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Flint Hills Resources Alaska, LLC

Revised Interim Remedial Action Plan Addendum

North Pole Refinery
North Pole, Alaska

July 31, 2013

ARCADIS

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Acronyms and Abbreviations

AAC	Alaska Administrative Code
ACL	alternative cleanup level
Addendum	Interim Remedial Action Plan Addendum
ADEC	Alaska Department of Environmental Conservation
ARCADIS	ARCADIS U.S., Inc.
AS	air sparge/air sparging
ASTM	ASTM International
AWS	alternative water solutions
Barr	Barr Engineering Company
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylene
city	North Pole, Alaska
COC	constituent of concern
COPC	constituent of potential concern
CSM	conceptual site model
DNR	Alaska Department of Natural Resources
DO	dissolved oxygen
DPR	dual-phase recovery
DRO	diesel range organics
Ecological CSM	Ecological Conceptual Site Model
FHRA	Flint Hills Resources Alaska, LLC
GAC	granular activated carbon
GC/MS	gas chromatography/mass spectrometry
gpm	gallons per minute
GRO	gasoline range organics

GVEA	Golden Valley Electric Association
IRAP	Interim Remedial Action Plan
IRM	Interim Remedial Measure
ITRC	Interstate Technology and Regulatory Council
LNAPL	light nonaqueous phase liquid
MCL	maximum contaminant level
NPR	North Pole Refinery
NSZD	natural source zone depletion
O&M	operation, maintenance, and monitoring
Onsite FS	Onsite Feasibility Study
POE treatment system	Point-of-Entry in-home water treatment system
Revised Draft Final HHRA	Revised Draft Final Human Health Risk Assessment
ROI	radius of influence
RSAP	Revised Sampling and Analysis Plan
SCR – 2011	Site Characterization Report – Through 2011
SCR – 2012	Site Characterization Report – 2012 Addendum
site	FHRA North Pole Refinery, an active petroleum refinery located on H and H Lane in North Pole, Alaska
TIC	tentatively identified compound
TWUP	temporary water use permit
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound
VPT	Vertical Profiling Transect
WWTP	wastewater treatment plant
µg/L	micrograms per liter

Executive Summary

This Revised Interim Remedial Action Plan Addendum (Addendum) proposes additional interim remedial actions to address light nonaqueous phase liquid (LNAPL) and groundwater impacts at the Flint Hills Resources Alaska, LLC (FHRA) North Pole Refinery, an active petroleum refinery located on H and H Lane in North Pole, Alaska (site). This Addendum focuses on constituents of concern identified in the Revised Draft Final Human Health Risk Assessment (ARCADIS U.S., Inc. [ARCADIS] 2012a) and data collected during site characterization activities as reported in the Site Characterization Report – Through 2011 (SCR – 2011; Barr Engineering Company [Barr] 2012a) and the Site Characterization Report – 2012 Addendum (SCR – 2012; ARCADIS 2013b). This Addendum was prepared in response to comments from the Alaska Department of Environmental Conservation including those received on February 11, 2013 and March 18, 2013.

LNAPL and groundwater data presented in the SCR – 2011 (Barr 2012a) and SCR – 2012 (ARCADIS 2013b) indicate that impacts are present across the developed areas of the site and groundwater impacts extend downgradient. This Addendum supplements the Interim Remedial Action Plan submitted in September 2010 that presented a plan to optimize the existing remediation system to aggressively address LNAPL and sulfolane-impacted groundwater onsite (Barr 2010). This Addendum provides the scope and layout of additional proposed onsite interim remedial actions to further reduce the potential for migration of sulfolane-impacted groundwater offsite and to reduce LNAPL mass at the site.

The following interim remedial actions are proposed for implementation:

- Upgraded groundwater extraction and dual-phase LNAPL recovery
- Expanded LNAPL recovery
- Additional groundwater extraction system
- Alternative water solutions program

For this Addendum, FHRA uses the 14 micrograms per liter alternative cleanup level referenced by the Alaska Department of Environmental Conservation (ADEC) in its July 19, 2012 letter (ADEC 2012). This Addendum is submitted subject to the positions and reservations expressed by FHRA in its August 20, 2012 letter (FHRA 2012).

1. Introduction

On behalf of Flint Hills Resources Alaska, LLC (FHRA), ARCADIS U.S., Inc. (ARCADIS) prepared this Revised Interim Remedial Action Plan Addendum (Addendum) for the FHRA North Pole Refinery (NPR), an active petroleum refinery located on H and H Lane in North Pole, Alaska (site). This Addendum proposes additional onsite remedial activities and supplements the Interim Remedial Action Plan (IRAP) submitted in September 2010 (Barr Engineering Company [Barr] 2010). The proposed work is intended to further control and remediate groundwater contaminated with sulfolane and hydrocarbons on the NPR property and document the Alternative Water Solutions (AWS) that have been implemented as an Interim Remedial Measure (IRM) to protect the affected or potentially affected community near the NPR.

It is acknowledged that in 18 Alaska Administrative Code (AAC) 75.990(115), the Alaska Department of Environmental Conservation (ADEC) defines the term “site” as an “area that is impacted, including areas impacted by the migration of hazardous substances from a source area, regardless of property ownership.” For this Addendum, the term “onsite” is the area that is located within the property boundary of the FHRA NPR, and the term “offsite” is the area located outside the property boundary in the downgradient north-northwest direction, based on the approximate extent of the dissolved-phase sulfolane plume detected at concentrations above the laboratory limit of detection (approximately 3 micrograms per liter [µg/L]).

Site conditions were previously evaluated in the Site Characterization and First Quarter 2011 Groundwater Monitoring Report (Barr 2011), the Site Characterization Work Plan Addendum (ARCADIS 2011), the Site Characterization Report – Through 2011 (SCR – 2011; Barr 2012a) and the Site Characterization Report – 2012 Addendum (SCR – 2012; ARCADIS 2013b). The Revised Draft Final Human Health Risk Assessment (Revised Draft Final HHRA; ARCADIS 2012a) evaluates whether concentrations of site-related constituents in groundwater pose a risk to onsite and offsite receptors.

The IRAP (Barr 2010) proposed a plan to optimize the existing remediation system to aggressively address light nonaqueous phase liquid (LNAPL) and sulfolane-impacted groundwater onsite. This Addendum provides the scope and layout of additional proposed onsite interim remedial actions to continue aggressive treatment of petroleum and sulfolane contamination, further reduce the potential for migration of sulfolane-impacted groundwater offsite, and reduce LNAPL mass at the site. The site location, facility features, and layout are shown on Figures 1-1 through 1-4.

1.1 Site Priorities

In a letter to FHRA dated August 18, 2011 (ADEC 2011), the ADEC listed priorities for the site per 18 AAC 75. FHRA has focused environmental activities to address the ADEC's priorities and significant work has been completed toward achieving the ADEC's priorities. To that end, FHRA reinforced its long-standing commitment in correspondence to ADEC on May 16, 2013, June 12, 2013, and June 19, 2013, whereby FHRA stated that it intended to continue to implement the AWS program as it is currently performing, as an IRM, while the final remedy process is being completed, including beyond the cleanup plan completion timeframe, and would be installing additional recovery wells, with the expectation being for all the onsite IRMs, once established, that they function to ensure groundwater leaving the FHRA property does not exceed the maximum contaminant levels (MCLs)/alternative cleanup levels (ACLs) currently applicable to NPR. With this in mind, the interim remedial actions proposed below continue to address the site priorities through aggressive remediation of sulfolane and LNAPL onsite and monitoring of remedial progress.

1.2 Report Organization

This Addendum is organized as follows:

- *Section 1 – Introduction*. This section describes the purpose and organization of this Addendum.
- *Section* 2 – *Background/Characterization*. This section provides some historical perspective and describes ongoing interim remedial activities.
- *Section 3 – Phase 8 Well Installation.* The section provides proposed wells along the north property boundary.
- *Section 4 – Proposed Interim Remedial Actions*. This section introduces the supplemental interim remedial actions proposed to address contamination at the site. This section describes conceptual designs and specifications for selected interim remedial strategies.
- *Section 5 – Waste Management Plan*. This section presents provisions for handling waste generated during remedial implementation and routine

operations and maintenance (O&M) and performance monitoring of the remediation systems at the site.

- *Section 6 – Implementation Schedule*. This section summarizes FHRA's proposed schedule for implementation of the scope of work summarized in this Addendum.

- *Section 7 – References.* This section lists the sources of information cited in this Addendum.

2. Background/Characterization

This section describes the general physical site conditions, current conceptual site model, and ongoing remedial actions at the site. The site history and site characterization activities are discussed in the SCR – 2011 (Barr 2012a), the SCR – 2012 (ARCADIS 2013b), and quarterly groundwater monitoring reports.

2.1 Site Description

The 240-acre site is located just inside the city limits of North Pole, Alaska (the city). The city is located approximately 13 miles southeast of Fairbanks, Alaska, within Fairbanks North Star Borough (Figure 1-1). NPR is an active petroleum refinery that receives crude oil feedstock from the Trans-Alaska Pipeline. The site was developed in the mid-1970s and operations began in 1977. Site features are shown on Figure 1-2. A detailed facility map is included in Appendix A.

Three crude oil processing units are located in the southern portion of the site, making up the process area. Tank farms are located in the central portion of the site. Truck-loading racks are located immediately north of the tank farms and a railcar-loading rack is located west of the tank farms. Wastewater treatment lagoons, storage areas, and two flooded gravel pits (the North and South Gravel pits) are located in the western portion of the site. Rail lines and access roads are located in the northernmost portion of the site. Along the southern site boundary, partially surrounded by the NPR, is an electrical generating facility (power plant) operated by Golden Valley Electric Association (GVEA). The power plant burns petroleum fuels produced at the site. The property south of the site and the GVEA power plant is occupied by the Petro Star, Inc. Refinery. An onsite site plan is presented on Figure 1-3.

Immediately north of the site are residential properties and the city's wastewater treatment plant (WWTP). The North Pole High School is located immediately north and west of the WWTP and the residential properties. An undeveloped parcel, owned by the Alaska Department of Natural Resources (DNR), lies between the site and the WWTP. The Tanana River is located to the south and west, flowing in a northwesterly direction toward Fairbanks. East of the site is property that is residential or undeveloped, the Old Richardson Highway, and the Alaska Railroad right-of-way. An offsite site plan is presented on Figure 1-4.

2.2 Physical Setting

The site and surrounding area are located on a relatively flat-lying alluvial plain that is situated between the Tanana River and Chena Slough (locally known as Badger Slough). The site is located on the Tanana River Floodplain. Up to 2 feet of organic soils are typically found in the undeveloped portions of the site. A discontinuous silt and silty sand layer that varies in thickness from 0 to 10 feet typically occurs beneath the organic soils. Alluvial sand and gravel associated with the Tanana River are present below the organic soil and silty layers. Depth to bedrock has been estimated at 400 to 600 feet below ground surface (bgs).

North Pole is located within an area of Alaska characterized by discontinuous permafrost (Ferrians 1965). Permafrost tends to act as a confining unit, impeding and redirecting the flow direction of groundwater (Glass et al. 1996). Based on regional information (Williams 1970, Miller et al. 1999), permafrost is assumed to be absent beneath the Tanana River.

The aquifer beneath the alluvial plain between the Tanana River and Chena River generally consists of highly transmissive sands and gravels (Cederstrom 1963, Glass et al. 1996). The Tanana River has a drainage area of approximately 20,000 square miles upstream of Fairbanks (Glass et al. 1996). Near the site, this aquifer is reportedly greater than 600 feet thick (at least 616 feet thick near Moose Creek Dam) (Glass et al. 1996). Beyond the zones of influence of the site groundwater recovery system, groundwater flow directions are controlled by discharge from the Tanana River to the aquifer and from the aquifer to the Chena River, as described by Glass et al. (1996). Variations in river stage through time are believed to be the primary cause of variations in flow direction through the aquifer between the rivers (Lilly et al. 1996, Nakanishi and Lilly 1998). Based on data from U.S. Geological Survey water table wells, the flow direction varies up to 19 degrees from a north-northwesterly direction to a few degrees east of north. The flow direction trends to the north-northwest in spring and more northerly in the summer and fall (Glass et al. 1996).

2.3 Ongoing Interim Remedial Activities

The ongoing remediation actions at the site include active groundwater recovery and treatment, active LNAPL recovery and recycling, and LNAPL natural source zone depletion (NSZD). The remediation system is described and evaluated in the SCR – 2011 (Barr 2012a). Additional status updates have been provided in the quarterly groundwater monitoring reports (ARCADIS 2013d). Replacement wells described in

Section 2.5.2 were installed during the first quarter 2013 and extraction from the wells was initiated during the second quarter 2013. Because data have not been finalized for second quarter 2013, the components of the active remediation systems during the previous sampling event (first quarter 2013) are described below:

- Groundwater recovery from five recovery wells through the first quarter 2013 (R-21, R-35R, R-39, R-40, and R-42).

- Installation of recovery wells R-43, R-44, R-45, and R-46.

- Recovered groundwater is treated through a prefilter for solids removal, a coalescer for LNAPL removal, and four air strippers for removal of volatile organic compounds (VOCs) before accumulating in the Gallery Pond. The groundwater from the Gallery Pond is then pumped through sand filters for solids removal and a 4-vessel granular activated carbon (GAC) system for sulfolane removal. The current layout of the groundwater recovery and treatment system is shown on Figure 2-1 and a process flow diagram of the current system is shown on Figure 2-2.

- Pneumatic LNAPL recovery systems are continuously operated at MW-138, R-20R, R-21, R-35R, R-40, and S-50. Additional pneumatic LNAPL recovery systems are operated seasonally at R-32 and R-33. The LNAPL recovery system currently used at S-50 was previously installed at O-2, but was moved due to low LNAPL recovery. FHRA also uses a hand-held product recovery pump at other locations (e.g., R-39) if LNAPL is present and recovery is possible.

The system described above includes improvements completed as part of the IRAP (Barr 2010); additional interim actions described in Section 2.3.2 were recently completed. To provide background for the existing system capabilities and performance as part of the overall comprehensive remedial strategy, this Addendum summarizes current operating conditions and performance through the first quarter 2013 for groundwater recovery and treatment (Section 2.3.1), LNAPL recovery (Section 2.3.3), and NSZD (Section 2.3.4).

2.3.1 Groundwater Recovery and Treatment

Table 2-1 summarizes the volume and discharge rate of recovered groundwater from the treatment system during 2009, 2010, 2011, 2012, and first quarter 2013. Groundwater recovery for each year is summarized below:

- 2009: 69,200,000 gallons
- 2010: 107,100,000 gallons
- 2011: 136,900,000 gallons
- 2012: 188,300,000 gallons
- 2013: 44,440,000 gallons (through the first quarter)

As shown in the groundwater recovery totals above and in Table 2-1, FHRA has continued to increase the total volume of recovered groundwater.

Pumping rates for the individual recovery wells are measured weekly and the average for first quarter 2013 for each well is shown in the table below. This table also presents the total and percent runtimes for first quarter 2013. The system reliability improvements completed as part of the IRAP (Barr 2010) have resulted in increased runtime and, as shown below, each recovery well maintained a runtime greater than 96 percent during first quarter of 2013.

Location	First Quarter 2013 Average Flow Rate	First Quarter 2013 Runtime	Percent Runtime
R-21	50 gpm	2,116 hours	98.0%
R-35R	84 gpm	2,104.5 hours	97.4%
R-39	86 gpm	2,075 hours	96.1%
R-40	50 gpm	2,075 hours	96.1%
R-42	114 gpm	2,090.5 hours	96.8%

Note:

gpm = gallons per minute

Recovered groundwater is pumped to an onsite groundwater treatment system that removes LNAPL and dissolved-phase contaminants. The current groundwater treatment system process flow diagram is provided on Figure 2-2. Section 5 of the SCR – 2011 (Barr 2012a) evaluates the performance of the groundwater treatment system and results are provided in the quarterly groundwater monitoring reports; thus, the results are not reiterated in this Addendum. However, results of the treatment system effectiveness are summarized below:

- The air stripper towers effectively removed the majority of dissolved-phase hydrocarbons from the recovered groundwater prior to discharge to the Gallery Pond.

- A GAC filter system was installed to remove sulfolane and any benzene, toluene, ethylbenzene, and xylenes (BTEX) constituents not removed by the air strippers.

- BTEX and sulfolane concentrations at the GAC system effluent have been below the limit of quantitation during every monitoring event since the GAC system went online on June 9, 2011.

- During multiple monitoring events, substantial sulfolane reduction has been observed across the air strippers and between the air stripper outlets and the GAC vessel inlet. The remaining sulfolane is captured by the GAC system and is destroyed when the GAC is changed out and thermally treated for disposal.

2.3.2 Replacement Groundwater Recovery Wells

During the second quarter 2013, FHRA completed installation of four additional recovery wells (R-43, R-44, R-45, and R-46). These new wells replaced R-39 and R-40, and augment capture in the R-21 area (Figure 2-1). A technical memorandum describing the proposed recovery wells was submitted to ADEC on September 14, 2012, and approval of the plan was received from the ADEC on October 3, 2012 (ADEC, pers. comm. 2012b). Installation of these new recovery wells is summarized in Section 4.1 of this Addendum. In addition, FHRA plans to install additional recovery wells to the west and a second groundwater treatment system as described in Section 4.4 of this Addendum.

2.3.3 Light Nonaqueous Phase Liquid Recovery

FHRA continues to perform LNAPL recovery via automated LNAPL skimmer systems in wells MW-138, R-20R, R-21, R-35R, and R-40 (Figure 2-1) when sufficient LNAPL is present. Seasonally operated LNAPL skimming systems are installed at R-32 and R-33. Manual product recovery was completed during the first quarter 2013 with a vacuum truck, portable product pump, or baildown testing at MW-176A, MW-334-15, O-10, O-11, O-27, R-14A, R-18, R-32, S-22, S-44, S-50, and S-51. The recovered LNAPL from the systems is accumulated in product storage tanks and is periodically recycled within a refinery process unit. Additional LNAPL is recovered by the groundwater recovery system and is removed by the coalescer installed ahead of the air stripper.

Table 2-2 summarizes the LNAPL recovery during the first quarter 2013. During this period, a total volume of 102 gallons of LNAPL was recovered. The majority of the recovery during the first quarter 2013 was from recovery wells R-21, R-32, and R-40.

Table 2-3 summarizes LNAPL recovery at the site since 1986. From 1986 through the first quarter 2013, approximately 393,980 gallons of LNAPL were recovered. LNAPL recovery volumes are decreasing despite more aggressive recovery efforts, which indicate that the volume of recoverable LNAPL is decreasing.

2.3.4 Natural Source Zone Depletion

NSZD is a combination of natural processes that reduce the mass of LNAPL through time. The SCR – 2011 (Barr 2012a) presents a qualitative assessment and quantitative estimate of NSZD. Results of the qualitative assessment across the site showed a decreasing trend in electron acceptors (proceeding downgradient) and increasing trend in biodegradation transformation products through the LNAPL-impacted areas. Biodegradation of LNAPL is occurring through a combination of dissolution and biodegradation in the saturated zone and volatilization and biodegradation in the unsaturated zone.

3. Phase 8 Well Installation

FHRA proposes to install new groundwater monitoring well nests along the northern property boundary. These wells will be used to confirm performance of the proposed interim remedial activities and that groundwater cleanup levels are being achieved at the site boundary through time. The proposed Phase 8 monitoring wells may be incorporated into the sulfolane groundwater monitoring network during future groundwater monitoring events, following development and an initial sampling event.

3.1 Phase 8 Wells at the Northern Property Boundary

Seven new well nests, with up to 33 new wells, are proposed along the northern property boundary to evaluate sulfolane concentrations as shown on Figure 3-1. The proposed wells will require clearance of vegetation and construction of access roads in the undeveloped portions of the site.

Each well nest will be composed of a water table well, a well screened above the top of permafrost (or 150 feet in depth), and additional wells at variable depths as summarized in Table 3-1. The proposed vertical spacing of wells at each location is dependent on the location of each nest relative to the centerline of the plume; wells closer to the centerline of the plume have a more dense vertical spacing. These proposed Phase 8 wells are also included in the Revised 2013 Onsite Site Characterization Work Plan (SCWP, ARCADIS 2013g).

3.2 Phase 8 Monitoring Well Installation

Because permafrost is encountered at variable depths downgradient from the facility process areas, drilling at each location has the potential to encounter permafrost. If encountered, permafrost will be logged in accordance with the procedures described in the RSAP, included as Appendix B to the Fourth Quarter 2012 Groundwater Monitoring Report (ARCADIS 2013c). The maximum depth proposed for deep borings is 150 feet bgs, top of permafrost (if encountered), or the maximum operational depth of the drill rig procured to complete the work. The locations of specific onsite wells that are proposed to delineate permafrost are presented in Table 3-1 and on Figure 3-1.

Where possible, the deepest well at each location will be installed first and the water table well will be installed second. This will allow the project team to add or remove proposed wells as needed. Final spacing of remaining wells will be determined based on the evaluation of subsurface conditions. For example, if permafrost is observed closer to the ground surface, fewer wells will be installed. Conversely, if permafrost is not observed within 130 feet of the ground surface, an additional well may be added. Geologic logging at each well nest will be completed only on the deepest well boring at each location.

Soils samples will be screened using a photoionization detector, and soil samples with readings exceeding 20 parts per million are proposed to be containerized and submitted to SGS Laboratories in Anchorage, Alaska. The submitted samples will be analyzed for the following:

- BTEX by United States Environmental Protection Agency (USEPA) Method 8021
- GRO by AK Method 101
- DRO by AK Method 102
- Sulfolane by USEPA modified Method 8270D with Isotope Dilution

Additional soil sampling at proposed northern property boundary well nests was proposed in the Additional Scope of Work for Site Characterization Activities to Refine the Evaluation of Fate and Transport of Sulfolane submitted to the ADEC on July 26, 2013 (ARCADIS 2013h).

Drilling, soil sampling, soil classification, soil screening, permafrost classification, and monitoring well installation will be completed in accordance with the procedures described in the RSAP (ARCADIS 2013c).

4. Proposed Interim Remedial Actions

FHRA proposes to upgrade the current groundwater extraction system with additional recovery wells, install an additional groundwater extraction system west of the current groundwater extraction system, and continue to implement the AWS program. The objectives of these interim actions are to meet the site priorities described in detail in Section 1.1 above. Also included is an update to the LNAPL removal activities proposed in the IRAP (Barr 2010). Figure 4-1 shows the approximate location of each proposed remedial action. The performance monitoring well networks are shown on Figures 4-2 and 4-3. This section discusses each of the proposed interim remedial actions for the site.

4.1 Upgraded Groundwater Extraction System and Light Nonaqueous Phase Liquid Dual-Phase Recovery

Upgrades to the current groundwater extraction and LNAPL dual-phase recovery (DPR) system and continued operation of that system are in progress. These upgrades were implemented to recover petroleum and sulfolane impacted groundwater onsite and to reduce sulfolane concentrations to the 14 µg/L ACL at the northern property boundary. The system upgrades will increase the capacity of the system to extract and treat groundwater and further improve the operational efficiency of the system.

The upgrades include installation of additional and replacement groundwater recovery wells at locations and depths that were determined through groundwater modeling. The model-based upgrades were proposed to the ADEC in the Technical Memorandum: Proposed Replacement Recovery Wells (Barr 2012b; Appendix B) and approved via email. The work was initiated in October 2012 and was completed in May 2013.

4.1.1 Basis for Technology Selection

Multiple groundwater treatment technologies were evaluated in the Draft Final Onsite Feasibility Study (Onsite FS; ARCADIS 2012b). The findings of that report with respect to groundwater extraction are summarized below:

- *Effectiveness*. The groundwater extraction system has been shown to capture sulfolane-impacted groundwater. The groundwater treatment system is effective at treating sulfolane in the extracted groundwater.

- *Implementability*. The groundwater extraction system is already in place and the proposed upgrades are readily implementable. The services and materials required for groundwater extraction system operation are widely available.

- *Cost*. The capital costs were considered low and operation and maintenance costs were considered high in the spectrum of considered remedial technologies.

4.1.2 Historical System Operations

Operation of the groundwater extraction system prior to the 2013 upgrades included groundwater recovery from five recovery wells (R-21, R-35R, R-39, R-40, and R-42) as discussed in Section 2.3. The groundwater extraction system has been effective at removing sulfolane and LNAPL from the aquifer.

4.1.3 Performance Metrics

Performance monitoring will be conducted to confirm the continued effectiveness of the groundwater extraction system. Hydraulic capture of the sulfolane and BTEX plumes will be assessed using fluid level and groundwater quality data. LNAPL mass reduction will be assessed by monitoring LNAPL volumetric recovery rates from the DPR system and measurement of LNAPL transmissivity. Performance monitoring for the upgraded groundwater extraction system (Section 4.1) and the proposed expanded groundwater extraction system (Section 4.4) is described in Section 4.4.4.

4.1.4 Permitting Requirements

Recovery well R-42 began operation upon receipt of an amended temporary water use permit (TWUP [A2011-48]) from the DNR. In addition to the TWUP for R-42, groundwater extraction from the historical recovery wells is conducted under DNR water use permit LAS24907. FHRA received the Amended Temporary Water Use Authorization TWUP A2011-48 on October 3, 2012 to account for increased extraction rates associated with the new and replacement extraction wells.

On September 29, 2011, the ADEC issued an administrative extension of Wastewater Disposal Permit 2005-DB0012. FHRA is currently reviewing proposed operational changes and an application to amend this permit is forthcoming. Discharge monitoring reports are currently submitted monthly by FHRA to the ADEC.

4.2 Air Sparge Barrier

An air sparge (AS) barrier was previously proposed in the original IRAP Addendum submitted to the ADEC on January 18, 2013 (ARCADIS 2013a) The basis for the AS barrier technology, a summary of the proposed pilot test, and a discussion of sulfolane aerobic degradation products are presented below.

4.2.1 Basis for Technology Selection

Multiple groundwater treatment technologies were evaluated in the Onsite FS (ARCADIS 2012b). The following summarizes the findings of that report with respect to AS:

- *Effectiveness*. Under the conditions present during the 2012 Air Sparge Pilot Test (Appendix C), AS was an effective technology to treat sulfolane-impacted groundwater. It is expected that effective reduction would be achieved in full implementation under site conditions as well. Implementation of an onsite AS system would provide an additional remedial barrier beyond the groundwater extraction system to minimize future migration of sulfolane downgradient of the treatment areas, at levels above the 14 µg/L ACL.

- *Implementability*. AS is a proven, conventional technology. The services and materials required for AS system construction and operation are widely available.

- *Cost*. The capital and O&M costs were considered moderate in the spectrum of considered remedial technologies.

4.2.2 2012 Air Sparge Pilot Test Summary

An AS pilot test was conducted in 2012 at the site. The pilot test was initiated by FHRA to evaluate the site-specific effectiveness of AS for in-situ treatment of sulfolane-impacted groundwater. Observations made from the ongoing AS pilot test are summarized below:

- Radius of influence (ROI) testing indicates that an air flow of 30 standard cubic feet per minute through a shallow sparge well (approximately 25 feet below water table) will deliver oxygen throughout the saturated zone with an ROI greater than 15 feet based on dissolved oxygen (DO) measurements.

- Groundwater samples collected from AS pilot test wells demonstrated sustained decreases of sulfolane within the treatment zone.

- The degree and rate of sulfolane removal correlated with increased DO concentrations.

- Sulfolane was removed during both continuous and pulsed operation of the AS.

- The dissolved iron and dissolved manganese concentrations in groundwater decreased during operation of the AS system. This result was anticipated based on the introduction of oxygen into the aquifer creating aerobic conditions, resulting in oxidation and precipitation of reduced iron and manganese.

Overall the pilot test demonstrated that AS is an effective remedial technology to stimulate in-situ degradation of sulfolane at the site (Appendix C) and provided information that supports design of a full-scale AS system.

4.2.3 Sulfolane Aerobic Degradation Products Summary

FHRA consultants have evaluated the means by which sulfolane could break down in the environment, the products that could be formed, and the chance that these products could pose unacceptable risk to human health or the environment. Using information available from published literature and site data, the team has outlined the expected pathways by which sulfolane may degrade in the presence of oxygen and considered the likely end products of this process. The team also has evaluated what would be expected to happen if breakdown began in the presence of oxygen and intermediate products moved away, into groundwater without abundant oxygen available. In sum, it is expected that in the presence of oxygen, sulfolane will break down rapidly through biologic (microbial) and/or abiotic mechanisms to the harmless and naturally abundant compounds carbon dioxide, water, and sulfite/sulfate. If breakdown begins under oxygenated conditions and intermediate products move to groundwater with little oxygen available, it is expected that breakdown will continue and also result in the harmless and naturally abundant compounds carbon dioxide, water and sulfite/sulfate. In addition, the team concludes that any potential intermediate products from sulfolane degradation would not persist or concentrate so as to pose an unacceptable risk to human health or the environment.

In the remainder of this section, we provide the bases for the conclusion about sulfolane degradation in the presence of oxygen. For the anaerobic evaluation, please consult the Analysis of Potential Degradation Products Memorandum (ARCADIS 2013e).

Determination of the mechanism of aerobic sulfolane degradation through observation and documentation of intermediates was not a planned objective of the AS pilot or bench studies (Appendix C and Onsite FS Appendix B; ARCADIS 2012b). Nonetheless, observations made during FHRA's bench and pilot testing programs have consistently demonstrated the loss of sulfolane without any clear indication of the formation of aerobic degradation intermediates. Technical literature describes some biological and abiotic processes by which aerobic sulfolane degradation *may* occur under certain conditions. However, like the work that FHRA has completed to date, the peer-reviewed literature does not provide any direct determination of the mechanisms for aerobic sulfolane degradation via observation and documentation of the presence of any intermediates.

Samples from both the AS pilot treatment zone and bench tests have been analyzed for tentatively identified compounds (TICs) via gas chromatography/mass spectrometry (GC/MS), and no accumulation of potential degradation intermediates has been observed. Members of the Technical Project Team Chemistry Subgroup reviewed the available laboratory data and concluded that there was no evidence of sulfolane-related breakdown products in the laboratory chromatograms. This suggests that any sulfolane intermediates that are detectable by GC/MS either are not formed at all, or if they are formed, are labile and quickly mineralized. This finding confirms others previously reported in the literature. For example, Greene et al. (2000) showed that sulfolane is readily biodegraded under aerobic conditions using controlled laboratory experiments, and potential intermediates (such as 4-hydroxy-butane sulfinic acid or butanol) were never detected (although sought), suggesting that any potential sulfolane intermediates would not accumulate under aerobic conditions.

The FHRA technical team has reviewed the available technical literature in light of what has been observed during bench and pilot tests. In addition, FHRA retained Dr. Lisa Gieg, professor at the University of Calgary and author of peer-reviewed literature on the topic of aerobic sulfolane degradation, to aid in the review. Potential aerobic sulfolane degradation intermediate compounds were predicted by Dr. Gieg, and the toxicology of these compounds was evaluated by ARCADIS toxicologists and submitted originally as Attachment F to the IRAP Addendum (ARCADIS 2013a), and was updated to include additional products when submitted with the Analysis of Potential Degradation Products Memorandum (ARCADIS 2013e). The following sections summarize FHRA's current understanding of the potential aerobic degradation mechanisms, potential intermediate compounds, and toxicological information for potential intermediate compounds identified. Finally the potential implications for performance monitoring of the AS barrier system are evaluated.

4.2.3.1 Bench Testing Tentatively Identified Compounds Analysis

As previously presented in the SCR – 2011 (Barr 2012a) and Appendix B to the Onsite FS (ARCADIS 2012b), abiotic mechanisms may play a role in the degradation of sulfolane in the Sulfinol process (Oasis 2010). Onsite remediation system sampling and the bench testing suggest that abiotic sulfolane destruction, if it occurs, is a rapid process, with a half-life on the order of hours (ARCADIS 2012b, Appendix B). According to the literature, the abiotic destruction of sulfolane via the pathways described above requires high temperatures, which are not present in the groundwater at the site (Wellisch et al. 1964).

The conditions necessary for abiotic destruction of sulfolane via this mechanism appear to be:

- Presence of iron/manganese oxides
- Active oxidation of iron by DO

As described in Appendix B of the Onsite FS (ARCADIS 2012b), Barr conducted a series of three bench tests to investigate the potential reasons for sulfolane removal that was occurring across the air strippers, gallery pond, and sand filters at the onsite remediation system. Observations were made during the third and final bench test to potentially understand the possible reaction pathway for sulfolane degradation documented across the onsite remediation system.

Testing was conducted at Barr's water treatment laboratory using lab-synthesized groundwater spiked with reagent-grade sulfolane. Test results demonstrated that sulfolane reduction was associated with backwash solids from the sand filters and also indicated that the rate of sulfolane reduction was greatest under aeration and at lower pH (6). As previously described, the sulfolane degradation reactions are likely to be rapid processes once initiated; therefore, the bench testing included specific tests in which solids were filtered to stop potential degradation reactions that might be mediated by metals associated with suspended solids. Several of the treatments exhibiting sulfolane removal, each sample's associated filtered solids (as well as the spiked control sample) were analyzed by GC/MS for TICs in order to identify potential intermediates of sulfolane degradation.

Barr reported the tentative identification of several potential sulfolane-related breakdown products in the treatments through their review of the TIC data; however, a subsequent thorough review of the available laboratory data (including electronic data files) by both quality assurance chemists from Environmental Standards, Inc. and Shane Billings of UAF indicated that accumulation of degradation intermediates was not evident in the bench testing samples.

4.2.3.2 Air Sparge Pilot Test Tentatively Identified Compounds Analysis

As discussed in Appendix C, the laboratory completed a review for TICs to scan for potential intermediate byproducts of sulfolane degradation during each completed AS pilot test monitoring event. The TIC scans completed as part of each sampling event were examined for potential sulfolane degradation intermediates based on the following criteria:

- Chromatographic peaks that were flagged by the lab
- Chromatographic peaks that were not in the laboratory method blanks
- Chromatographic peaks that were not internal standards or surrogate compounds
- Chromatographic peaks that were present in downgradient wells but not the upgradient well

While some chromatographic peaks were sporadically detected during the pilot test, they were generally present in both upgradient and downgradient wells and inconsistently present from one event to the next.

4.2.3.3 Additional Evaluation of Potential Intermediates of Sulfolane Degradation

Dr. Lisa Gieg, a noted researcher in the field of organic contaminant degradation, further evaluated the potential for accumulation of intermediates. Dr. Gieg previously conducted studies on aerobic degradation of sulfolane. Through collaboration with Dr. Gieg and review of the available information, the FHRA technical team identified the following possible intermediates of aerobic sulfolane degradation:

- Potential Biological Degradation Intermediates Under Aerobic Conditions:

  - 4-Hydroxy-butane sulfinic acid
  - Butanol
  - Butyraldehyde
  - Butanoic acid

- Potential Abiotic Degradation Intermediates Under Aerobic Conditions:

  - Butanesulfinate
  - Octane-1,8-sulfinate

- Potential Biological Degradation Intermediates From Abiotic Intermediates Under Aerobic Conditions:

  - 4-Hydroxy butane sulfinate
  - Butanol
  - Octane-1-sulfinate
  - 8-Hydroxy-octanesulfinate
  - Octanol

A technical memorandum summarizing potential aerobic degradation intermediates and pathways discussed in peer-reviewed literature, and the most likely potential aerobic degradation pathways and intermediates based on previous abiotic and biodegradation studies with sulfolane is included as Appendix D.

Several of the identified compounds are naturally occurring compounds that may be associated with the natural processes in the aquifer. They would also be highly biodegradable and would be used by a broad range of microbial communities as food sources. The following section summarizes the evaluation of the toxicity of these potential intermediates.

4.2.3.4 Toxicological Evaluation of Potential Intermediates

Several chemical structures have been identified as potential biotic or abiotic breakdown intermediates of sulfolane. It is not known if these chemical species are formed or, if they were formed, whether they would be stable in the environment. ARCADIS reviewed the available toxicological data on these compounds and analogous structures to determine if any toxicological information was available. In the absence of toxicological data, ARCADIS completed predictive toxicological modeling to predict the potential toxicological properties of those compounds.

Because many of the compounds do not have available toxicity data, modeling was completed for sulfolane to evaluate the reliability of the predictive model.

In all cases, the potential intermediates are known or predicted to be less toxic than sulfolane. Detailed results of the literature search and predictive model runs are presented in Appendix E.

4.2.3.5 University Investigations

As discussed above, a review by Shane Billings (a research chemist at the UAF) of the TIC scan data collected by Barr during bench testing supports previous conclusions that intermediate compounds were not detected in the laboratory analysis (pers. com., December 7, 2012).

The UAF is currently conducting several laboratory studies to directly evaluate the potential for sulfolane degradation under various environmental conditions, including aerobic conditions, and the mechanisms that would be responsible for that degradation. As part of this work, UAF will identify potential sulfolane-degrading bacteria present in groundwater and soil at the site. These results will be incorporated into the evaluation of degradation mechanisms and potential intermediates.

4.2.3.6 Summary

The conclusion of the FHRA technical team is that it is highly unlikely that there will be accumulation of sulfolane degradation intermediates during AS. This conclusion is based on laboratory and field investigations previously discussed, review of available literature on the degradation of sulfolane, review of available literature about what sulfolane intermediates may be expected, and consultation with a leading expert in the field of organic contaminant degradation in aquatic systems.

Peer-reviewed published laboratory studies focusing on sulfolane biodegradation have shown that sulfolane is readily biodegraded under aerobic conditions (studies cited in Appendix D). Biodegradation studies conducted in the laboratory are ideal for identifying metabolic intermediates that may form during the biodegradation of any contaminant because they typically involved closed, controlled environments where intermediates can potentially accumulate transiently through time and be identified. Such biodegradation studies were conducted with sulfolane by Greene et al. (2000) wherein potential sulfolane intermediates were sought in controlled laboratory incubations. Aside from the innocuous end-products carbon dioxide and sulfate, other predicted sulfolane intermediates (e.g., shown in Appendix D) were never detected

(Greene et al. 2000). This result suggests that sulfolane biodegradation intermediates do not accumulate, even under ideal laboratory /test conditions.

Bench scale tests conducted by Barr confirmed this lack of accumulation of potential sulfolane intermediates. Furthermore, toxicological assessments of potential sulfolane intermediates showed that these are known or predicted to be less toxic than sulfolane (Appendix E). As stated above, any proposed intermediates of sulfolane degradation (biotic or abiotic) are of lower concern than sulfolane because they would not be expected to accumulate, and have lower toxicity than sulfolane.

Analytical data from both the AS pilot treatment zone studies and laboratory bench tests have been analyzed for chemical compounds, including TICs, via GC/MS analyses, and no accumulation of potential degradation intermediates has been observed. The lack of detectable breakdown products during bench testing and AS pilot testing demonstrates that any sulfolane degradation intermediates that are detectable by GC/MS either are not formed, or if they are formed, are labile and easily degraded by a wide range of microbial communities or abiotic processes. Technical literature describes some biological and abiotic processes by which aerobic sulfolane degradation *may* occur under certain conditions. An evaluation of potential degradation pathways and intermediate products performed by the FHRA project team resulted in a list of possible degradation pathways and degradation intermediates (Appendix D).

Although there is no evidence that any intermediate chemicals *are* formed in the aquifer, the next step in the FHRA project team's evaluation process was to investigate whether such chemicals might be harmful to human health or the environment *if* they were formed and accumulated in the groundwater. A review of available toxicological information for the potential degradation intermediates conducted by ARCADIS concluded that aerobic degradation of sulfolane via AS is highly unlikely to produce degradation intermediates that are more harmful to human health and the environment than sulfolane itself (Appendix E). Each of the possible intermediate compounds has a lower measured or predicted toxicity than sulfolane. Four of the compounds (butanoic acid, butyraldehyde, butanol, and octanol) are approved food additives by the U.S. Food and Drug Administration and are all compounds that occur in nature. Because they are naturally occurring, they may be associated with the natural processes in the aquifer.

While for the reasons stated above, an air sparge system is a viable IRM for the site, in its letter to the ADEC dated May 16, 2013, FHRA withdrew its consideration of the proposed AS system at that time. Instead, FHRA now proposes to install recovery wells and a new groundwater treatment system to the west of the existing groundwater recovery system as outlined in Section 4.4.

4.3 Updated Light Nonaqueous Phase Liquid Recovery

FHRA proposes to continue current LNAPL skimming operations and to evaluate the transmissivity and recoverability of LNAPL in accessible areas of the site. Continuous and seasonal ongoing LNAPL skimming will recover mobile LNAPL, reduce LNAPL mass, and reduce the potential for future LNAPL plume expansion until the final cleanup plan is implemented. Additional LNAPL data collection to support the feasibility study is ongoing and will be reported in the 2013 addendum to the site characterization report. This section provides an update to the previous IRAP submitted in 2010 (Barr 2010).

4.3.1 Basis for Technology Selection

Multiple LNAPL treatment technologies were evaluated in the Onsite FS (ARCADIS 2012b). The findings of the Onsite FS (ARCADIS 2012b) with respect to LNAPL skimming are summarized below:

- *Effectiveness*. Consistent recovery of LNAPL has been demonstrated during operation of the existing LNAPL skimming systems. LNAPL recovery will continue to further reduce the LNAPL mass and mobility of the LNAPL.

- *Implementability*. LNAPL skimming is readily implementable as demonstrated by ongoing operations. The services and materials required for LNAPL skimming installation and operation are widely available.

- *Cost*. Capital and O&M were considered low in the spectrum of considered remedial technologies.

4.3.2 Historical Operation

As discussed in Section 2.3, active remediation is ongoing to recover LNAPL at the site. From 1986 through the first quarter 2013, approximately 393,980 gallons of LNAPL were recovered at the site. Annual recovery volumes have generally decreased as remediation has progressed and the volume of recoverable LNAPL has decreased.

4.3.3 Updated Basis of Design

4.3.3.1 Skimming Well Selection and Operational Time Frames

To-date volumetric LNAPL recovery rates and LNAPL transmissivities indicate that LNAPL at the site is recoverable. However, additional LNAPL transmissivity data collection is needed to develop a final LNAPL remedial strategy at the site. A revised LNAPL transmissivity data collection plan to support the development of this strategy was proposed in the Revised 2013 Onsite SCWP (ARCADIS 2013g). A final LNAPL recovery and petroleum remediation strategy will be developed in the Onsite Cleanup Plan.

4.3.3.2 Equipment and Implementation

A typical pneumatic skimmer consists of a submersible air-driven pump, with an intake located behind a hydrophobic filter. The intake and filter are located on a vertical slide apparatus; the density of the filter allows the intake to be placed at the LNAPL/water interface.

The typical operational configuration of a skimming system will include the following components:

- Two-inch-diameter monitoring well or 4-inch-diameter recovery well
- Compressed air supply for the skimmer pump
- Collection drums for the recovered product
- Well houses to insulate the skimmer systems from freezing conditions

Wells identified for continuous LNAPL recovery will be equipped with a Geotech Keck Spoiler pneumatic skimming unit with a floating, hydrophobic pump intake to target removal of LNAPL. The pump will be equipped with a tank full shut-off switch. Tubing and wiring associated with the skimming devices will be placed abovegrade. Specifications for the pneumatic LNAPL skimmer systems are included as Appendix F.

Compressed air will be used to run the Geotech Keck Spoiler skimmer pumps and lift LNAPL from the pump intake to the surface, where it will be collected in a 55-gallon drum prior to recycling within the facility. Temporary abovegrade connections will be made to existing compressed air manifolds at recovery well locations, where possible. Each recovery system will be equipped with a dedicated LNAPL storage container, complete with overfill prevention controls and secondary containment. Recovery wells and their associated equipment will be housed in dedicated enclosures for locations that are proposed for continuous skimming.

During periods of high water table elevation (generally during the summer months) when the LNAPL smear zone may be submerged, flow of LNAPL into recovery wells is expected to be minimal and skimming may be discontinued until groundwater elevations drop.

At locations where LNAPL transmissivity is found to be low, non-continuous or seasonal LNAPL skimming may be proposed. At these locations a Geotech Keck Spoiler may be temporarily installed or a manual portable recovery pump or vacuum truck will be used.

4.3.4 Performance Monitoring

As discussed in the 2010 IRAP (Barr 2010), LNAPL recovery rates and thicknesses were used to evaluate LNAPL recovery performance. This section provides an update to those performance metrics to include LNAPL transmissivity and remove LNAPL thickness from consideration when evaluating the performance of LNAPL recovery operations. The updated metrics will be used to assess the effectiveness of LNAPL recovery:

- LNAPL transmissivity calculations
- LNAPL recovery volume and LNAPL recovery rate from each well

4.3.4.1 Light Nonaqueous Phase Liquid Transmissivity

LNAPL transmissivity is a measure of LNAPL recoverability within the groundwater environment. The magnitude of LNAPL transmissivity can be used as an endpoint criterion for LNAPL mass removal using LNAPL hydraulic recovery systems (American Petroleum Institute 2012).

LNAPL transmissivity will be calculated from data collected during bail-down testing and manual and automated skimming. An LNAPL baildown test is initiated by quickly removing LNAPL accumulated in a well. The rate of LNAPL flow into the well is a function of soil and LNAPL properties discussed above and the magnitude of the initial hydraulic gradient toward the well developed during LNAPL removal. The baildown test response is influenced by the prevalent fluid levels at the time of testing. A routine LNAPL baildown test program has been initiated that will measure the range of LNAPL transmissivity under different fluid level conditions.

LNAPL transmissivities calculated from baildown test and/or skimming data will inform and determine the method of LNAPL recovery operations for each well as discussed above. LNAPL recovery in a well will be suspended when recovery rates become insignificant and the LNAPL transmissivity reaches a value of less than 0.8 square foot per day (Interstate Technology and Regulatory Council [ITRC] 2009), which ITRC suggests as the threshold for beneficial reduction in overall LNAPL mass.

LNAPL transmissivity measurement and data analysis methods are consistent with the American Society for Testing and Materials International (ASTM) Standard Guide for Estimation of LNAPL Transmissivity (ASTM 2012).

4.3.4.2 Light Nonaqueous Phase Liquid Recovery Volume

LNAPL recovery volumes from individual recovery systems will be used as a performance metric to assess the effectiveness of LNAPL recovery. Recoverability of LNAPL generally decreases as remediation progresses and as the volume of recoverable LNAPL decreases. Each recovery system will be monitored monthly to track the volume of product recovered. The locations of the individual systems will be modified, if necessary, to relocate the systems to wells with the highest recovery.

4.4 Additional Groundwater Extraction System

In addition to the installation of four new groundwater and LNAPL DPR wells described in Section 4.1, FHRA proposes to install two or more additional recovery wells and a second separate groundwater treatment system to remediate sulfolane contamination at the site and reduce sulfolane concentrations to the ACL of 14 µg/L at the northern property boundary. As described in the Technical Memorandum: Proposed Replacement Recovery Wells (Barr 2012b, Appendix B), groundwater modeling indicates that the western portion of the sulfolane plume is not currently being captured by the groundwater recovery system. Thus, FHRA proposes to install two or more additional recovery wells west of the current line of recovery wells to provide capture across the entire width of the plume (Figure 4-4). Although it is an interim corrective action, this system is designed with consideration of being part of the final comprehensive remedial strategy.

4.4.1 Expanded Groundwater Recovery

Two new recovery wells will be installed between existing recovery well R-42 and the North Gravel Pit, as shown on Figure 4-4. Similar to the recent recovery well additions described in Appendix B, the calibrated regional groundwater model constructed for the site was used to evaluate multiple scenarios with varying well locations, well depths, and pumping rates. Particle tracking was used to evaluate and optimize groundwater capture in the area of the current groundwater extraction system and predict capture of the proposed expanded system under the various scenarios. The proposed well locations shown on Figure 4-4 are the preferred locations based on the modeling results (as described below) and site logistics.

Estimated screened intervals and well depths for the proposed wells are summarized in the following table.

Estimated Screen Intervals for Proposed Recovery Wells

Proposed Recovery Well	Total Depth (feet bgs)	Screened Interval (feet bgs)
R-47	42	5-40
R-48	42	5-40

The proposed well depths and pumping rates evaluated by the model were based on the target sulfolane capture goal equal to the ACL (14 µg/L). To meet the 14 µg/L capture goal, recent analytical results from monitoring wells MW-309-65 and MW-310-65 indicated that groundwater must be captured to a depth of approximately 65 feet bgs within this area.

Groundwater capture provided by the recovery wells was depicted with the groundwater flow model using particle tracking techniques. Particles were simulated horizontally along an east-west line at model nodes spanning from west of the Southwest Area soil impacts to east of the Extraction Unit as shown in Appendix G (Figures 1A through 1H). Vertically, particles were simulated at depths approximating the water table and at 20, 40, and 65 feet bgs. The particles migrate with flowing groundwater and create tracks indicating their individual, three-dimensional flow paths. Because there is seasonal variation in groundwater flow directions due primarily to changes in stage of the Tanana River, particle tracks were developed for conditions representing high and low river stage, corresponding to typical summer and winter river stages, respectively. As a result, there are two sets of particle tracks presented to depict groundwater capture from representative depths.

The particle tracks depict the zones from which groundwater is captured by the recovery wells, as indicated by tracks that converge at the wells. Particles were added to the model iteratively to depict the outer edges of groundwater capture for each depth interval and river stage condition. As shown in Appendix G (Figures 1A through 1H), the recovery wells provide a high degree of capture at the planned pumping rates (described in Section 4.4.1.1) to at least 65 feet bgs. The particle tracking results also demonstrate the termination of particle tracks west of the proposed recovery wells at the North Gravel Pit. Sulfolane in groundwater flowing through the North Gravel Pit is believed to degrade based on the ongoing monitoring results at MW-141 and the MW-301 series which indicate that sulfolane is not migrating beyond the North Gravel Pit.

Refinement of this capture analysis model will be completed based on aquifer testing conducted in May and June 2013 (Barr 2013). Once review of the aquifer test results are completed and appropriate model updates applied, the capture evaluation will be updated and the recovery well design, including the potential for additional recovery wells, will be modified as necessary. The ADEC will be notified of any proposed changes.

4.4.1.1 Recovery Well Design

Pilot borings will be completed at the proposed recovery well locations to evaluate the local geology in advance of final well and screen design. Soil samples will be continuously field-screened during pilot boring advancement and finer-grained units will be submitted for sieve grain-size analysis. The screen design will be completed based on the gradation of the finer-grained materials.

The proposed recovery well casings will be constructed of schedule 40, ASTM A-53 carbon steel. The well screens will be welded wire stainless steel with flat base plates and 2-foot sumps. The individual pumping systems will consist of residential well pump and motor assemblies, and the specifications will be determined through the design process. A typical well construction drawing is included in Appendix H. Filter pack installation will be evaluated based on the results of the pilot borings.

The planned pumping rates take into account the estimated production capacity for the new recovery wells based on the performance of the existing wells and the recently completed aquifer testing. Estimated pumping rates for the proposed and existing recovery wells, which were used for the groundwater model particle tracking, are summarized in the following table.

Design Pumping Rates for Proposed Wells

Recovery Well	Design Pumping Rate (gpm)	Estimated Maximum Capacity (gpm)	Casing Diameter (inches)	Total Depth (feet)
R-21	40	90	8	21 (depth of inner screen installed in 2011 – total original well depth is 24.2 feet)
R-35R	65	90	8	39
R-39	removed from service		10	24.2
R-40	removed from service		10	25.2
R-42	85	120	8	35.0
R-43	85	115	12	42.2
R-44	90	115	12	42.8
R-45	65	70	12	31.7
R-46	40	45	12	32.2
Proposed R-47	120	To Be Determined	12	42
Proposed R-48	80	To Be Determined	12	42
Total	**670 gpm**			

As previously noted, the groundwater model projects that proposed well depths and flow rates are sufficient to increase the capture zone and overall recovery of impacted groundwater to span the width of the sulfolane plume. Note that well total depths shown in Appendix G vary slightly from those listed in Table 3, because Appendix G includes the depth of the model layer representing the well screen depth. There is some minor variability between the model depth and actual depth due to site topography variations and the number of model layers.

4.4.1.2 Monitoring Well Installation

Additional nested monitoring wells (as shown on Figure 4-4) will be installed to aid in assessing the effectiveness of the groundwater recovery system. The individual well nests will be screened across the water table, from 50 to 55 feet bgs, and from 70 to 75 feet bgs. Additionally, borings will be advanced up to 150 feet bgs at two locations to determine the depth to permafrost.

Soils samples will be collected at proposed monitoring well EGWRT-6 (Figure 4-4) to evaluate potential petroleum impacts. Soil samples will be screened using a photoionization detector; samples with readings exceeding 20 parts per million are proposed to be containerized and submitted to SGS Laboratories in Anchorage, Alaska. The submitted soil samples will be analyzed for BTEX by USEPA Method 8021.

Proposed performance monitoring at these locations is discussed in Section 4.4.4.

4.4.2 Groundwater Treatment System

FHRA proposes to install a second GAC treatment system to remove sulfolane from groundwater pumped from the proposed recovery wells. Pilot testing and continued monitoring of the existing onsite GAC treatment system has demonstrated successful removal of sulfolane; however the existing system does not have capacity for two additional recovery wells and increased flow rates. The existing GAC treatment system will continue to be used for existing recovery wells. The proposed additional recovery wells are located sidegradient and beyond the footprint of the BTEX plume. Therefore, air strippers will not be installed because removal of VOCs is not required. If low-levels of VOCs are found in the extracted groundwater they will be removed by the GAC system.

To facilitate long-term reliable operation, FHRA will install an aerated gallery pond and media filter, similar to the existing system, for removal of iron and manganese and potential beneficial degradation of sulfolane prior to treatment through the GAC system. A preliminary process flow diagram is provided in Appendix H.

FHRA is currently employing its internal Project Management Guidelines process which is a highly structured engineering review process, to evaluate the treatment system design reported in this document for long-term reliable operation; therefore, design changes will be communicated to the ADEC as decisions are finalized. Currently, FHRA is evaluating components such as:

- Potential option to route groundwater from recovery well R-42 to the new system to allow future flexibility.
- Type of media for the media filter based on potential manganese removal. Options include silica sand, greensand, or dual media.
- Addition of air scour to the media filters to optimize backwashing.

FHRA proposes to install the new treatment system east of the North Gravel Pit as shown on Figure 4-4. FHRA plans to route the discharge to the North Gravel Pit.

4.4.3 Proposed Aquifer Testing

Upon startup of the proposed system, FHRA will complete single-well aquifer testing on the two new recovery wells and evaluate the hydraulic capture zone of the fully expanded groundwater recovery system. Both the single-well and full capture zone aquifer testing is planned for the third quarter 2014. A work plan for this work will be submitted under separate cover.

4.4.4 Performance Monitoring

Operation of the groundwater extraction system involves groundwater recovery from seven recovery wells (R-21, R-35R, R-42, R-43, R-44, R-45, and R-46). Additional recovery wells (R-47 and R-48) are planned, as discussed in Section 4.4.

Performance monitoring completed to date has demonstrated that the groundwater extraction system is effective at removing sulfolane from the aquifer and enhancing LNAPL recovery. The hydraulic capture evaluation for the sulfolane and BTEX plumes will be expanded and consistent with previous assessments based on groundwater elevation and quality data, evaluation of groundwater elevation data, and groundwater flow modeling. LNAPL mass reduction will be assessed by monitoring LNAPL volumetric recovery rates from the DPR system and measurement of LNAPL transmissivity.

4.4.4.1 Groundwater

4.4.4.1.1 Hydraulic Capture

FHRA will measure groundwater elevations in select monitoring wells and nests to evaluate the horizontal and vertical hydraulic capture of the system. The depth to groundwater will be measured monthly and used to generate water table elevation contour plots and plots of vertical head differences between nested wells. Evaluations of groundwater capture based on the water table elevation contour plots will be included in the quarterly groundwater monitoring reports. The groundwater model will also be used to evaluate capture.

The proposed hydraulic capture performance monitoring network includes the following locations as shown on Figure 4-3: MW-113, MW-125, MW-130, MW-135, MW-136, MW-137, MW-175, MW-186 A/B/E, MW197 A/B, MW-199, MW-307, MW-309-15/66, MW-334-15/65, O-2, O-3, O-4, O-5, O-6, O-12, O-19, O-24, R-14A, R-18, R-22, R-39, R-40, S-32, S-43, S-44, S-50, and S-51.

Additionally, proposed monitoring well nests EGWRT-1, EGWRT-2, EGWRT-3, EGWRT-4, EGWRT-5, and EGWRT-6 (Figure 4-4) will be added to the performance network upon installation of the proposed expanded groundwater recovery system. As described in the Revised 2013 Onsite SCWP (ARCADIS 2013g), installation of a new well nest is planned at well O-19 to enhance upgradient monitoring. Additionally, monitoring wells screened in the 10 to 55 feet below water table groundwater zone are proposed for installation adjacent to observation wells O-5, O-12, O-24, and O-26, and these will be added to the performance monitoring network upon installation. With the addition of the proposed well nests, a nested monitoring well will be located upgradient and near each recovery well across the breadth of the sulfolane plume. The current monitoring well networks are summarized in Table 4-1.

Groundwater elevation will be manually measured monthly, contoured, and used to evaluate capture at the water table and in cross section. The frequency and timing of measurements will be reevaluated periodically during operation of the full groundwater recovery system. In addition, the extent of vertical capture will be inferred based on maps of vertical head differences from manual measurements. Dataloggers are currently installed in several of the wells listed above, including well nests at MW-186, MW-309, and MW-334, and provide additional continuous groundwater elevation data for evaluating variations in groundwater elevations between measurement events. It is anticipated that during some months, the number and locations of frozen wells may prevent complete evaluation of the capture zone.

The recently completed start-up aquifer testing results will be submitted to the ADEC in a separate technical memorandum. This memo will include a hydraulic capture zone evaluation for the modified recovery system in its current configuration. Following completion of this data analysis, FHRA will evaluate the results and present an updated hydraulic capture zone evaluation to the ADEC. If additional performance monitoring is required, it will be proposed in the start-up testing summary report.

4.4.4.1.2 Contaminant Capture

FHRA will monitor sulfolane and BTEX concentrations in groundwater on a quarterly and semiannual basis, respectively. To evaluate the results, existing monitoring locations have been categorized as upgradient, within the treatment zone, and downgradient as shown on Figure 4-2 and described below:

- Upgradient monitoring locations: O-6, O-19, MW-130, MW-175, and S-43.
- Within the treatment zone locations: O-2, O-5, MW-113, MW-125, MW-186 A/B/E, MW-199, MW-309-15/66, MW-334-15/65, R-39, and R-40.
- Downgradient monitoring locations: MW-127, MW-129, MW-139, MW-142, MW-145, MW-154A/B, O-3, O-4, O-12, O-24, and O-26.

The groundwater capture zone analysis is ongoing. Performance monitoring wells identified for containment capture may be modified as necessary. The current monitoring well networks are summarized in Table 4-1

Beginning with the First Quarter 2013 Groundwater Monitoring Report (ARCADIS 2013d), FHRA has provided an expanded discussion of sulfolane and BTEX concentrations at the performance monitoring locations to evaluate performance of the groundwater recovery system. Upon installation of the proposed recovery wells and monitoring well nests described in Section 4.4, the performance monitoring network will be expanded to include the following:

- Upgradient monitoring locations: EGWRT-1 and O-19 well nest;
- Within the treatment zone locations: EGWRT-2, EGWRT-3, EGWRT-4, and the planned well in the O-5/MW-199 area; and
- Downgradient monitoring location: EGWRT-5, EGWRT-6, and the planned deeper wells at O-12, O-24, and O-26.

In addition to collecting groundwater quality data from monitoring wells, FHRA will continue to monitor BTEX and sulfolane concentrations in extracted groundwater from each active recovery well on a monthly basis. The mass recovery rate for each recovery well will be calculated and reported to the ADEC in the quarterly groundwater monitoring reports.

4.4.4.2 Light Nonaqueous Phase Liquid

LNAPL recovery and recoverability will be assessed by monitoring LNAPL volumetric recovery rates from the DPR system and measuring LNAPL transmissivity. DPR LNAPL recovery performance will be evaluated by recording the volume of LNAPL recovered. These data will be used in conjunction with groundwater extraction rates to calculate LNAPL transmissivity through time. Also, LNAPL transmissivity testing will be completed in nearby monitoring wells. As LNAPL is recovered from the subsurface, the transmissivity will decrease due to the decrease in LNAPL saturation. Because LNAPL recoverability and transmissivity are interrelated, the volume recovery rate will also decrease.

DPR will recover LNAPL from the groundwater extraction wells via in-well LNAPL skimming pumps. The performance monitoring network is summarized below:

- Monthly measurements of LNAPL volume recovered and calculation of LNAPL transmissivity from the groundwater extraction wells as discussed in Section 4.3.4

- Semiannual LNAPL transmissivity testing at monitoring wells within the zone of influence of the groundwater extraction system (MW-186A, MW-334-15, O-2, R-14A, S-39, S-50, and S-51), if sufficient LNAPL is present (greater than 0.5 foot).

4.4.5 Permitting

Acquisition of several permits is required prior to operation of the expanded groundwater extraction system including:

- A new or amended temporary water use permit from the DNR to include the proposed recovery wells.

- A new or amended discharge permit from the ADEC staff in the Wastewater Discharge Program to receive a discharge permit for the proposed system.

- Building and zoning permits from local municipalities.

Additional permits may be required as determined through the FHRA construction management process.

4.5 Alternative Water Solutions Program – Management Plan

As described in previous submittals, FHRA initiated a comprehensive response plan that includes an ongoing commitment to supply the sulfolane-affected and potentially affected citizens of North Pole and the North Star Borough with an alternative water solution beyond the cleanup plan completion timeframe. These AWS options include: long-term delivery of bottled water, bulk water tank systems, and Point-of-Entry in-home water treatment systems (POE treatment systems). An AWS Program – Management Plan, previously submitted to the ADEC as draft, for the AWS options has been finalized by FHRA and is included as Appendix I.

4.6 Revised Point-of-Entry Treatment System Feasibility Study and Design Report

As stated above, a POE treatment system is one of the alternative water solutions. Point-of-Entry treatment refers to treatment of water at the point where it enters a residence, as opposed to treatment at a centralized facility prior to distribution to individual residences. FHRA prepared a Revised Point-of-Entry Treatment System Feasibility Study and Design Report, which describes the results of a feasibility study conducted to evaluate potential POE treatment systems to treat groundwater impacted with sulfolane. The results of this feasibility study are included in the report, which is provided as an Attachment to the AWS Program – Management Plan (Appendix I). This report was originally submitted to ADEC in February 2011; the revised report is included as Attachment B to Appendix I of this Addendum to provide an update on actions taken since submittal, which include in-home pilot testing and modifications to the treatment system design based on the results of the testing.

4.7 Reliability Testing

FHRA continues to conduct reliability monitoring and testing on facility refining and distribution equipment to achieve and maintain source control. The inspection process and operational policies are in place to eliminate systemic releases or leaking issues and minimize the potential for new spills. FHRA will continue to notify the ADEC if leaks or spills occur, as required by ADEC regulations.

4.8 Active Facility Operational Constraints

The NPR is an operating facility that will continue to be in operation throughout implementation and operation of the proposed interim remedial strategy. Consequently, the active facility infrastructure imposes constraints on the onsite remedial actions by restricting access to LNAPL and groundwater located near and under the existing infrastructure. Modifications to the onsite scope of work proposed above may be necessary based on conflicts with current operations identified during the internal FHRA construction management process.

5. Waste Management Plan

Groundwater extraction and LNAPL recovery (DPR, skimming, and manual recovery) are proposed for treatment of hydrocarbon- and sulfolane-impacted groundwater, and LNAPL. It is anticipated that wastewater, soil, LNAPL, and carbon will be generated during operations.

5.1 Groundwater

Extracted groundwater will be treated via the groundwater treatment systems. Purge water generated during monitoring, LNAPL skimming, and other remedial or monitoring activities will be treated via the facility process wastewater treatment system.

5.2 Soil

Soil generated during well installations and construction activities will be managed per the RSAP (ARCADIS 2013c).

5.3 Light Nonaqueous Phase Liquid

LNAPL recovered via onsite recovery operations will be recycled through the facility product refining systems.

5.4 Granular Activated Carbon

Spent carbon generated by operation of the groundwater extraction system will be handled and disposed of at regular intervals per the Updated Spent Carbon Management Plan (ARCADIS 2013f). The spent carbon will be transferred to super-sacks and transported to Organic Incineration Technology, Inc. for thermal treatment to destroy the captured sulfolane.

6. Implementation Schedule

FHRA's proposed implementation schedule for the interim remedial strategy described in this Addendum is included as Appendix J. This schedule includes managing the design of each alternative through the NPR facility design process, implementation, remediation system start up, O&M and performance monitoring, and installation reporting. O&M and performance monitoring summaries and progress reports will be included in quarterly groundwater monitoring report submittals.

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Appendix **A**

NPR Facility Map

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Appendix **B**

Remediation Well Installation Technical Memorandum

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Appendix **C**

Updated Air Sparge Pilot Test Report

Appendix **D**

Technical Memorandum – Potential Metabolites of Aerobic Sulfolane Biodegradation by Microorganisms

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Appendix **E**

Technical Memorandum –
Toxicological Assessment of Potential Intermediates of Sulfolane Breakdown

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Appendix **F**

Geotech Keck Spoiler Cut Sheet

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Appendix **G**

Modeled Groundwater Extraction Particle Tracking Figures

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Appendix **H**

Draft Expanded Groundwater Extraction System Construction Drawings

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Appendix I

Alternative Water Solutions Program – Management Plan

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Appendix **J**

Proposed Implementation Schedule