removal/grouting would create short-term risks to workers (construction, outdoor, office) related to heavy equipment use, open excavation, fugitive dust and emissions, and/or stockpiled soils. These risks can be mitigated through the use of PPE, resident relocation, and/or engineering controls. – There will also be greater short-term impacts, disruptiveness, and inconvenience to surrounding properties associated with noise, emissions, dust, truck traffic, and equipment use during construction activities in comparison to Alternative 2 due to greater remedy duration.	**– Moderate** – Construction activities associated with source removal and piping removal/grouting would create short-term risks to workers (construction, outdoor, office) related to heavy equipment use, open excavation, fugitive dust and emissions, and/or stockpiled soils. These risks can be mitigated through the use of PPE, resident relocation, and/or engineering controls. – There will also be short-term impacts, disruptiveness, and inconvenience associated with noise, emissions, dust, truck traffic, equipment, and restricted access to certain areas during construction activities.	**– High** –– This alternative would pose no significant short-term risks to workers and would not be intrusive.	**– High** – Baseline alternative would pose no significant short-term risks to workers and residents at the Historic Union property and would not be intrusive.

Table 6.5d Evaluation of Remediation Alternatives, Historic Union Property

Evaluation Criteria	1 (Source Removal)	2 (Targeted Source Removal)	3 (Institutional/Engineering Controls Only)	4 (Baseline)
Implementability	**– Moderate** – Excavation is a reliable technology with a proven track record. – Equipment and contractors are available. – Implementation challenges include procuring access to the Historic Union property for the duration of the remedy, potential for undercutting the building, engineering controls needed to ensure resident/worker/public safety during excavation, measures needed to minimize disruption to occupants of the Historic Union property, and the logistics associated with trucking material to the nearest landfill. – Less implementable than Alternative 2 because of the greater volume and depth of soil to be excavated.	**– High** – Excavation is a reliable technology with a proven track record. – Equipment and contractors are available. – Implementation challenges include procuring access to the Historic Union property for the duration of the remedy, engineering controls needed to ensure resident/worker/public safety during excavation, measures needed to minimize disruption to occupants of the Historic Union property, and the logistics associated with trucking material to the nearest landfill. – More implementable than Alternative 1 because of the lesser volume and depth of soil to be excavated.	**– High** – Institutional and engineering controls are implementable.	N/A
Cost	High cost due to greater volume and depth of soil to be excavated relative to Alternative 2. Moderate uncertainty due to design contingency based on the actual field conditions and logistical constraints encountered.	Moderate cost due to lesser volume and depth of soil to be excavated relative to Alternative 1. Moderate uncertainty due to design contingency based on the actual field conditions and logistical constraints encountered.	Low cost (relative to other alternatives). Low level of uncertainty.	N/A
Community Acceptance/ Regulatory Approval	– Regulatory approval is likely due to the protectiveness, effectiveness, and implementability of this approach. – Community acceptance and property access may be challenging because third party access is required and because the remedy would be more intrusive and longer in duration in comparison to the baseline alternative and Alternative 2.	– Regulatory approval is likely due to the protectiveness, effectiveness, and implementability of this approach. – Community acceptance and property access are less challenging than Alternative 1 due to shorter duration of this alternative.	– Regulatory approval may be limited due to the potential risks posed by source material left in place. – Community acceptance may be moderate due to perceived risk issues associated with leaving source material in place. Property access will not be required for this alternative.	Regulatory approval is not expected because of the low degree of protectiveness and the long-term potential risks to human health and the environment.
Conclusion	This alternative was not selected because of the high cost, implementability challenges, and greater short-term impacts.	This alternative was selected because it offers a high level of effectiveness and protectiveness while also being implementable and cost-effective. It is also likely to receive regulatory approval.	This alternative was not selected because it does not reduce contaminant mass and there are associated long-term effectiveness and protectiveness concerns.	This alternative was not selected because the remedy offers a low level of overall protectiveness and is not likely to receive regulatory approval.

Notes:

MGP = Manufactured Gas Plant; N/A = Not Applicable; NAPL = Non-aqueous Phase Liquid; PPE = Personal Protective Equipment; RAO = Remedial Action Objective.

The shaded cells highlight the selected remedial alternative.

6.6.5 Culligan

The evaluation of remediation alternatives for the Culligan property is presented in Table 6.5e. The preferred remedial approach for the Culligan property is Alternative 1 (Targeted Source Removal), for the following reasons.

- Through the removal of source material, the elimination of preferential pathways (pipes), and the use of institutional/engineering controls, Alternative 1 (Targeted Source Removal) would provide a significantly higher level of protectiveness and long-term effectiveness in comparison to Alternative 2 (Baseline). Engineering controls, such as placing a marker layer at the base of the excavation, would further promote protectiveness by controlling potential exposure to source material.
- Alternative 1 is a readily implementable and cost-effective option. Any challenges associated with property access, worker/public safety, disruptions to the community (*e.g.*, truck traffic), and disruption to building occupants, while significant, can be managed. Further, it is likely to receive regulatory approval because of its protectiveness, effectiveness, and implementability. Community acceptance and property access may be challenging, because it would be more temporarily disruptive to tenants. However, proactive communication can be used to gain community acceptance.
- Alternative 2 (Baseline) was rejected because it would not remove or treat the impacted media at the property, and thus, would not achieve the mass reduction- or risk reduction-related RAOs for the Site vicinity. Further, for this reason, it is not likely to receive regulatory approval.

The preferred remedial approach is based on the current use of the property and is contingent upon obtaining access to the property and regulatory approval.

Table 6.5e Evaluation of Remediation Alternatives, Culligan Property

Evaluation Criteria	1 (Targeted Source Removal)	2 (Institutional/Engineering Controls Only)	3 (Baseline)
Overall Protection of Human Health/Environment	**– High** – Targeted source removal alternative would effectively mitigate the human health risk associated with direct exposure to impacted media by removing source material in the vicinity of piping along the eastern property boundary. – Removal of source material would decrease the MGP contaminant flux to groundwater and soil vapors over time, thus enhancing the long-term attenuation and stability of impacts to both media and decreasing long-term risks associated with exposure to MGP constituents. – Institutional controls (and potentially additional remediation) could be needed to protect receptors from exposure to impacted media in zones that are not remediated and other zones in the event of future redevelopment.	**– Low** – This alternative would offer a low level of protectiveness because the use of institutional/ engineering controls would limit direct exposure to impacted soil and groundwater.	**– Low** – The baseline alternative would not achieve RAOs and risk-based goals.
Long-term Effectiveness/ Permanence	**– High** – Targeted source removal would permanently and effectively limit the long-term potential for direct contact to impacted media. – Removal and grouting of MGP pipes in combination with source removal would effectively mitigate off-Site migration of MGP constituents *via* groundwater and soil vapor, thus promoting long-term attenuation and stability of impacts to both media. – Institutional controls and potential remediation could be needed in zones that are not remediated and other zones to ensure long-term effectiveness/ permanence in the event of future redevelopment.	**– Low** – No assurance of long-term effectiveness, because source material would be left in place and continue to impact soil, groundwater, and soil vapor.	**– Low** – No assurance of long-term effectiveness because source material would be left in place and continue to impact soil, groundwater, and soil vapor.
Reduction of Toxicity, Mobility, Volume (TMV) Through Treatment	**– High** – Targeted source removal would permanently reduce the TMV of source	**– Low** – No reduction in TMV of source material.	**– Low** – No reduction in TMV of source material.
Short-term Effectiveness	**– Moderate** – Construction activities associated with source removal and piping removal/ grouting would create short-term risks to workers (construction, outdoor, office) related to heavy equipment use, open excavation, fugitive dust and emissions, and/or stockpiled soils. These risks can be mitigated through the use of PPE, resident relocation, and/or engineering controls. – There will also be short-term impacts and disruptiveness associated with noise, emissions, dust, truck traffic, and equipment during construction activities.	**– High** – This alternative would pose no significant short-term risks to workers and would not be intrusive.	**– High** – The baseline alternative would pose no significant short-term risks to workers at the Culligan property and would not be intrusive.

Table 6.5e Evaluation of Remediation Alternatives, Culligan Property

Evaluation Criteria	1 (Targeted Source Removal)	2 (Institutional/Engineering Controls Only)	3 (Baseline)
Implementability	**– High** – Excavation is a reliable technology with a proven track record. – Equipment and contractors are available. – Implementation challenges include procuring access to the Culligan property for the duration of the remedy, the potential for undercutting the building, engineering controls needed to ensure worker/public safety during excavation, measures needed to minimize disruption to occupants of the Culligan property, and the logistics associated with trucking material to the nearest landfill.	**– High** – Institutional and engineering controls are implementable.	N/A
Cost	Moderate cost. Moderate uncertainty due to design contingency based on actual field conditions and logistical constraints encountered.	Low cost (relative to other alternatives). Low level of uncertainty.	N/A
Community Acceptance/ Regulatory Approval	– Regulatory approval is likely due to the protectiveness, effectiveness, and implementability of this approach. – Community acceptance and property access may be challenging because third party access is required and because the remedy would be more intrusive and longer in duration in comparison to the baseline alternative.	– Regulatory approval may be limited due to the potential risks posed by source material left in place. – Community acceptance may be moderate due to perceived risk issues associated with leaving source material in place. Property access will not be required for this alternative.	Regulatory approval is not expected because of the low degree of protectiveness and long-term potential risks to human health and environment.
Conclusion	This alternative was selected because it offers a high level of effectiveness and protectiveness while also being implementable and cost-effective. It is also likely to receive regulatory approval.	This alternative was not selected because it does not reduce contaminant mass and there are associated long-term effectiveness and protectiveness concerns.	This alternative was not selected because the remedy offers a low level of overall protectiveness and not likely to receive regulatory approval.

Notes:

MGP = Manufactured Gas Plant; N/A = Not Applicable; PPE = Personal Protective Equipment; RAO = Remedial Action Objective.

The shaded cells highlight the selected remedial alternative.

6.7 Conceptual Remedy Layout

A conceptual remedy layout for the Site and its vicinity was created for the targeted source removal options at each property that were selected based on the comparative analysis. This conceptual remedy will be refined through a remedial design process and adjusted as necessary based on the conditions encountered in the field during implementation and subject to access and cooperation from the property owners. Further, this conceptual remedy is based on current use of the properties and is contingent upon obtaining access to the properties and regulatory approval.

The potential source material or risk-driving locations highlighted in Figure 6.1 were used to guide the areas targeted for excavation. Figure 6.1 does not include areas that initially contained source material but were excavated and properly disposed of during the course of the Site investigation (Carlson McCain, 2015a,b,c; see Attachment J); these locations are shown in Figure 6.2. The samples shown on Figure 6.2 are pre-remediation samples (*i.e.*, samples taken from material that was later removed) and no longer require remediation.

The planned remediation areas for the Site and its vicinity are shown in Figure 6.3. Consistent with Gradient (2016), a vapor intrusion mitigation system will be installed at the Heartland property (subject to access and cooperation from the property owner). Targeted source removal excavations will be completed in the Heartland property northern parking lot (up to 8 ft bgs), the eastern portion of the URI property parking lot (up to 5 ft bgs), and along the Historic Union and Culligan property boundaries (up to 8 ft bgs). Shallow soil removal (up to 2 ft bgs) will also be completed on the remainder of the Heartland property northern parking lot, the northern section of the Heartland property eastern lawns, and the remainder of the URI property parking lot. Additionally, marker layers will be placed at the base of each excavation as a clear indication of areas below which impacted material might still be present.

Deeper targeted source removal excavations (up to 12 ft bgs) will be performed in the Heartland property southern parking lot in the areas of the former tar settling tanks, tar well, and portions of the former retorts (Figure 6.3). Shallow soil removal (up to 2 ft bgs) will be completed on the rest of the Heartland property southern parking lot. Excavations in 12th Street North to remove grouted gas holder supply lines and along utility piping (up to 8 ft bgs) will be completed during future street reconstruction work, with timing to be coordinated with the City of Fargo.

Institutional controls, including soil, groundwater, and/or vapor management plans (as appropriate) will be implemented for the former MGP Site and the areas in the immediate vicinity to achieve RAOs at all the properties. A monitoring plan utilizing the permanent monitoring network established for the RI (Figure 6.4) will be created to assess the stability and attenuation of impacts during and after remedy implementation.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 1995. "Toxicological profile for Stoddard Solvent." June. Accessed at http://www.atsdr.cdc.gov/toxprofiles/tp79.pdf.

Agency for Toxic Substances and Disease Registry (ATSDR). 2007. "Toxicological Profile for Lead." 582p., August. Accessed at http://www.atsdr.cdc.gov/toxprofiles/tp13.pdf.

Barr Engineering Co. (Barr). 2015a. "Field Investigation Work Plan, NP Avenue Right of Way Between North University Drive and 11th Street North, Fargo, North Dakota (Draft)." Report to Northern States Power Co. 13p., July 21.

Barr Engineering Co. (Barr). 2015b. "Vapor Assessment Work Plan, Former Union Storage and Transfer Complex, Fargo, North Dakota (Draft)." Report to Northern States Power Co. 18p., July 23.

Barr Engineering Co. (Barr). 2015c. Technical Memorandum by S. Gaffin and M. Sands to A. Peterson (Northern States Power Co.) re: NP Avenue Right-of-Way Investigation Results (Draft). 146p., October 5.

Barr Engineering Co. (Barr). 2015d. Technical Memorandum by S. Gaffin, R. Heimbach, and M. Sands to A. Peterson (Northern States Power Co.) re: Historic Union Complex Investigation Results (Draft). 432p., October 5.

Barr Engineering Co. (Barr). 2015e. Technical Memorandum by S. Gaffin, R. Heimbach, and M. Sands to A. Peterson (Northern States Power Co.) re: United Refrigeration, Inc. Property Investigation Results (Draft). 468p., December 21.

Barr Engineering Co. (Barr). 2015f. Technical Memorandum by S. Gaffin, R. Heimbach, and M. Sands to A. Peterson (Northern States Power Co.) re: Heartland Apartments Property Investigation Results (Draft). 282p., December 21.

Barr Engineering Co. (Barr). 2015g. Technical Memorandum by S. Gaffin, R. Heimbach, and M. Sands to A. Peterson (Northern States Power Co.) re: 11th and 12th Streets North Rights-of-Way Investigation Results (Draft). 509p., December 21.

Barr Engineering Co. (Barr). 2015h. Technical memorandum by E. Lund and M. Sands to K. Carney and A. Peterson (Xcel Energy) re: Northern Pacific Avenue right-of-way investigation results. Report to Northern States Power Co. 183p., August 14.

Barr Engineering Co. (Barr). 2015i. "Heartland surface soils sampling field notes." 4p., November.

Barr Engineering Co. (Barr). 2016a. "Attachment A01: Preliminary Investigation of the Fargo MGP Site Work Plan Addendum 01 - United Refrigeration, Inc., Fargo, Cass County, North Dakota." Report to Northern States Power Co. 14p., April 1.

Barr Engineering Co. (Barr). 2016b. "Attachment B01: Preliminary Investigation of the Fargo MGP Site Work Plan Addendum 02 - Heartland Apartments, Fargo, Cass County, North Dakota." Report to Northern States Power Co. 18p., April 1.

Barr Engineering Co. (Barr). 2016c. "Attachment C01: Preliminary Investigation of the Fargo MGP Site Work Plan Addendum 03 - City of Fargo Rights-of-Way, Fargo, Cass County, North Dakota." Report to Northern States Power Co. 15p., April 1.

Barr Engineering Co. (Barr). 2016d. "Attachment D01: Preliminary Investigation of the Fargo MGP Site Work Plan - Culligan Property, Fargo, Cass County, North Dakota." Report to Northern States Power Co. 21p., April 1.

Barr Engineering Co. (Barr). 2016e. "Preliminary Investigation of the Fargo MGP Site Work Plan – Supplement 01: United Refrigeration, Inc., Heartland Apartments, City of Fargo Rights-of-Way, Culligan, Fargo, Cass County, North Dakota." Report to Northern States Power Co. 24p., April 1

Barr Engineering Co. (Barr). 2016f. "Preliminary Investigation of the Fargo MGP Site Work Plan - 1213 NP Avenue Property - East Building (Draft)." Report to Northern States Power Co. 14p., September 16.

Barr Engineering Co. (Barr). 2016g. Technical Memorandum to A. Peterson (Northern States Power Co.) re: City Rights-of-Way Investigation Results (Draft). 794p., August 30.

Barr Engineering Co. (Barr). 2016h. Technical Memorandum to A. Peterson (Northern States Power Co.) re: Culligan Property Investigation Results (Draft). 321p., August 30.

Barr Engineering Co. (Barr). 2016i. Technical Memorandum to A. Peterson (Northern States Power Co.) re: Heartland Apartments Property Investigation Results (Draft). 1,611p., August 30.

Barr Engineering Co. (Barr). 2016j. Technical Memorandum to A. Peterson (Northern States Power Co.) re: Historic Union Complex Monitoring Results (Draft). 329p., August 30.

Barr Engineering Co. (Barr). 2016k. Technical Memorandum to A. Peterson (Northern States Power Co.) re: United Refrigeration, Inc. Property Investigation Results (Draft). 323p., August 30.

Barr Engineering Co. (Barr). 2016l. "Technical Memorandum to A. Peterson (Northern States Power Co.) re: 1213 NP Ave Property Investigation Results (Draft)." 118p., November 1.

Barr Engineering Co. (Barr). 2016m. "Quality Assurance Project Plan, Former Fargo MGP Site, Fargo, North Dakota (Revision 1.0)." Report to Northern States Power Co. 2,141p., April.

Barr Engineering Co. (Barr). 2016n. Internal memorandum to A. Peterson (Xcel Energy) re: Cyanide analytical methods summary and recommendations. 7p., March 21.

Barr Engineering Co. (Barr). 2016o. Internal memorandum by D. Pasi and W. Swanson to M. Sands and R. Heimbach re: Cyanide summary and recommendations. 4p., January 15.

Barr Engineering Co. (Barr). 2016p. "Apartment Building Layout, Heartland Apartments, Fargo, ND. (Draft)." Prepared for Xcel Energy. 1p., January 13.

Beck, BD; Seeley, MR; Ghosh, RS; Drivas, PJ; Shifrin, NS. 2006. "Human health risk assessment of cyanide in water and soil." In *Cyanide in Water and Soil: Chemistry, Risk, and Management*. (Eds.: Dzombak, D; Ghosh, R., Wong-Chong, GM), Taylor & Francis, Boca Raton, FL. p309-330.

Bowers, TS; Shifrin, NS; Murphy, BL. 1996. "Statistical approach to meeting soil cleanup goals." *Environ. Sci. Technol.* 30(5):1437-1444. Accessed at http://pubs.acs.org/doi/pdf/10.1021/es9407047.

Bradley, LJN; Magee, BH; Allen, SL. 1994. "Background levels of polycyclic aromatic hydrocarbons (PAH) and selected metals in New England urban soils." *J. Soil Contam.* 3(4):349-361.

Byllesby Engineering & Management Corp.; H.M. Byllesby & Co.; Northern States Power Co. 1911-1958. "Fargo MGP engineering drawings."

Carlson McCain. 2015a. "Street Reconstruction Environmental Oversight North Pacific Avenue: North Pacific Avenue between 10th and 12th Streets North (Draft)." Report to Northern States Power Co. December 22.

Carlson McCain. 2015b. "Fargo Manufactured Gas Plant Pipe Removal Report, North Pacific Avenue between 10th Street North and 12th Street North (Draft)." Report to Northern States Power Co. d/b/a Xcel Energy. 354p., October 2.

Carlson McCain. 2015c. "MGP Pipe Removal Report, Union Storage & Transfer Property, 1120 North Pacific Avenue, Fargo, North Dakota (Revised Draft)." Report to Northern States Power Co. d/b/a Xcel Energy. 14p., August 11.

Cass County, North Dakota. 2015. "Cass County Roads Shapefile." GIS Dept. Accessed at https://www.casscountynd.gov/county/depts/GIS/Pages/GISHome.aspx.

Coss, T. [Xcel Energy]. 2015. Letter to C. Erikson (North Dakota Dept. of Health) re: Fargo Manufactured Gas Plant site investigation. 4p., August 28.

Dewey, AL. 1913a. "James Kennedy's asphalt plant, Fargo, N.D." North Dakota State University Libraries, Institute for Regional Studies (Fargo, ND), rs007641, July 25. Accessed at http://digitalhorizonsonline.org/cdm/singleitem/collection/uw/id/8361/rec/1.

Dewey, AL. 1913b. "James Kennedy's Asphalt Plant, Fargo, N.D." North Dakota State University Libraries, Institute for Regional Studies. rs007642, July 25. Accessed at http://digitalhorizonsonline.org/cdm/singleitem/collection/uw/id/8360/rec/1.

Environmental Data Resources, Inc. 2016. "11 12th St N, Fargo, ND 58102: The EDR Radius Map™ Report." 147p., April 14.

Environmental Research and Technology, Inc.; Koppers Co., Inc. 1984. "Handbook on Manufactured Gas Plant Sites." Report to Utility Solid Waste Activities Group, Superfund Committee, Edison Electric Institute. September.

Environmental Systems Research Institute (ESRI). 2016a. "World Topographic Map." February 5. Accessed at http://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f.

Environmental Systems Research Institute (ESRI). 2016b. "World Imagery: Aerial imagery web mapping service." February 8. Accessed at https://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9.

Fargo, North Dakota. 2012. "GO2030 Fargo Comprehensive Plan." Dept. of Planning and Development. 268p., May 24. Accessed at https://www.cityoffargo.com/attachments/7af68cf9-8314-4c94-a7ed-93c08f457bd8/_GO2030%20Comprehensive%20Plan%20-%20final.pdf.

Fargo, North Dakota. 2015a. "Fargo GIS public map service." Accessed at http://gis.cityoffargo.com/Link/jsfe/index.aspx.

Fargo, North Dakota. 2015b. "City of Fargo Parcels Shapefile." Accessed at http://gis.cityoffargo.com/Link/jsfe/index.aspx.

Fargo, North Dakota. 2015c. "City of Fargo Utility Lines GIS file." September 30.

Fargo, North Dakota. 2016. "Parcel Information Database." Accessed at http://www.fargoparcels.com/index.asp.

Gradient. 2015a. "Work Plan – Preliminary Investigation of the Fargo Manufactured Gas Plant (MGP) Site: United Refrigeration, Inc. Property, Heartland Apartments Property, 11th and 12th Street North Rights of Way, Fargo, Cass County, North Dakota." Report to Northern States Power Co., Minneapolis, MN. October 5.

Gradient. 2015b. "Historical Review of the Fargo Manufactured Gas Plant." Report to Northern States Power, Minneapolis, MN. 82p., October 9.

Gradient. 2016. "Preliminary Evaluation of the Vapor Intrusion Pathway and Comparative Analysis of Alternatives, Heartland Apartments Property, Fargo Former MGP Site, Fargo, Cass County, North Dakota." Report to Northern States Power Co. 55p., April 1.

Great Plains Environmental. 1994. "Environmental Site Investigation, Berke Block, Fargo, North Dakota." Report to First Trust Bank. 5p., October 14.

Heimbach, R; Sands, M. [Barr Engineering Co.]. 2016. Letter to C. Erickson (North Dakota Dept. of Health [NDDH]) re: Former Fargo MGP Site - Draft 12th Street Sewer Corridor Excavation and Pipe Grouting Work Plan. 5p., July 18.

Holzkamm, T; Dormanen, D. 2001. "The History and Growth of the City of Fargo: Historic Context Study (Revised Edition)." Fargo Historic Preservation Commission, Fargo, ND. 74p.

Humble Oil and Refining Co. 1972. Letter to W. Groth (Fargo, North Dakota Fire Dept.) re: Surplus Humble Oil Co. Services Station, N. University and N.P. Ave. 1p., April 27.

International Water Institute. 2016. "LiDAR digital elevation model (DEM)." Red River Basin Decision Information Network. Accessed at http://gis.rrbdin.org/lidardownload/index.html.

Minnesota Pollution Control Agency (MPCA). 2009. "Summary of Tier 2 Industrial Soil Reference Value Information." Site Remediation Section, June.

Morrison Knudsen Corp. 1994. "Preliminary Assessment, Fargo Town Gas Site, Fargo, North Dakota." Report to US EPA Region VIII. 41p., February 22.

National Archives and Records Administration (NARA). 1937. "Aerial image of Fargo, North Dakota and surrounding area." AAB-69-20, October 15.

National Oceanic and Atmospheric Administration (NOAA). 2002. "Fargo, North Dakota Climate." Report to National Oceanic and Atmospheric Administration (NOAA), National Weather Service Central Region, Scientific Services Division. 165p., April. Accessed at http://climate.umn.edu/pdf/fargo_climate.pdf.

New Jersey Dept. of Environmental Protection (NJDEP). 2008. "Chemical Properties for Calculation of Impact to Ground Water Soil Remediation Standards." Site Remediation Program, 4p. Accessed at http://www.nj.gov/dep/srp/guidance/rs/chemproperties.pdf.

North Dakota Department of Health (NDDH). 2015. Letter from M. Mittelsteadt to B. Ehlis (Wenck Associates, Inc.) re: No further action letter. 1p., January 23.

North Dakota Dept. of Health (NDDH). 2003. Letter to D. Liffrig [re: Environmental Site Investigation Report prepared by Great Plains Environmental for the Jacque Stockman Property]. 1p., September 26.

North Dakota Dept. of Health (NDDH). 2006a. "Environmental Site Investigation Report." 4p., November.

North Dakota Dept. of Health (NDDH). 2006b. "Guidelines for Investigations of Contaminant Release Sites." 6p., November.

North Dakota Geological Survey. 1974. "Physical Data for Land-Use Planning, Cass County, North Dakota and Clay County, Minnesota: An Inventory of Mineral, Soil, and Water Resources." Report to Fargo-Moorhead Metropolitan Council of Governments. North Dakota Geological Survey Report of Investigation 54. 29p.

North Dakota Information Technology Department; North Dakota GIS Technical Committee. 2016. "Well and aquifer locations." Accessed at https://www.nd.gov/itd/statewide-alliances/gis.

North Dakota State Water Commission. 2016. "Groundwater/surface water data." Accessed at http://www.swc.nd.gov/info_edu/map_data_resources/groundsurfacewater.

Northern States Power Co. (NSP). 1925. "September 25: Fargo old gas plant [photograph]." Northern States Power Co. 003_Page 1-1.

Northern States Power Co. (NSP); Wallwork, W.W. Fargo, Inc. 1966. "Lease and agreement between North States Power Company and Wallwork, W.W. Fargo Inc. re: Block 40, Roberts Second Addition to the City of Fargo exclusive of the land occupied by the Garage and Warehouse." 10p., April 1.

Northern Technologies, Inc. (NTI). 2014. "Geotechnical Exploration and Engineering Review, Union Storage Building Remodel, Fargo, North Dakota." Report to Northern States Power Co. 239p., September 2.

Research Triangle Institute (RTI). 1988. "US Production of Manufactured Gases: Assessment of Past Disposal Practices." Report to US EPA, Office of Research and Development. EPA-600/2-88-01, 410p., February.

Sanborn Fire Insurance Maps. 1888-1969. "Certified Sanborn Map Report: 11 12th St. North, Fargo, ND 58102 [Source maps dated 1888-1969] – Block 41." 22p., July 31.

Sanborn Fire Insurance Maps. 1896. "Certified Sanborn Map Report: 11 12th St. North, Fargo, ND 58102 [Source maps dated 1888-1969] – Block 41." 22p., July 31.

Stanek, EJ III; Calabrese, EJ; Xu, B. 2012a. "Meta-analysis of mass-balance studies of soil ingestion in children." *Risk Anal.* 32(3):433-447.

Stanek, EJ III; Xu, B; Calabrese, EJ. 2012b. "Equation reliability of soil ingestion estimates in mass-balance soil ingestion studies." *Risk Anal.* 32(3):448-463.

Stanek, EJ; Calabrese, EJ; Barnes, R; Pekow, P. 1997. "Soil ingestion in adults - Results of a second pilot study." *Ecotoxicol. Environ. Saf.* 36:249-257.

Syracuse Research Corp. 2007. "User's Guide for the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) [Windows version]." Report to US EPA, Office of Superfund Remediation and Technology Innovation, Technical Review Workgroup for Metals and Asbestos (TRW). EPA 9285.7-42; EPA 540-K-01-005. 59p., May. Accessed at https://semspub.epa.gov/work/11/176289.pdf.

Union Light, Heat, and Power Co. 1920. "Union Light, Heat, and Power Co. Real Estate Plans." 5p., July 1.

University of Florida. 2005. "Technical Report: Development of Cleanup Target Levels (CTLs) for Chapter 62-777, F.A.C (Final)." Center for Environmental & Human Toxicology. Report to Florida, Dept. of Environmental Protection, Division of Waste Management. 310p., February.

US EPA Region V. 2010. "Record of Decision for Ashland/Northern States Power Lakefront Site, Ashland, Wisconsin." 433p., September.

US EPA. 1988. "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (Interim final)." Office of Emergency and Remedial Response. OSWER Directive 9335.3-01; EPA-540/G-89-004. 186p., October.

US EPA. 1989a. "Risk Assessment Guidance for Superfund (RAGS). Volume I: Human Health Evaluation Manual (Part A) (Interim final)." Office of Emergency and Remedial Response, NTIS PB90-155581, EPA-540/1-89-002, 287p., December.

US EPA. 1989b. "The Feasibility Study: Development and Screening of Remedial Action Alternatives." Office of Solid Waste and Emergency Response (OSWER). OSWER Directive 9355.3-01FS3. 4p., November. Accessed at https://semspub.epa.gov/work/HQ/174411.pdf.

US EPA. 1991. "Risk Assessment Guidance for Superfund (RAGS). Volume I: Human Health Evaluation Manual - Supplemental Guidance: Standard Default Exposure Factors (Interim final)." Office of Emergency and Remedial Response. OSWER Directive 9285.6-03; NTIS PB91-921314. 20p., March 25.

US EPA. 1993. "Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons (Final)." Environmental Criteria and Assessment Office, EPA/600/R-93/089, 24p., July.

US EPA. 1994. "Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children." Technical Review Workgroup for Lead. Report to US EPA, Office of Emergency and Remedial Response. OERR Publication 9285.7-15-1, EPA540-R-93-081, NTIS PB93-963510, February.

US EPA. 1995. Memorandum to EPA Regional Directors re: Land use in the CERCLA remedy selection process. Office of Solid Waste and Emergency Response (OSWER). OSWER Directive No. 9355.7-04. 11p., May 25.

US EPA. 1997. "Explanation of Significant Differences, Sediment Operable Unit, Fields Brook Site, Ashtabula, Ohio." EPA/ESD/R05-97/070. 19p., August 15.

US EPA. 2002a. "Technical Approaches to Characterizing and Cleaning up Brownfields Sites: Railroad Yards." Office of Research and Development, National Risk Management Research Laboratory. EPA/625/R-02/007. 83p., July.

US EPA. 2002b. "Supplemental guidance for developing soil screening levels for Superfund sites." Office of Solid Waste and Emergency Response (OSWER). OSWER 9355.4-24. 187p., December.

US EPA. 2003. "Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil." Technical Review Workgroup for Lead. Report to US EPA, Office of Solid Waste and Emergency Response/Office of Emergency and Remedial Response (Washington, DC) EPA-540-R-03-001; OSWER Directive 9285.7-54, January.

US EPA. 2004. "Risk Assessment Guidance for Superfund (RAGS). Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) (Final)."Office of Superfund Remediation and Technology Innovation, EPA/540/R/99/005, OSWER 9285.7-02EP, PB99-963312, 156p., July.

US EPA. 2011. "Exposure Factors Handbook: 2011 Edition." Office of Research and Development. National Center for Environmental Assessment (NCEA). EPA/600/R-090/052F. 1,436p., September.

US EPA. 2012. "Standard Operating Procedures for Residential Pesticide Exposure Assessment." Office of Chemical Safety and Pollution Prevention, Office of Pesticide Programs, Health Effects Division, 582p., October.

US EPA. 2014. Memorandum from D. Stalcup (Office of Solid Waste and Emergency Response) to Superfund National Policy Managers, Regions 1-10 re: Human Health Evaluation Manual, Supplemental Guidance: Update of standard default exposure factors. OSWER Directive 9200.1-120, 7p., February 6.

US EPA. 2015. "Vapor Intrusion Screening Level (VISL) Calculator (Version 3.4.2)." Office of Solid Waste and Emergency Response (OSWER), September 3.

US EPA. 2016. "Regional Screening Level (RSL) Summary Table (TR=1E-6, HQ=0.1)." 11p., May.

US Geological Survey (USGS). 2001. "Geochemistry of Soils from the PLUTO Database." Accessed at http://tin.er.usgs.gov/pluto/soil.

US Geological Survey (USGS). 2005. "Major- and Trace-Element Concentrations in Soils from Two Continental-Scale Transects of the United States and Canada." USGS Open-File Report 2005-1253. Accessed at http://pubs.usgs.gov/of/2005/1253.

US Geological Survey (USGS). 2011. "Trace Elements and Radon in Groundwater Across the United States, 1992-2003." USGS Scientific Investigations Report 2011–5059. 131p.

Various. 1992-2007. "North Dakota Dept. of Health documentation re: 30 University Drive, Fargo, North Dakota." 161p.

Virginia Dept. of Environmental Quality (VADEQ). 2014. "Table 2.13: Groundwater: Construction worker." August 12. Accessed at http://www.deq.virginia.gov/Programs/LandProtectionRevitalization/RemediationProgram/VoluntaryRemediationProgram/VRPRiskAssessmentGuidance/Tables.aspx.

Wenck Associates, Inc. (Wenck). 2015a. "Corrective Action Implementation Report for a Fuel Oil UST Basin 1026 NP Avenue, Fargo, ND." Report to 1026 NP Avenue LLP. 73p., January.

Wenck Associates, Inc. (Wenck). 2015b. "Supplemental Phase II Environmental Site Assessment and Pilot Test Report, Former Dry Cleaner Site, 20 University Drive, Fargo, North Dakota." Report to Fredrick Estate. 195p., October 5.

Wenck Associates, Inc. (Wenck); Benker, A. [North Dakota Dept. of Health (NDDH)]. 2015. "Technical Memorandum to C. Erickson (North Dakota Dept. of Health (NDDH)) re: 20 University Drive, Fargo, North Dakota." 4p., December 28.

Wisconsin Dept. of Natural Resources (WDNR). 2002. "White Paper No. 11 - Comparison of SQTs, RALs, RAOs, and SWACs for the Lower Fox River: Response to Public Comments Received." 7p., December.

Xcel Energy. Undated. "Miscellaneous maps provided by Xcel Energy." 29p.

Zonge International, Inc. 2015. "Data Acquisition and Processing Report, Ground Penetrating Radar Survey and Transient Electromagnetic Survey in Fargo, North Dakota for Barr Engineering Inc." 73p., December 10.