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Flint Hills Resources Alaska, LLC

Fourth Quarter 2012 Groundwater Monitoring Report

North Pole Refinery
North Pole, Alaska
DEC File Number: 100.38.090

March 1, 2013

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Table of Contents

Acronyms and Abbreviations **vii**

1. Introduction **1**

2. Site Setting **2**

2.1 Site Description 2

2.2 Physical Setting 2

2.3 Hydraulic Gradient Study 3

3. Current Groundwater Monitoring Program and Methods **4**

3.1 Groundwater Elevation and Light Nonaqueous Phase Liquid Monitoring 4

3.2 Baildown Testing 5

3.2.1 Background 5

3.2.2 Methods 6

3.3 Groundwater Sampling Priorities 7

3.4 Groundwater Sampling Methods 7

3.5 Groundwater Monitoring Analytical Methods 8

3.6 Geochemical Parameter Monitoring 8

3.7 Private Well Sampling 9

4. Groundwater Monitoring Results **11**

4.1 Groundwater Elevation 11

4.2 Surface-Water Elevation 13

4.3 Light Nonaqueous Phase Liquid Monitoring Results 13

4.3.1 Light Nonaqueous Phase Liquid Extent 13

4.3.2 Light Nonaqueous Phase Liquid Thickness 13

4.4 Baildown Testing Results 14

4.5 Onsite Monitoring Well Sampling Results 15

4.5.1 Benzene, Toluene, Ethylbenzene, and Total Xylenes 15

4.5.2 Sulfolane 16

4.5.2.1 Water Table 16

4.5.2.2 10 to 55 Feet Below the Water Table 16

4.5.2.3 55 to 90 Feet Below the Water Table 16

4.5.2.4 90 to 160 Feet Below the Water Table 17

4.5.2.5 Vertical Profiling Transect 17

4.5.3 Sulfolane Mass Flux 18

4.6 Offsite Monitoring Well Sampling Results 20

4.6.1.1 Water Table 20

4.6.1.2 10 to 55 Feet Below the Water Table 20

4.6.1.3 55 to 90 Feet Below the Water Table 20

4.6.1.4 90 to 160 Feet Below the Water Table 21

4.7 Statistical Analysis of Benzene, Toluene, Ethylbenzene, and Total Xylenes, and Sulfolane Data 21

4.7.1 Benzene, Toluene, Ethylbenzene, and Total Xylenes Statistical Evaluation 21

4.7.1.1 Nondetects, Decreasing, or Stable Trends 22

4.7.1.2 Increasing Trends 22

4.7.1.3 No Trend 23

4.7.2 Sulfolane Statistical Evaluation 24

4.7.3 Nondetects, Decreasing, or Stable Trends 25

4.7.4 Increasing Trend 26

4.7.5 No Trend 26

4.7.6 Trend Changes Using Only USEPA Method 1625B Data 28

4.8 Private Well Sampling Results 29

4.9 Geochemical Parameters 30

4.9.1 Principal Component Analysis 31

4.9.2 Discriminant Analysis 32

4.10 Non-Routine Sample Collection 33

4.10.1 Chemical of Potential Concern Analysis 33

4.10.2 Air Sparging Pilot Test 34

4.10.3 2012 Site Characterization Activities 34

4.10.4 Perfluorinated Compound Sampling 35

5. Remediation System Results and Evaluation 36

5.1 Groundwater Recovery 36

5.1.1 Groundwater Capture Evaluation 38

5.1.2 Mass Recovery 40

5.2 Light Nonaqueous Phase Liquid Recovery 41

5.3 Groundwater Treatment Evaluation 41

5.4 Summary of Non-Routine Repairs, Changes, and Maintenance 43

6. Analytical Quality Assurance and Quality Control 44

6.1 Water Sample Data Quality 44

6.2 Sample Handling 45

6.3 Analytical Sensitivity 47

6.4 Accuracy 48

6.5 Precision 50

6.6 Data Quality Summary 51

7. Conclusions and Recommendations 52

8. References 54

Tables

Table 1-1 Field Activities

Table 3-1 Well Construction Parameters

Table 3-2 Groundwater Elevation Monitoring Well Network

Table 3-3 LNAPL Thickness Monitoring Network

Table 3-4 LNAPL Migration Monitoring Network

Table 3-5 BTEX Monitoring Network

Table 3-6a Sulfolane Monitoring Network – On-site

Table 3-6b Sulfolane Monitoring Network – Off-site

Table 4-1 Groundwater Well Field Parameter Results

Table 4-2 Groundwater Elevation and LNAPL Thickness

Table 4-3 LNAPL Thickness Results

Table 4-4 LNAPL Migration Monitoring Well Network Results

Table 4-5 LNAPL Baildown Testing and Analysis Results

Table 4-6 BTEX Analytical Results

Table 4-7 Sulfolane Analytical Results

Table 4-8 Sulfolane Analytical Results – Vertical Profiling Transect

Table 4-9 Sulfolane Mass Flux Results

Table 4-10 Residential Well Sulfolane Results – Initial Sampling Event

Table 4-11 Residential Well Sulfolane Results – Resampling Event

Table 4-12 Geochemical Field Parameter Results

Table 4-13 Geochemical Parameter Analytical Results

Table 4-14 COPC Analytical Results

Table 5-1 Remediation System Operation – Groundwater Recovery

Table 5-2 Groundwater Recovery System – Sulfolane Mass Recovery

Table 5-3a-e Groundwater Recovery System – Sulfolane Mass Recovery per Recovery Well

Table 5-4 Fourth Quarter 2012 LNAPL Recovery

Table 5-5 Annual LNAPL Recovery

Table 5-6 Remediation System Operation – Treatment System Performance

Figures

Figure 2-1 Site Location

Figure 2-2 Current Site Features

Figure 2-3 Site Plan – Onsite

Figure 2-4 Site Plan – Offsite

Figure 3-1 Private Well Search Areas and Sulfolane Results

Figure 4-1 Groundwater Contour Map – On-site Wells at Water Table

Figure 4-2 Groundwater Contour Map – Off-site Wells at Water Table

Figure 4-3 Groundwater Contour Map – On-site Wells at 10-55 Feet Below Water Table

Figure 4-4 Groundwater Contour Map – Off-site Wells at 10-55 Feet Below Water Table

Figure 4-5 Groundwater Contour Map – On and Off-site Wells at 55-90 Feet Below Water Table

Figure 4-6 Groundwater Contour Map – On and Off-site Wells at 90-160 Feet Below Water Table

Figure 4-7 LNAPL Monitoring Data

Figure 4-8 2011 and 2012 LNAPL Transmissivity

Figure 4-9 Analytical Results for BTEX at Water Table

Figure 4-10 Analytical Results for BTEX at 10-55 Feet Below Water Table

Figure 4-11 Analytical Results for BTEX at 55-90 Feet Below Water Table

Figure 4-12 Analytical Results for BTEX at 90-160 Feet Below Water Table

Figure 4-13 Analytical Results for Sulfolane at Water Table

Figure 4-14 Analytical Results for Sulfolane at 10-55 Feet Below Water Table

Figure 4-15 Analytical Results for Sulfolane at 55-90 Feet Below Water Table

Figure 4-16 Analytical Results for Sulfolane at 90-160 Feet Below Water Table

Figure 4-17 Sulfolane at the Vertical Profiling Transect

Figure 4-18 Sulfolane Mass Flux Rates – First Quarter 2012

Figure 4-19 Sulfolane Mass Flux Rates – Second Quarter 2012

Figure 4-20 Sulfolane Mass Flux Rates – Third Quarter 2012

Figure 4-21 Analytical Results for Sulfolane Greater than160 Feet Below Water Table

Figure 4-22 Principal Component Plot – Transect 1

Figure 4-23 Principal Component Plot – Transect 2

Figure 4-24 Discriminant Analysis Plot

Figure 4-25 Air Sparge Pilot Test Site Layout

Figure 5-1 Current Groundwater Recovery and Treatment System Layout

Figure 5-2 Current Process Flow Diagram – Groundwater Capture and Treatment System

Figure 5-3 Groundwater Recovery and Treatment System - Proposed Recovery Wells

Figure 5-4 Sulfolane Analytical Data – MW-127

Figure 5-5 Sulfolane Analytical Data – MW-131

Figure 5-6 Sulfolane Analytical Data – MW-139

Figure 5-7 Sulfolane Analytical Data – MW-142

Figure 5-8 Sulfolane Analytical Data – MW-143

Appendices

A Revised SAP

B Baildown Testing API Outputs

C Historical Data Tables for Groundwater Elevation and LNAPL Thickness, BTEX, Sulfolane, Geochemical Parameters, Private Wells, COPCs, and Culvert Water Elevations

D Analytical Laboratory Reports

E ADEC QA/QC Checklists

F Field Data Sheets

G Hydrographs

H Sulfolane Mass Flux Methods

I Mann – Kendall Trend Charts

J Level IV Data Validation Reports

Acronyms and Abbreviations

2012 SCWP	2012 Site Characterization Work Plan
AAC	Alaska Administrative Code
ACL	alternative cleanup level
ADEC	Alaska Department of Environmental Conservation
AFCEE	Air Force Center for Environmental Excellence
ARCADIS	ARCADIS U.S., Inc.
ASTM	ASTM International
Barr	Barr Engineering Company
bgs	below ground surface
BMS	billable matrix spike
BMSD	billable matrix spike duplicate
BTEX	benzene, toluene, ethylbenzene, and total xylenes
CCV	continuing calibration verification
city	North Pole, Alaska
COC	chain of custody
COPC	chemical of potential concern
CSIA	carbon stable isotope analysis
DNR	Alaska Department of Natural Resources
DO	dissolved oxygen
Draft Final Onsite FS	Draft Final Onsite Feasibility Study
ESI	Environmental Standards, Inc.
FHRA	Flint Hills Resources Alaska, LLC
ft^2/day	square foot per day
ft/ft	foot per foot
g/day	grams per day

GAC	granular activated carbon
GC/MS	gas chromatography/mass spectrometry
gpm	gallons per minute
GVEA	Golden Valley Electric Association
IRAP	Interim Removal Action Plan
IRAP Addendum	Interim Remedial Action Plan Addendum
ITRC	Interstate Technology & Regulatory Council
lb/day	pound per day
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LNAPL	light nonaqueous phase liquid
LOQ	limit of quantitation
MAROS	Monitoring and Remediation Optimization System
mg/L	milligrams per liter
MS	matrix spike
MSD	matrix spike duplicate
NPR	North Pole Refinery
O&M	operation and maintenance
PCA	principal component analysis
PFC	perfluorinated compound
power plant	electrical generating facility
QA	quality assurance
QC	quality control
report	Fourth Quarter 2012 Groundwater Monitoring Report
reporting period	fourth quarter 2012
RPD	relative percent difference

SAP	Sampling and Analysis Plan
SCR – 2011	Site Characterization Report – Through 2011
SCR – 2012	Site Characterization Report – 2012 Addendum
SCWP Addendum	Site Characterization Work Plan Addendum
SGS	SGS Laboratories
site	Flint Hills Resources Alaska, LLC North Pole Refinery, located on H and H Lane in North Pole, Alaska
SOP	Standard Operating Procedure
SWI	Shannon & Wilson, Inc.
TOC	total organic carbon
TPT	Technical Project Team
TWUP	temporary water use permit
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound
VPT	vertical profiling transect
WO	work order
WWTP	wastewater treatment plant
µg/L	micrograms per liter
°C	degrees Celsius

1. Introduction

On behalf of Flint Hills Resources Alaska, LLC (FHRA), ARCADIS U.S., Inc. (ARCADIS) prepared this Fourth Quarter 2012 Groundwater Monitoring Report (report) for the FHRA North Pole Refinery (NPR), an active petroleum refinery located on H and H Lane in North Pole, Alaska (site). This report is considered the 2012 annual report and contains analyses performed annually including a hydraulic gradient assessment, sulfolane and benzene statistical trends, mass flux analysis, geochemical principal component analysis (PCA), and geochemical discriminant analysis. Several of these analyses were originally presented in the Site Characterization Report - Through 2011 (SCR – 2011; Barr Engineering Company [Barr] 2012); the results and interpretations will be updated in an addendum to this report as described in Section 2.3.

This report summarizes field activities completed during the fourth quarter 2012 (reporting period). Field activities completed during the reporting period include onsite and offsite groundwater and light nonaqueous phase liquid (LNAPL) monitoring, baildown testing, private well monitoring, onsite remediation system operation and maintenance (O&M), well installation, additional site characterization activities, and pilot testing. Table 1-1 summarizes the field activities completed during the reporting period.

Field activities were completed by qualified persons, as defined by 18 Alaska Administrative Code (AAC) 75.990. Shannon & Wilson, Inc. (SWI) of Fairbanks, Alaska completed groundwater monitoring, baildown testing, private well monitoring, remediation system monitoring, and well installation. FHRA field staff, under Barr's direction, completed remediation system O&M activities. ARCADIS, Barr, and SWI completed additional site characterization and pilot testing activities.

2. Site Setting

This section describes the site and the site's physical setting, and summarizes the current groundwater monitoring program at the site.

2.1 Site Description

The site is located on 240 acres 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 2-1). 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.

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. Previously, a truck-loading rack was located between the railcar-loading rack and the tank farms, near the intersection of Distribution Street and West Diesel. 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). FHRA representatives indicated that the power plant burns heavy aromatic gas oil (diesel 4) and other fuels produced at the site. The property south of the site and the GVEA power plant is occupied by the Petro Star, Inc. Refinery. Figure 2-2 illustrates the main features on or near the site. An Onsite Site Plan is presented on Figure 2-3 and an Offsite Site Plan is presented on Figure 2-4.

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 of property, 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.

2.2 Physical Setting

The site and the surrounding North Pole 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).

The city is located within an area of Alaska characterized by discontinuous permafrost (Ferrians 1965). Permafrost tends to act as a confining layer, limiting the flow 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 Slough generally consists of highly transmissive sands and gravels under water table conditions (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 near Moose Creek Dam) (Glass et al. 1996). Beyond the zones of influence of the NPR 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 generally varies 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 Hydraulic Gradient Study

FHRA prepared a Standard Operating Procedure (SOP) for groundwater elevation monitoring and submitted the SOP to the Alaska Department of Environmental Conservation (ADEC) for approval. The SOP includes methods for estimating errors associated with groundwater elevation measurements. The groundwater elevation measurements are used to estimate vertical hydraulic gradients within well nests and horizontal hydraulic gradients and groundwater flow directions between groups of wells. An addendum to this report that presents and analyzes these gradient and flow direction estimates will be submitted to the ADEC once the SOP is approved.

3. Current Groundwater Monitoring Program and Methods

The current onsite and offsite groundwater monitoring program was originally proposed in the Site Characterization and First Quarter 2011 Groundwater Monitoring Report (Barr 2011) and was subsequently revised in the Site Characterization Work Plan Addendum (SCWP Addendum; ARCADIS 2011) and the SCR – 2011 (Barr 2012). Table 3-1 summarizes well construction details. Tables 3-2, 3-3, 3-4, 3-5, 3-6a, and 3-6b summarize the groundwater elevation monitoring well network; LNAPL thickness monitoring well network; LNAPL migration monitoring well network; benzene, toluene, ethylbenzene, and total xylenes (BTEX) monitoring well network, and sulfolane monitoring well network (including both onsite and offsite wells), respectively. Well locations are shown on Figures 2-3 and 2-4.

Routine quarterly groundwater monitoring and sampling was performed as part of the ongoing operations to characterize onsite LNAPL, dissolved-phase BTEX, and onsite and offsite sulfolane impacts. Methods used for non-routine analyses and analyses performed annually are described or referenced in corresponding sections.

Groundwater monitoring was completed according to the procedures summarized in the Sampling and Analysis Plan (SAP) initially presented in Appendix M of the Site Characterization Work Plan (Barr 2010a). The SAP is updated on a continuous basis and submitted periodically; updates are tracked in Appendix A of the SAP. The SAP is referred to in this report as the project SAP. Revisions and updates have been incorporated into the project SAP, which is included as Appendix A of this report. Table 1-1 summarizes the field activities completed during the reporting period.

Groundwater monitoring data are used to assess changes and any trends that may be present at the site and to characterize the effectiveness of the onsite groundwater recovery system. A statistical analysis of BTEX and sulfolane concentration trends was originally presented in the SCR – 2011 (Barr 2012). Updated BTEX and sulfolane regression analyses are presented in Section 4.7 of this report.

3.1 Groundwater Elevation and Light Nonaqueous Phase Liquid Monitoring

Depth to groundwater was measured on November 1 and 2, 2012 from an extensive network of onsite and offsite wells. As described in the SCR – 2011 (Barr 2012), the LNAPL monitoring network was expanded and measurements were collected to determine the LNAPL thickness and potential migration to confirm the stability of the LNAPL plume. LNAPL thickness and migration measurements were collected monthly from monitoring wells during this reporting period on October 15 and 16, November 29, and December 27 and 28, 2012.

Depth to water and LNAPL thickness measurements were completed according to the project SAP (Appendix A). Measurements were collected from site monitoring wells with an oil/water interface probe. If present, LNAPL thickness was calculated based on depth to groundwater and LNAPL measurements. Groundwater elevation was calculated using the previously surveyed top of casing elevation and the groundwater elevation. Groundwater elevation where LNAPL was present was corrected for the appropriate LNAPL-specific gravity value presented in the SCR – 2011 (Barr 2012). Onsite and offsite wells were resurveyed in November 2012 to account for frost-jacking and settling of monitoring well casings due to regional weather patterns.

In addition to manual water-level measurements, automated measurements were collected from several wells using vented Global WL-16 automated water-level loggers, vented In-Situ Level Troll 500 loggers, or unvented In-Situ Rugged Troll 100 loggers. Each WL-16 is a combined pressure transducer and data logger with automatic barometric pressure and temperature compensation. One Barotroll® logs the barometric pressure for the In-Situ Troll loggers. Each logger is calibrated to provide a direct elevation reading and is programmed to measure water levels on an hourly basis. A total of 68 transducers are currently deployed in 24 onsite wells and 44 offsite wells to observe hydrogeological conditions between wells screened at various depths within the suprapermafrost aquifer, as reported in the Site Characterization Report – 2012 Addendum (SCR – 2012; ARCADIS 2013a).

FHRA prepared an SOP for groundwater elevation monitoring and submitted the SOP to the ADEC for approval. Once approved, groundwater elevation measurements downloaded from deployed transducer will be evaluated to estimate vertical hydraulic gradients within well nests and horizontal hydraulic gradients and groundwater flow directions between groups of wells, as discussed in Section 2.3.

3.2 Baildown Testing

LNAPL baildown testing is currently performed semiannually during the second and fourth quarters to characterize LNAPL transmissivity at the site. The LNAPL transmissivity results are used to quantify relative LNAPL recoverability to focus LNAPL recovery efforts in areas that have higher recovery potential and to establish practical limits of recovery.

3.2.1 Background

The recoverability of LNAPL at an environmental site is influenced by many factors, including LNAPL saturation in the impacted soil, soil permeability, and physical properties of the LNAPL. The saturation and permeability directly influence the relative permeability of LNAPL. Due to the interactions of groundwater, air, and LNAPL within petroleum-impacted soil, the relative permeability of LNAPL is less than the overall soil permeability. Moreover, the physical properties of the LNAPL influence the rate that LNAPL can flow within the

formation. An empirical method to assess LNAPL recoverability at the field scale is to test LNAPL transmissivity, which integrates all of the relevant factors influencing LNAPL recoverability. LNAPL transmissivity is commonly characterized using short-term duration LNAPL stress testing, also called LNAPL baildown testing.

An LNAPL baildown test is initiated by quickly removing LNAPL accumulated in a well, making it analogous to a groundwater rising-head slug test. 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. Multiple baildown tests may be required to describe the range of LNAPL transmissivity under different fluid level conditions at sites with significant potentiometric surface fluctuations.

The relative observed recovery data resulting from LNAPL baildown tests can be inspected to provide a qualitative sense of the recoverability of LNAPL. A short period for the LNAPL to recover to approximately the thickness measured prior to the test indicates favorable recoverability, whereas an extended period for LNAPL recovery points to poor recoverability.

LNAPL baildown tests that have sufficient LNAPL discharge into the well (recovery) can be quantitatively analyzed to determine LNAPL transmissivity under the test conditions. The calculated LNAPL transmissivity can be used to quantitatively characterize the LNAPL bulk transport conditions onsite and comparatively assess LNAPL recoverability. LNAPL recovery using hydraulic methods (e.g., dual-phase extraction, skimmer pumping, vacuum truck operations) is typically not effective for areas where LNAPL transmissivity is less than 0.1 to 0.8 square foot per day (ft^2/day; Interstate Technology & Regulatory Council [ITRC] 2009).

3.2.2 Methods

Pre-test depth to air/LNAPL and LNAPL/groundwater interfaces are recorded using an oil/water interface probe prior to starting a baildown test. The baildown tests are initiated by evacuating LNAPL from a well using a peristaltic pump or bailer. The fluids removed from the well are collected in a graduated cylinder and the total volume of LNAPL and groundwater are documented. After LNAPL has been purged from the well to the extent practical, routine fluid level measurements are taken using the oil/water interface probe. At sites where rapid recharge is expected, the manual fluid level measurement approach may be augmented using a potentiometric surface data logger. Fluid level data are initially collected in short intervals, typically on the order of every minute, at test initiation and adjusted thereafter based on the test-specific rate of LNAPL recovery. This process is continued as long as it is viable or necessary based on field logistics and data quality

objectives, respectively. The baildown testing protocol is described in ARCADIS' SOP for LNAPL Baildown Test, which is included as Appendix C to the project SAP (Appendix A).

One or two LNAPL baildown tests were completed at 12 monitoring wells in October 2012: MW-176A, MW-186, O-10, O-11, O-13, O-19, O-27, R-14A, S-22, S-39, S-50, and S-51. Tests conducted at wells MW-186A, O-11, O-19, and S-39 were not analyzed for various reasons as discussed in Section 4.4. Hydrographs of wells with analyzed baildown tests, showing depth to product, depth to water, and corrected water table elevation during the baildown tests are included with the American Petroleum Institute (API) tool output in Appendix B. Other relevant information such as geologic data from soil boring logs, lithologic cross-sections (where available), and well screen intervals are also included on the hydrographs to show how fluid level elevations relate to the well screen and to changes in lithology outside the borehole. All depths on the hydrographs are plotted in units of feet below ground surface.

Baildown tests were analyzed using methods per ASTM International (ASTM) standards. Analysis for baildown tests include two modified slug tests methods: Bouwer and Rice (1976) and Cooper et al. (1967)/Jacob and Lohman (1952). All methods of analysis are presented in the API tool.

3.3 Groundwater Sampling Priorities

In response to several quarterly sampling events where inclement weather reduced the opportunity to collect samples from all wells within each monitoring well network, well networks were evaluated and each well was assigned a priority (one through four). Tables 3-5, 3-6a and 3-6b summarize the priority levels assigned to each well in the BTEX and sulfolane monitoring networks, respectively. Priority levels for each monitoring well network were also updated in the project SAP (Appendix A).

During the reporting period, samples were not collected from 15 out of 54 wells from the BTEX monitoring network and 62 out of 253 wells from the sulfolane monitoring network due to inclement weather. Four wells in the sulfolane monitoring network were not sampled because the wells were frozen or dry. One well in the sulfolane network was damaged and could not be sampled. Non-sampled wells are summarized in Tables 4-6 and 4-7, which also include BTEX and sulfolane results, respectively.

3.4 Groundwater Sampling Methods

Groundwater samples collected during the reporting period were generally sampled in accordance with the project SAP (Appendix A). Groundwater was purged from each sampled well using dedicated or portable pumps. Purging was conducted until geochemical parameters stabilized or three well volumes of groundwater were pumped from the well. A

YSI ProPlus multiprobe or equivalent was used to monitor geochemical parameters, including temperature, conductivity, dissolved oxygen (DO), pH, and oxidation-reduction potential.

3.5 Groundwater Monitoring Analytical Methods

Upon collection, groundwater samples were stored in iced coolers and submitted to SGS Laboratories (SGS) of Anchorage, Alaska under proper chain of custody (COC) procedures. Groundwater analytical samples were submitted for the following quarterly analyses:

- BTEX by United States Environmental Protection Agency (USEPA) Method 8260B
- Sulfolane by modified USEPA Method 1625B with isotope dilution gas chromatography/mass spectrometry (GC/MS)

SGS developed an SOP for modified USEPA Method 1625B/8270D with isotope dilution GC/MS, in accordance with a Key Elements document prepared by the Chemistry Subgroup of the Technical Project Team (TPT). The SOP was approved by the ADEC via email on May 18, 2011.

3.6 Geochemical Parameter Monitoring

Geochemical parameter monitoring is currently conducted semiannually during the second and fourth quarters to characterize the potential for dilution, biological degradation, or abiotic reactions that may attenuate sulfolane in-situ. Geochemical parameter analytical samples were submitted to SGS for analyses, as outlined in the project SAP (Appendix A).

Field parameter measurements including temperature, electrical conductivity, DO, and pH were collected from the sulfolane monitoring well network. A YSI ProPlus multiprobe, calibrated according to the manufacturer's instructions, was used to obtain the measurements. Total manganese, dissolved manganese, reduced manganese, total iron, ferrous or dissolved iron, and ferric or reduced iron were measured in the field using Hach Company reagents and a DR/2010 field spectrophotometer, following the manufacturer's instructions. Oxidized iron species are determined by the difference between total iron and reduced iron in the Hach Co. measurements, or between total iron and dissolved iron in the laboratory measurements.

Reduced manganese was determined using Hach Co. reagents and a modification of the protocol for manganese analysis. The Hach Co. manganese analysis employs the "PAN method," which is capable of detecting low levels of manganese. In this method, an ascorbic acid reagent is added to the sample initially to reduce all oxidized forms of

manganese to dissolved manganese. After adding an alkaline-cyanide reagent to mask potential interferences, the PAN indicator is then added to combine with the dissolved manganese to form an orange-colored complex that is measured colorimetrically. Reduced manganese was measured in the samples by omitting the addition of ascorbic acid, which allowed measurement of the reduced manganese present in the sample prior to adding the reducing agent. Oxidized manganese is then determined by the difference between total and reduced manganese.

3.7 Private Well Sampling

A door-to-door survey was previously conducted downgradient of the site to identify private water-supply wells in Search Areas 1 through 9 (Figure 3-1). Site characterization activities began offsite in 2009. Since that time, permanent buildings within the search areas were visited and residents were surveyed to determine the presence of wells on the properties. If a well was identified, information regarding well construction details and water usage was requested. If a drinking-water well was present on a property, permission to collect a groundwater sample for sulfolane analysis was requested. The overall search area was expanded until private well water sample results were non-detect for sulfolane.

Well search efforts began in Search Area 9 during the third quarter 2012 to determine sulfolane detections in the area of the northernmost city fire well, as discussed in the Third Quarter 2012 Groundwater Monitoring Report (ARCADIS 2012b). Survey efforts continued in Search Area 9 during the reporting period. Search Area 9 is located within residential neighborhoods that are supplied with city water. The Search Areas are shown on Figure 3-1.

SWI surveyed residents at permanent structures within Search Area 9 during the reporting period to obtain information about whether a well is present on the property. If a well was identified, SWI requested well construction details, water usage information, and permission to collect a groundwater sample for sulfolane analysis. During the reporting period, wells were identified in two locations in Search Area 9; however, groundwater samples were unable to be collected; one sample was sealed and the other was frozen.

Previously sampled wells within and near the edges of the sulfolane plume that had not yielded samples containing detectable sulfolane were resampled during 2012, with a few locations being completed during the reporting period. This resampling event included two private wells during the reporting period, which are included in the comprehensive dataset presented on Figure 3-1.

Twelve additional samples were collected from wells outside the search areas in response to call-in requests submitted to FHRA (Figure 3-1).

As of December 31, 2012, FHRA resampled 171 wells during 2012 that previously did not contain detectable concentrations of sulfolane during the previous sampling events from areas near the edge of the plume. Throughout the project (between November 11, 2009 and December 31, 2012), FHRA sampled 581 wells within the search areas. In addition, 145 private well samples were collected from outside the search areas at locations near the defined search areas (e.g., sharing a driveway) or where FHRA was contacted (by a landowner, resident, or a real estate agent) with requests for testing. Historical private well analytical results are included in Appendix C. Copies of laboratory reports were provided to the well owners. Residential laboratory reports and associated ADEC data review checklists for the reporting period are presented in Appendices D and E, respectively. Sampling locations are shown on Figure 3-1.

4. Groundwater Monitoring Results

Groundwater impacts have been, and continue to be, characterized through the analysis of gauging data and groundwater samples collected from onsite and offsite monitoring wells. This section presents results of gauging data and groundwater analyses of onsite well samples (analyzed for BTEX and/or sulfolane), offsite well samples (analyzed for sulfolane), private well samples (analyzed for sulfolane), and non-routine samples collected during the reporting period. Groundwater field parameters, groundwater elevation and LNAPL thickness measurements, LNAPL migration measurements, BTEX analytical results, sulfolane analytical results, sulfolane mass flux results, residential well analytical results, geochemical parameters results, and other chemical of potential concern (COPC) analytical results are presented in Tables 4-1 through 4-14. Field data sheets are included as Appendix F. Historical groundwater elevation and LNAPL thickness measurements, BTEX analytical results, sulfolane analytical results, geochemical analytical results, and private well analytical results are included as Appendix C. Laboratory analytical reports and ADEC review checklists are included as Appendices D and E, respectively.

4.1 Groundwater Elevation

Depth to water measurements were collected from monitoring wells on November 1 and 2, 2012. During the reporting period, groundwater gradient was interpreted to be to the north-northwest, which is consistent with historical groundwater data. Depth to water measurements and groundwater elevation data are summarized in Table 4-2. Potentiometric maps are included for each monitoring zone: water table, 10 to 55 feet below the water table, 55 to 90 feet below the water table, and 90 to 160 feet below the water table Figures 4-1 through 4-6). Onsite groundwater gradients of approximately 0.001 and 0.0011 foot per foot (ft/ft) were calculated at the water table and at 10 to 55 feet below the water table, respectively, during the reporting period. The offsite groundwater gradients at the water table and at 10 to 55 feet below the water table were calculated at 0.0007 and 0.0008 ft/ft, respectively. The groundwater gradients at 55 to 90 feet below the water table and 90 to 160 feet below the water table were calculated at 0.0012 and 0.0011 ft/ft, respectively.

In addition to manual water-level measurements, automated measurements were collected with transducers from nine monitoring wells and 21 well nests. Transducer data were downloaded on December 26, 27, 28 and 31, 2012 and January 4, 2013; hydrographs indicate a maximum groundwater elevation during mid-July and late July to early August. Data from well nests were used to observe differences in groundwater elevations between wells screened at various depths within the suprapermafrost aquifer. The following observations were made from data collected during the reporting period and are based on draft hydrographs presented in Appendix G and do not take into account errors in the water elevation data that will be estimated once the SOP described in Section 2.3 is complete:

- An upward vertical gradient is evident on hydrographs from 12 well nests.
- A downward vertical gradient is evident on hydrographs from four well nests.
- Vertical gradients varied between upward during low groundwater elevations and downward during peak groundwater elevations during the reporting period in well nest MW-322-15/150.
- No vertical gradient was evident during fourth quarter 2012 for well nest MW-328-15/151.

Several pressure transducer data logs are incomplete between the dates of October 1, 2012 and January 4, 2013. The pressure transducers installed in monitoring wells MW-175, MW-179B, MW-179C, MW-179D, MW-186B, and MW-306-150 have incomplete data logs for the reasons outlined in the table below.

Monitoring Well	Reason for Data Loss	Dates Affected
MW-175	Batteries expired on 11/5/2012.	11/5/2012 to 12/31/2012
MW-179B	Pressure transducer is frozen in the well. Cannot communicate with pressure transducer— batteries are likely expired.	10/1/2012 to 12/31/2012 Note: A partial log may still be recovered once the well has thawed and communication with the device can be established.
MW-179C	Pressure transducer is frozen in the well. Cannot communicate with pressure transducer— batteries are likely expired.	10/1/2012 to 12/31/2012 Note: A partial log may still be recovered once the well has thawed and communication with the device can be established.
MW-179D	Pressure transducer is frozen in the well. Cannot communicate with pressure transducer— batteries are likely expired.	10/1/2012 to 12/31/2012 Note: A partial log may still be recovered once the well has thawed and communication with the device can be established.
MW-186B	Log did not save properly to file due to possible software issue. Software has now been updated with the manufacturer's most recent software.	10/1/2012 to 12/27/2012
MW-306-150	Batteries expired on 12/3/2012	12/3/2012 to 12/31/2012

A detailed evaluation of 2012 transducer data and hydraulic gradients will be submitted under separate cover, as discussed in Section 2.3.

4.2 Surface-Water Elevation

Measurements were recorded from gauging points located at the North and South Gravel pits on November 2, 2012. The North Gravel Pit measurement was taken from a surveyed mark on an I-beam above a grate in the fire pump house that sits over the water on the southeast end of the pit (Figure 4-1). The South Gravel Pit measurement was taken from a 12-foot staff gauge in the pond (Figure 4-1). The North and South Gravel pits were measured during the reporting period at elevations of 484.23 and 491.06 feet above mean sea level. Data are summarized in Table 4-2 and presented on Figure 4-1. Additionally measurements were recorded at seven culvert locations (Figure 4) prior to the reporting period during 2012. Historical gauging data are summarized in Appendix C.

4.3 Light Nonaqueous Phase Liquid Monitoring Results

As described in the SCR – 2011 (Barr 2012), new observation wells (O-5 through O-29) were installed to better define LNAPL occurrence at the site. Additionally, O-30 was installed during the third quarter 2012 period to better define the eastern extent of LNAPL. Well O-30 was inadvertently not gauged during the reporting period, however preliminary gauging data collected during first quarter 2013 did not indicate the presence of LNAPL at this location. LNAPL thickness measurements were collected on October 15 and 16, November 29, and December 27 and 28, 2012 from a network of monitoring, observation, and recovery wells screened across the water table. An apparent LNAPL thickness was measured in 28 wells during October 2012, in 26 wells during November 2012, and in 28 wells during December 2012. A visible sheen or trace (not measureable in the field) was recorded in three wells during October 2012, in four wells during November 2012, and in three wells during December 2012. During the reporting period (on October 15, 2012), a maximum LNAPL thickness of 2.50 feet was measured at monitoring well MW-176A. Well MW-176A is located adjacent to Containment Area 1 (Figure 2-3).

4.3.1 Light Nonaqueous Phase Liquid Extent

LNAPL migration measurements were collected from wells along the perimeter of the LNAPL plume on October 16, November 29, and December 27 and 28, 2012. LNAPL was not measured in any of the LNAPL migration monitoring wells during the reporting period (Table 4-4).

4.3.2 Light Nonaqueous Phase Liquid Thickness

LNAPL thicknesses and the LNAPL footprint observed during the reporting period are similar to historical footprints. The presence of LNAPL does not necessarily suggest recent or ongoing migration of LNAPL, but rather is defining the extent of the LNAPL plume because a well is now placed in an area where no well was historically located. To delineate

the vertical and horizontal extent of LNAPL impacts near well O-27, FHRA conducted a laser-induced fluorescence/ultraviolet optical screening tool investigation according to the methods described in the 2012 SCWP (ARCADIS 2012a). Results indicate that the extent of LNAPL near O-27 is defined (ARCADIS 2013a). LNAPL thickness and migration data are summarized in Tables 4-3 and 4-4, respectively, and maximum thickness data from the reporting period are presented on Figure 4-7.

4.4 Baildown Testing Results

Qualitative assessment of the LNAPL baildown test results suggests moderate LNAPL transmissivity in most of the wells tested. Results for all baildown tests are included in Table 4-5.

Quantitative estimates of LNAPL transmissivity could not be made at several of the wells planned for baildown testing for the following reasons:

- Baildown tests completed at wells O-11 and S-39 could not be quantitatively analyzed due to a lack of measurable LNAPL discharge from the formation to the well during the test, which lead to inability to fit data in the API tool.

- The initial baildown test completed at well O-19 could not be analyzed due to a lack of LNAPL drawdown, leading to inability to fit data in the API tool.

- Second baildown tests at wells MW-186A and O-19 could not analyzed due to a negligible LNAPL thicknesses in wells at test commencement. ASTM suggests a minimum of 0.5 foot of accumulated LNAPL to provide adequate transmissivity analysis (ASTM 2012). As a result, these tests are assumed to have transmissivity of 0 ft^2/day.

Tests at wells MW-176A, MW-186A, O-10, O-13, O-27, R-14A, S-22, S-50, and S-51 were analyzed using the API tool. LNAPL transmissivity values for these wells are presented in Table 4-5. Output from the API tool is included for each test in Appendix B.

LNAPL transmissivity estimates at wells MW-186A, R-14A, S-22, and S-51 are within or below the range of 0.1 to 0.8 ft^2/day suggested by the ITRC as the lower limit of practicable recoverability (ITRC 2009). This indicates that LNAPL is minimally recoverable surrounding these test locations. Transmissivity calculations for wells MW-176A, O-10, O-13, O-27, and S-50 were above the ITRC criterion of 0.1 to 0.8 ft^2/day, indicating potential for beneficial reduction of the LNAPL mass in areas surrounding these wells via ongoing recovery operations. LNAPL transmissivity results are depicted on Figure 4-8.

4.5 Onsite Monitoring Well Sampling Results

BTEX data are collected semiannually during the second and fourth quarters. BTEX results for the reporting period, summarized in Table 4-6 and plotted on Figure 4-9, show the inferred extent of the dissolved-phase BTEX plume at the water table. Deeper BTEX sampling from groundwater zones beneath the water table were recommended in the SCR – 2011 (Barr 2012). BTEX sampling results for wells screened at 10 to 55, 55 to 90 and 90 to 160 feet bgs below the water table are presented on Figures 4-10, 4-11, and 4-12, respectively.

Sulfolane data were collected from wells that are on annual, semiannual and quarterly schedules and from newly installed monitoring wells. Samples collected from 92 onsite wells during the reporting period were submitted for sulfolane analysis using the isotope dilution method. These data are presented in Tables 4-7 and 4-8. Sulfolane data collected from monitoring wells are plotted on Figures 4-13 through 4-16 to show the estimated extent of the dissolved-phase sulfolane plumes at the following depth intervals: water table, 10 to 55 feet below the water table, 55 to 90 feet below the water table, and 90 to 160 feet below the water table.

Twenty-two of the 92 groundwater samples were collected from vertical profiling transect (VPT) wells and analyzed for sulfolane; results are described in Section 4.5.2.5. Data are summarized in Table 4-8 and presented on Figure 4-17. Sulfolane concentrations for VPT wells in each groundwater zone are also presented on Figures 4-13 through 4-16.

For this report, FHRA uses the 14 micrograms per liter (µg/L) alternative cleanup level (ACL) referenced by the ADEC in a letter dated July 19, 2012 (ADEC 2012). This report is submitted subject to the positions and reservations expressed by FHRA in a letter dated August 20, 2012 (FHRA 2012). The ACL of 14 µg/L was used to evaluate sulfolane groundwater data collected during the reporting period. Historical sulfolane analytical results are included as Appendix C.

4.5.1 Benzene, Toluene, Ethylbenzene, and Total Xylenes

During the reporting period, benzene was detected above the ADEC groundwater cleanup level of 5 µg/L, with results ranging from 36.4 µg/L (MW-139) to 130 µg/L (MW-125). Benzene concentrations detected in the samples collected from MW-113, MW-180A, and MW-334-65 were flagged by the laboratory as estimated as described in Section 6. Figure 4-9 depicts an isopleth map at the water table to show the inferred extent of the BTEX plume. BTEX results are summarized in Table 4-6. Historical BTEX analytical results are included as Appendix C.

Benzene was not detected above the ADEC groundwater cleanup level of 5 µg/L in wells screened below the water table zone. Figures 4-10, 4-11, and 4-12 depict analytical results for BTEX at 10 to 55, 55 to 90, and 90 to 160 feet below the water table, respectively. Select wells screened within 10 to 55, 55 to 90, and 90 to 160 feet below the water table will be sampled in 2013 as proposed in the 2013 Onsite Site Characterization Work Plan (ARCADIS 2013b).

A statistical analysis of benzene trends was originally presented in the SCR – 2011 (Barr 2012). This analysis was updated with 2012 data and is presented in Section 4.7.

4.5.2 Sulfolane

4.5.2.1 Water Table

Sulfolane was detected above the ACL of 14 µg/L in samples collected from 24 onsite monitoring and observation wells screened across the water table, with results ranging from 23.6 µg/L (duplicate sample, MW-131) to 6,090 µg/L (O-1). Sulfolane concentrations detected in groundwater samples collected from wells MW-303-CMT-9, O-6, and O-24 were flagged by the laboratory as estimated as described in Section 6. The maximum sulfolane concentration of 6,090 µg/L was detected in the groundwater sample collected from well O-1, which exhibited a maximum concentration of 10,400 µg/L in November 2011. The estimated extent of the sulfolane plume is identified as an isopleth based on the ACL and is presented on Figure 4-13.

4.5.2.2 10 to 55 Feet Below the Water Table

Sulfolane was detected above the ACL of 14 µg/L in groundwater samples collected from 11 onsite wells at 10 to 55 feet below the water table, with results ranging from 16.5 µg/L (duplicate sample, MW-174A) to 304 µg/L (duplicate sample, MW-178B). Sulfolane concentrations detected in the groundwater samples collected from wells MW-304-CMT-20, MW-304-CMT-60, MW-305-CMT-18, and MW-334-65 were flagged by the laboratory as estimated as described in Section 6. The estimated extent of the sulfolane plume from 10 to 55 feet below the water table is identified as an isopleth based on the ACL and is presented on Figure 4-14.

4.5.2.3 55 to 90 Feet Below the Water Table

Sulfolane was detected above the ACL of 14 µg/L in three groundwater samples collected from onsite wells screened at 55 to 90 feet below the water table, with concentrations ranging from 16.7 µg/L (MW-186E) to 94.3 µg/L (duplicate sample, MW-154B). Sulfolane concentrations detected in groundwater samples collected from wells MW-304-70, MW-304-80, and MW-304-96 were flagged by the laboratory as estimated as described in

Section 6. The estimated extent of the sulfolane plume at 55 to 90 feet below the water table is identified as an isopleth based on the ACL and is shown on Figure 4-15.

4.5.2.4 90 to 160 Feet Below the Water Table

Sulfolane was not detected above the ACL of 14 µg/L in groundwater samples collected from any onsite monitoring wells screened at 90 to 160 feet below the water table. Sulfolane analytical results at this depth are presented on Figure 4-16.

Sulfolane results are summarized in Table 4-7. Historical sulfolane analytical results are included as Appendix C. A statistical analysis of sulfolane trends was originally presented in the SCR – 2011 (Barr 2012). This analysis was updated with 2012 data and is presented in Section 4.7.

4.5.2.5 Vertical Profiling Transect

Groundwater sampling was conducted at the VPT wells to evaluate vertical distribution of sulfolane concentrations; however the dataset for the reporting period is incomplete due to inclement weather conditions preventing sampling of several locations within the VPT. Sulfolane results for the VPT wells are summarized in Table 4-8 and shown on Figure 4-17. Additionally, Figures 4-13 through 4-16 show sulfolane concentrations for the VPT cluster locations at depths appropriate for each figure.

Sulfolane was not detected above laboratory reporting limits at the MW-301 cluster during the reporting period. Samples were not collected from the 30-, 50-, and 70-foot depth intervals due to inclement weather. Historically, J-flagged sulfolane detections have been estimated at the 50- and 70-foot depths (Appendix C).

At the MW-302 well cluster, sulfolane in groundwater was detected at a maximum concentration of 59.4 µg/L in the sample collected from the 20-foot bgs depth interval. A lower sulfolane concentration (18.1 µg/L) was detected at the 40-foot bgs depth interval. MW-302-10 was frozen/dry and was not sampled. Samples were not collected from the 30-, 50-, 70-, 80-, 95-, and 110-foot depth intervals due to inclement weather. Sulfolane results above 14 µg/L have been detected historically in samples from the 30-, 50-, 70- and 80-foot depth intervals (Appendix C).

In samples collected from the MW-303 well cluster, sulfolane in groundwater was detected at a maximum concentration of 61.2 µg/L at 19 feet bgs. A lower sulfolane concentration (35.2 µg/L) was detected at the 39-foot depth interval. Samples were not collected from the 29-, 49-, 59-, 70-, 80-, 95-, and 130-foot depth intervals due to inclement weather. Sulfolane results above 14 µg/L have been detected historically in samples from the 29-, 49-, 59-, and 70-foot depth intervals (Appendix C).

At the MW-304 cluster, sulfolane in groundwater was detected at a maximum concentration of 299 µg/L in the sample collected at 15 feet bgs. Sulfolane concentrations decreased with depth from the 15- foot interval, with concentrations of 79.5, 11.4, 6.45 J, and 4.79 J µg/L observed at the 20-, 30-, 50-, 60-, and 70- foot depths, respectively. A sulfolane concentration of 5.00 J was detected in the groundwater sample collected from the 20-foot depth, which is inconsistent with historical data at this location. MW-304-CMT-10 was frozen/dry and was not sampled. Samples were not collected from the 40-, 125-, and 150-depth intervals due to inclement weather. Sulfolane results above 14 µg/L have been detected historically in samples from the 40-foot depth interval (Appendix C).

At the MW-305 cluster, sulfolane was detected at 10.0 J µg/L at the 18-foot depth interval. Samples were collected from the 38- and 58-foot depth intervals, but concentrations were below laboratory detection limits. Samples were not collected from the 28-, 48-, 58-, 80-, and 100-foot depth intervals due to inclement weather. Sulfolane results above 14 µg/L have been detected historically in samples from the 28-foot depth interval (Appendix C).

Sulfolane was not detected in samples collected from the 10-, 15-, and 20-foot depth intervals at the MW-306 cluster. Samples were not collected at the 40-, 50-, 60-, 70-, 80-, 100-, and 150-foot depth intervals due to inclement weather. Sulfolane has not been detected historically in this well cluster (Appendix C).

4.5.3 Sulfolane Mass Flux

An analysis of mass flux using analytical data collected across the VPT well cluster transect during November 2011 was presented in the SCR – 2011 (Barr 2012). Methods to calculate mass flux and site-specific geologic input data are included as Appendix H. The Mass Flux Toolkit (Toolkit) developed by GSI Environmental for the Department of Defense Environmental Security Technology Certification Program (Farhat et al. 2006) was used to calculate sulfolane mass flux across the VPT. The initial sulfolane mass flux across the VPT was calculated from data collected in November 2011 (Barr 2012) and was estimated at approximately 86 grams per day (g/day [0.19 lb/day]).

To provide an update of mass flux during 2012, data collected during the first, second and third quarters of 2012 and geologic site-specific data were used to calculate sulfolane flux across the VPT during these time periods. Data for the reporting period is not included because the VPT dataset is incomplete due to inclement weather conditions preventing sampling of the VPT. Mass flux was estimated at approximately 62 g/day (0.14 pound per day [lb/day]), 83 g/day (0.18 lb/day), and 73 g/day (0.16 lb/day) across the VPT plane during the first, second, and third quarters of 2012, respectively. Mass flux rates across the VPT are presented on Figures 4-18, 4-19, and 4-20. The zones targeting the majority of mass flux are summarized in Table 4-9.

During the first quarter 2012, the majority of sulfolane mass flux (65%) was discharged across the VPT near MW-302 (water table to approximately 90 feet bgs) and MW-304 (water table to approximately 40 feet bgs) (Figure 4-18). The percent of total mass flux increased near MW-302 from 20 to 36%, and decreased near MW-304 from 47 to 29% (Table 4-9). Because data were not collected from the 10-, 20-, and 30-foot intervals at MW-301 during the first quarter, previous fourth quarter 2011 data were used in the Toolkit. Additionally, sample concentrations within 50 feet bgs (35 feet below the water table) at MW-301 was flagged as estimated by the lab. This assumption may skew the mass discharge estimation, reducing the relative magnitude of the total contribution to flux of the zones of the transect where sulfolane was actually detected with certainty. Additionally, data were not collected from the 10- and 20-foot intervals at MW-304, the Toolkit interpolated sulfolane concentrations at these locations, which may skew mass flux in these zones in addition to the overall mass flux during first quarter 2012.

During the second quarter 2012, the majority of sulfolane mass flux (57%) was discharged near MW-304 (water table to approximately 40 feet bgs) (Figure 4-19), which is consistent with November 2011 results. The percent of total mass flux decreased near MW-302 from 30 to 20%, which is consistent with results from November 2011 (Table 4-9). Because data were not collected from the 10-, 20-, 30-, and 40-foot intervals at MW-301 during the second quarter, fourth quarter 2011 data were used in the Toolkit. Additionally, sample concentrations within 50 and 70 feet bgs (35 and 65 feet below the water table) at MW-301 were flagged as estimated by the lab. This assumption may skew the mass discharge estimation, reducing the relative magnitude of the total contribution to flux of the zones of the transect where sulfolane was actually detected with certainty.

During the third quarter 2012, the majority of sulfolane mass flux (51%) was discharged near MW-304 (water table to approximately 40 feet bgs) (Figure 4-20), which is consistent with previous results. The percent of total mass flux increased near MW-302 from 20 to 30% (Table 4-9). Because data were not collected from the 30-, 40-, and 50-foot intervals at MW-302, the Toolkit interpolated sulfolane concentrations at these locations, which may skew mass flux in these zones. Also, sample concentrations within 50 to 70 feet bgs (35 to 65 feet below the water table) at MW-301 were flagged as estimated by the laboratory. These assumptions may skew the mass discharge estimations, reducing the relative magnitude of the total contribution to flux of the zones of the transect where sulfolane was actually detected with certainty.

During each quarter, sample intervals for VPT well clusters MW-301 and MW-306 indicated a low mass discharge. There may be no significant mass flux of sulfolane at the lateral edges of the plume at these locations, but is indicated in part due to the assumption outlined above that for the sake of completing the mass flux calculations, nondetectable sulfolane concentrations are equal to one-half of the detection limit.

4.6 Offsite Monitoring Well Sampling Results

During this reporting period, groundwater samples were collected from 94 offsite monitoring wells and submitted for sulfolane analysis. These data are presented in Table 4-7. Sulfolane data are plotted on Figures 4-13 through 4-16 to show the estimated extent of the dissolved-phase sulfolane plumes at the following depth intervals: water table, 10 to 55 feet below the water table, 55 to 90 feet below the water table, and 90 to 160 feet below the water table. Historical sulfolane analytical results are included as Appendix C.

4.6.1.1 Water Table

Sulfolane was detected above the ACL of 14 µg/L in groundwater samples collected from 17 monitoring wells screened at the water table, ranging from 15 µg/L (MW-194A) to 231 µg/L (MW-161A). Sulfolane concentrations detected in groundwater samples collected from the following wells were flagged by the laboratory as estimated as described in Section 6: MW-168A, MW-169A, MW-187, MW-193A, MW-308-15, MW-316-15, and MW-317-15. Sulfolane concentrations detected in groundwater samples collected from wells MW-164A and MW-167A were flagged as estimated due to quality control failures. The estimated extent of the sulfolane plume is identified as an isopleth based on the ACL and is presented on Figure 4-13.

4.6.1.2 10 to 55 Feet Below the Water Table

Sulfolane was detected above the ACL of 14 µg/L in groundwater samples collected from 20 wells screened at 10 to 55 feet below the water table, with results ranging from 24.7 µg/L (MW-182B) to 297 µg/L (MW-161B). The sulfolane concentration detected in the groundwater sample collected from MW-185B was flagged by the laboratory as estimated as described in Section 6. Sulfolane concentrations detected in groundwater samples collected from the following wells were flagged as estimated due to quality control failures: MW-164B, MW-164C, MW-165-B, MW-166B, MW-167B, and MW-169C. The estimated extent of the sulfolane plume is identified as an isopleth based on the ACL and is presented on Figure 4-14.

4.6.1.3 55 to 90 Feet Below the Water Table

Sulfolane was detected above the ACL of 14 µg/L in groundwater samples collected from three wells screened at 55 to 90 feet below the water table, with results ranging from 19.1 µg/L (MW-317-71) to 84.3 µg/L (MW-160B). Sulfolane was not detected in the sample collected from well MW-170B. The estimated extent of the sulfolane plume is identified as an isopleth based on the ACL and is presented on Figure 4-15.

4.6.1.4 90 to 160 Feet Below the Water Table

Samples collected from 10 offsite monitoring wells screened at 90 to 160 feet below the water table were analyzed for sulfolane during the reporting period. Sulfolane was detected above the ACL of 14 µg/L in the groundwater sample collected from one well near Horseshoe Way (MW-332-150), at a concentration of 186 µg/L. One sulfolane result from MW-185C (4.22J µg/L) was flagged by the laboratory as estimated as described in Section 6. Results are presented on Figure 4-16.

4.7 Statistical Analysis of Benzene, Toluene, Ethylbenzene, and Total Xylenes, and Sulfolane Data

The Mann-Kendall Trend Analysis is a nonparametric statistical method for determining trends for concentrations of a given constituent at a given monitoring well. The protocol described in the Monitoring and Remediation Optimization System (MAROS) will be used to complete the Mann-Kendall Trend analysis for sulfolane in select groundwater monitoring wells. MAROS is a decision support tool developed by the Air Force Center for Environmental Excellence (AFCEE) in order to use statistical methods based on site specific data. The use of MAROS for Mann-Kendall analysis was applied to historical and current groundwater monitoring data. The analysis trends are expressed as probably increasing, increasing, probably decreasing, decreasing, stable, or no trend.

A statistical and graphical evaluation of BTEX and sulfolane concentration trends at monitoring wells is being used to evaluate plume migration and stability, and interim remedial action effectiveness, and to identify relationships between dissolved-phase concentrations, groundwater elevations, and flow directions. Sulfolane results for private wells were not evaluated because sufficient data have not been collected.

4.7.1 Benzene, Toluene, Ethylbenzene, and Total Xylenes Statistical Evaluation

Groundwater collected from wells with detectable concentrations of toluene, ethylbenzene, and xylenes is located within the footprint of the benzene plume. In reviewing of the historical BTEX data, in almost all cases where the benzene concentration in a groundwater sample is below its groundwater-cleanup level, no other BTEX analyte exceeds its groundwater-cleanup level. The exception to this is a single sample (MW-334-15) in December 2012, in which benzene was not detected above its LOD, but toluene (6,340 µg/L) and ethylbenzene (745 µg/L) were each greater than their respective groundwater-cleanup levels. This was the first sampling event for this location. However, a 2012 hydropunch location installed near this well (HP-16) had a benzene concentration in the sample collected from the 15-foot interval.

Trend data from 65 wells were reviewed, some of which had up to 59 sampling events. Results of the trend analyses are presented in Table 1 of Appendix I and discussed below.

4.7.1.1 Nondetects, Decreasing, or Stable Trends

As shown in Table 1 (Appendix I), no analytes detected, decreasing, probably decreasing, or stable trends were identified at about one-half of the wells in the BTEX well network. No BTEX analytes have been detected in several of the wells outside the onsite process areas (e.g., wells MW-101, MW-101A, MW-102, MW-104, MW-105, MW-105A, MW-118, MW-129, MW-131, MW-133, MW-134, and MW-141), some of which are screened at depths well below the water table (MW-101, MW-102, MW-104, MW-105A, MW-118, and MW-129). Additionally, BTEX has not been detected in groundwater collected from offsite well locations (MW-148A, MW-148B, MW-149A, MW-149B, and MW-153A).

Decreasing or probably decreasing trends in benzene were identified in groundwater from wells MW-110 and MW-139, west of the NPR's rail spur, and in groundwater from wells MW-124, MW-135, MW-136, and MW-137 near the southeast corner of the truck-loading rack. A decreasing benzene trend was also observed in groundwater from well MW-130, west of recovery well R-35R. At the wells where decreasing benzene concentrations were identified by MAROS, the other BTEX analytes were generally either "decreasing" or "stable." One exception to this is a "probably increasing" trend for total xylenes in groundwater from MW-136; it is unclear why this may be the case, but it may be an artifact of a few relatively high xylenes concentrations detected there in late 2009.

Stable benzene concentration trends were identified in groundwater from wells MW-115, MW-116, and MW-138, near the crude extraction units, and in groundwater from well MW-125, south of the truck-loading rack, and north of the truck-loading rack at MW-140. The other BTEX analytes in groundwater from these wells exhibited either stable or no concentration trend, or there were no analyte detections in in groundwater from the well.

4.7.1.2 Increasing Trends

The statistical analysis indicated increasing or probably increasing trends for one or more BTEX analytes in groundwater from wells MW-132 (benzene and xylenes), MW-136 (xylenes), and MW-113 (ethylbenzene). Data are summarized in Table 1 of Appendix I. Well locations are presented on Figure 2-3.

Well MW-132 is located near the northwest corner of Containment Area 8, and northwest of Tank 110, and the benzene and xylenes trends there were characterized as "probably increasing." Benzene and xylenes concentrations in groundwater from this well were near or below the laboratory reporting limit from 1999 until April 2010, when benzene, ethylbenzene, and xylenes concentrations exhibited an apparently short-term concentration

increase, and benzene exceeded its ADEC groundwater-cleanup level in October 2010. The benzene concentration was back below its groundwater-cleanup level by the November 2010 sampling event. This short-term spike in benzene and xylenes concentrations following several years with low BTEX concentrations caused the MAROS evaluation to characterize these analytes' long-term concentration trends as "probably increasing." All four BTEX analytes at this well have been well below their respective groundwater-cleanup levels since November 2010 (four monitoring events).

Well MW-136 is located near the southeast corner of the truck-loading rack. As suggested above, the "probably increasing" trend for xylenes at MW-136 may be an artifact of a few relatively high xylenes concentrations detected there in late 2009. Concentrations for the other BTEX analytes are decreasing (benzene), stable (ethylbenzene), or do not exhibit a concentration trend (toluene). The benzene concentration in groundwater at this location has been above its groundwater-cleanup level since sampling began there in 2001. Benzene, toluene, and ethylbenzene commonly exceed their respective ADEC groundwater-cleanup levels at this location.

Well MW-113 is located west of the distribution office and rail spur at the site, and east of recovery well R-42. The MAROS evaluation indicated there is an "increasing" ethylbenzene trend in groundwater from MW-113. The ethylbenzene concentration was below the reporting limit in groundwater at this location from 1994 through January 2012, when it was detected below the ADEC groundwater cleanup level (700 µg/L) at 3.40 µg/L; there were two more detections of ethylbenzene in April 2012 (1.72 µg/L) and October 2012 (3.70 µg/L). These concentration changes are likely the result of changes in the localized groundwater gradient following active operation of recovery well R-42.

4.7.1.3 No Trend

There was no concentration trend identified for benzene in groundwater from wells MW-109, MW-111, and MW-113, located west of the rail spur at the NPR. Well MW-111 will not be included in future evaluations because it has been destroyed and will be replaced in a different location (ARCADIS 2013b). These wells are located at or near the western edge of the BTEX plume, and the absence of a clear concentration trend likely reflects fluctuating concentrations in that area. Data are summarized in Table 1 of Appendix I. Well locations are presented on Figure 2-3.

There was also no clear concentration trend for benzene in groundwater from MW-126, northeast of the truck-loading rack, and in groundwater from MW-127 on the northwestern corner of the truck-loading rack. Benzene has limited detections in groundwater from MW-126, with some detections above 100 µg/L before 1993, and few detections since then. The most recent benzene detections in groundwater from this well were below the benzene groundwater-cleanup level of 5 µg/L in 2007 (1.52 µg/L) and in 2010 (1.00 µg/L). The other

BTEX analytes at this location exhibited no detections above laboratory reporting limits. The benzene concentration in groundwater from MW-127 increased from below the reporting limit in 1997 to a maximum of 500 µg/L in 2001; the concentration decreased from that maximum to below the reporting limit in 2005, with some occasional detections since then. The latest benzene result at that location was below the reporting limit. Xylenes also exhibit no concentration trend at MW-127.

Groundwater from wells MW-142, MW-143, MW-144, and MW-145 also exhibit no benzene concentration trends. These wells are located at or near the northern extent of the BTEX plume, and benzene has been detected in groundwater from these wells infrequently. Benzene was detected twice below its cleanup level in groundwater from wells MW-144A and MW-145 between 2006 and 2011, and was also detected below its cleanup level during 2009 in groundwater from MW-143. Benzene was detected in groundwater from MW-142 periodically between 2002 and 2005, and again below its cleanup level in 2008, 2009, and 2011. BTEX concentrations in groundwater at these locations do not exceed groundwater-cleanup levels.

Toluene, ethylbenzene, and/or xylenes do not exhibit concentration trends in groundwater from wells MW-115, MW-116, MW-124, MW-125, MW-132, MW-135, MW-136, and MW-139. The analytes exhibit no concentration trends and do not exceed their ADEC groundwater-cleanup level in groundwater from each well except MW-136. Well MW-136 is located within the benzene plume and toluene has exceeded its cleanup level in groundwater from MW-136 over the last few years.

4.7.2 Sulfolane Statistical Evaluation

Results from the Mann-Kendall test and MAROS evaluation of 285 wells are summarized in Table 1 of Appendix I. For some wells, the trend evaluation was conducted using two data sets with different sulfolane analysis methods:

- One evaluation used analytical data obtained from sulfolane analyses between April 2006 and the current reporting period; this data set includes sulfolane concentrations derived from both analytical methods used for the analysis in this project (i.e., USEPA Method 8270D and USEPA Method 1625B with isotopic dilution).

- The second trend evaluation used only the sulfolane data obtained from USEPA Method 1625B, which was introduced in the third quarter 2011.

Consequently, the second trend evaluation used a substantially smaller data set than the first; up to seven concentration values from the USEPA Method 1625B were available for the assessment. Of the 273 monitoring wells with sulfolane data generated by USEPA Method 1625B, 158 wells provided enough data (at least four data points) to conduct the

trend assessment. Wells with an insufficient data points are included on trend charts in Appendix I.

USEPA Method 1625B “corrects” the sulfolane analyte concentration using recovery information for isotopically labeled sulfolane added to the analytical sample, and appears to yield somewhat higher sulfolane results than for samples analyzed using the prior Method 8270D. Apparent increasing trends at some wells may be partly attributable to the change in analytical methods during the later sampling episodes, after implementation of the Method 1625B analysis. Use of data generated only by Method 1625B removes the possibly confounding influence of assessing concentration trends based on data from the two analytical methods. Other limitations may be introduced, however, as described in Section 4.7.6 below.

Apparent trends evaluated using each of the two data sets and changes in the trends that occur upon restricting the analysis to only the USEPA Method 1625B data are discussed below. Concentration graphs for these wells present the data obtained using both sulfolane analytical methods, and are provided in Appendix I.

4.7.3 Nondetects, Decreasing, or Stable Trends

As shown in Table 1 (Appendix I), 65 locations have not yielded samples containing detectable sulfolane using the data from 2006 through the reporting period; 52 locations have no detectable sulfolane using only the USEPA Method 1625B data (at least four points) to conduct the trend assessment. Well locations with insufficient data points were included in the analysis presented in Appendix I, but reported as "insufficient". Data trends in these wells are not discussed further in the text.

Using the data set that includes data from both sulfolane analytical methods, the MAROS trend evaluation indicated that sulfolane concentrations in groundwater at 51 wells are decreasing or likely decreasing, and concentrations in groundwater at 40 wells are stable (Table 1 , Appendix I). This data set includes the air sparge monitoring wells (AS-MW-1 through AS-MW-8), with samples analyzed using only USEPA Method 1625B. Groundwater from wells exhibiting decreasing or stable concentrations include all air sparge monitoring wells, most of the water table wells, and most of the wells screened from 10 to 55 feet below the water table located within the plume, from the site northwestward through the Ford Subdivision and Homestead Drive to the levee (Figures 2-3 and 2-4). Also included are many of the wells in the VPT, and onsite well MW-154A (screened to 75 feet bgs).

Using data only from the USEPA Method 1625B analyses (i.e., third quarter 2011 through the reporting period), sulfolane concentrations exhibited decreasing trends in groundwater from 40 well locations, and groundwater from 51 well locations exhibited stable concentrations as defined by MAROS. For these assessments, four to seven analytical results were included for each well. Groundwater from five of the wells exhibited decreasing

trends using only the Method 1625B data and were characterized as having either no trend (MW-125 and MW-152B) using the data from 2006 through the reporting period, or as having a stable sulfolane concentration (MW-142, MW-148B, and MW-160B). Groundwater from nine wells exhibited a stable sulfolane concentration using only the Method 1625B data and were characterized as having no trend using the data from 2006 through the reporting period (MW-130, MW-138, MW-159A, MW-161B, MW-164B, MW-169A, MW-182A, MW-185A, and MW-185B); groundwater from seven of the stable wells with the smaller data set exhibited decreasing trends using the larger data set containing results from both methods (MW-101, MW-101A, MW-110, MW-139, MW-143, MW-150A, and MW-154A). The sulfolane concentration history for well MW-153B was evaluated as increasing using the data from 2006 through the reporting period, but was considered as having a stable concentration using the USEPA Method 1625B data.

4.7.4 Increasing Trend

Using the data from 2006 through the reporting period, groundwater concentrations from nine wells (MW-153B, MW-161A, MW-166A, MW-166B, MW-167A, MW-167B, MW-168A, MW-187, and MW-301-CMT-50) were found to have increasing trends. Most of these wells are located at or near the downgradient edge of the plume, except wells MW-153B (near the northern site boundary) and MW-301-CMT-50 (at the western end of the VPT). Data are summarized in Table 1 of Appendix I. Well locations are presented on Figures 2-3 and 2-4.

Using only the USEPA Method 1625B data, groundwater from two wells (MW-113 and MW-301-CMT-50) was found to have increasing sulfolane concentration trends, and groundwater from three wells (MW-154B, MW-167A, and MW-167B) had sulfolane concentrations that were considered “probably increasing” as defined by MAROS. Groundwater from three of the wells (MW-166A, MW-166B, and MW-168A) was considered as having increasing concentration trends using the data from 2006 through the reporting period, and did not have sufficient Method 1625B data available to assess the concentration trends. As previously noted, MW-113 is located near R-42 and changes in sulfolane concentrations are likely attributable to changes to the groundwater gradient as a result of capture at R-42.

4.7.5 No Trend

Using the data from 2006 through the reporting period, the MAROS evaluation characterized the sulfolane concentrations as having no trend in groundwater from 22 wells. Some of these wells have a relatively small sample set, with four to nine values and varying concentrations. These include well MW-169C on the levee northwest of the site, and the MW-185 well nest near the inferred northern sulfolane plume boundary, with a few low-level sulfolane detections. Well MW-161B is screened to a depth of approximately 50 feet bgs, and is part of the MW-161 well nest west of the Bradley Sky Ranch; sulfolane concentrations in groundwater at this well nest have fluctuated from 170 to 320 µg/L. At well

MW-182A, located near the northern plume boundary, groundwater has exhibited sulfolane concentrations that have varied from 15 to 25 µg/L. Groundwater in well MW-183A, located near the northwestern plume boundary, has exhibited sulfolane concentrations ranging from approximately 70 to 95 µg/L, with one estimated sulfolane concentration below the LOQ. Data are summarized in Table 1 of Appendix I. Site features and well locations are presented on Figures 2-2, 2-3, and 2-4.

Wells MW-178B and MW-179B are located within the sulfolane plume onsite, north of Crude Unit #2. Sulfolane concentrations in groundwater from MW-178B have varied from less than 100 µg/L to approximately 300 µg/L, while sulfolane concentrations in groundwater from MW-179B have either been below detection or estimated below the LOQ. Well MW-125 is located onsite, south of the truck-loading area. Two groundwater samples from MW-125 exhibited detectable sulfolane concentrations in 2011; sulfolane concentrations have been below the reporting limit in 2012. MW-130 is also located onsite, between containment areas CA4 and CA6, and has been sampled eight times beginning in 2011. Sulfolane concentrations in groundwater from this well have fluctuated between approximately 620 and 1,100 µg/L. Well MW-105A is located upgradient from the crude processing units. One groundwater sample from this well exhibited detectable sulfolane concentrations during summer 2012; this was temporary and attributed to sulfolane associated with BioTrap deployment.

Other wells with no trend based on data from 2006 through the reporting period have a larger data set, ranging from 13 to 48 samples. These wells (e.g., MW-152B, MW-154B, MW-159A, MW-164A, and MW-164B) are located either mid-plume with variable concentrations ranging from 20 to 200 µg/L, or onsite near source areas (e.g., MW-138), with higher concentrations in the past but with sulfolane below the reporting limit in recent years (e.g., MW-106 and MW-109).

Using only the USEPA Method 1625B data (from four to six samples per well), groundwater collected from two wells exhibited no apparent sulfolane concentration trend, but using the larger data set from both analytical methods they were considered “probably decreasing” (wells MW-125 and MW-152B). As noted above, groundwater collected from monitoring well MW-154B was considered “probably increasing,” based on the data collected since the third quarter 2011. Groundwater collected from nine wells (MW-130, MW-138, MW-159A, MW-161B, MW-164B, MW-169A, MW-182A, MW-185A, and MW-185B) were considered “stable” using the Method 1625B data, but were considered having no trend using the larger data set. Groundwater collected from three wells (MW-109, MW-179B, and MW-183A) did not have sufficient data to assess their concentration trends based only on the USEPA Method 1625B data.

4.7.6 Trend Changes Using Only USEPA Method 1625B Data

As indicated above, some apparent increasing trends at select wells may be partly attributable to the change in analytical methods during the later sampling events, after implementation of the USEPA Method 1625B analysis. Using data generated only by USEPA Method 1625B removes the potentially confounding influence of assessing concentration trends based on data from the two analytical methods; however, some wells have relatively small data sets if using only the USEPA Method 1625B data. Consequently, the statistical confidence in trends based on the more recent data using USEPA Method 1625B is lower than that provided by the larger data set from 2006 through the reporting period. In addition, data sets limited to the time when Method 1625B was used often will span a shorter time frame than does the complete data set for a given well, and the more recent sets are less likely to include data from across a broad range of seasonal conditions. In some instances, these differences may affect the trend assessment. Data are summarized in Table 1 of Appendix I. Well locations are presented on Figures 2-3 and 2-4.

Of the 285 trends evaluated using the data from 2006 through the reporting period, 33 wells either did not have any data collected following the method change, or did not have the minimum number of USEPA Method 1625B data required to assess trends. Sufficient data from 74 well locations were provided by each method to allow the assessment of concentration trends. Of these, there was no difference in trend using either data set at 35 locations. Restricting the MAROS trend assessment to data provided only by USEPA Method 1625B changed the statistical trends at the remaining 39 locations.

Sulfolane concentration trends at three wells changed from “no trend” (MW-106) or “decreasing” (MW-149A and MW-149B), to “all results non-detect” because sulfolane results were below the reporting limit for the USEPA Method 1625B analyses.

Concentration trends changed at 14 wells where sulfolane was considered to be “decreasing” or “probably decreasing” using the data from 2006 through the reporting period. Reanalysis of the trends using the USEPA Method 1625B data set changed the decreasing trend assessments to “stable” at seven wells (MW-101, MW-101A, MW-110, MW-139, MW-143, MW-150A, and MW-154A), and to “no trend” at well MW-158A. The concentration trends at the six remaining locations using the USEPA Method 1625B data changed from “decreasing” to “probably decreasing,” or from “probably decreasing” to “decreasing.”

Eight wells (MW-166A, MW-166B, MW-167A, MW-167B, MW-168A, MW-187, and MW-161A) located at or near the downgradient edge of the sulfolane plume were determined to have “increasing” concentration trends based on the data from 2006 through the reporting period. In addition, well MW-153B, located near the northern site boundary, was also determined to have an increasing sulfolane concentration trend. Of these wells, three wells (MW-166A, MW-166B, and MW-168A) at the leading edge of the sulfolane plume did not

have sufficient data to assess concentration trend changes using only the USEPA Method 1625B data.

The trend for the data at well MW-153B changed from “increasing” to “stable,” ranging from concentrations of 28 to 36 µg/L, using the USEPA Method 1625B data. The trend at two other wells (MW-161A and MW-187) changed from “increasing” to “no trend” using the more recent Method 1625B data:

- The recent sulfolane concentration data for well MW-161A ranged from 150 to 230 µg/L.
- The recent sulfolane concentration data for MW-187 contained low levels of sulfolane at estimated concentrations below the LOQ.

Using the Method 1625B data, sulfolane concentrations at the MW-167A/B well nest, near the downgradient edge of the plume, changed from “increasing” to “probably increasing.”

In addition to the wells noted above, concentration trends changed from “stable” to “increasing” at MW-113, and from “no trend” to “increasing” at MW-154B, using only the USEPA Method 1625B data.

Changes in some concentration trends have been observed when the data are broken out by analytical method, which also introduces differences in time frame and seasonal capture. Some “increasing” trends using the data from 2006 through the reporting period may be partly attributable to the change in analytical methods during the later sampling events, after implementation of the USEPA Method 1625B analysis. Use of data generated only by USEPA Method 1625B removes the possibly confounding influence of assessing concentration trends based on data from two analytical methods, but introduces other limitations. Accumulation of a larger data set using USEPA Method 1625B will be helpful.

4.8 Private Well Sampling Results

As stated in Section 3.6, sampling of residential wells was conducted from November 11, 2009 through December 31, 2012. Since November 2009, groundwater samples have been collected from 581 private wells located within the search areas and analyzed for sulfolane. Samples collected through May 11, 2011 were analyzed for sulfolane using USEPA Method 8270D. Subsequent samples were analyzed using USEPA Method 1625 with isotope dilution. Initial results from 12 private wells and two private well resamples collected during the reporting period are presented in Tables 4-10 and 4-11; historical data points are shown on Figure 3-1 and historical data are presented in Appendix C. Both the initial and resampled well data from this reporting period are presented on Figure 3-1 with color-gradation to indicate the concentration.

Historically, sulfolane concentrations in private wells have ranged from less than the limit of quantitation (LOQ) to 443 µg/L. Sulfolane was not detected (reported as less than the limit of detection) in all private well samples collected during the reporting period. Residential locations sampled for the first time during this reporting period were analyzed for sulfolane using USEPA Method 1625B with isotope dilution and are presented in Table 4-10. Data resampled during this reporting period are compared in Table 4-11.

Laboratory reports and ADEC data review checklists for residential samples collected during the reporting period are included in Appendices D and E, respectively.

Of the private wells that were sampled for sulfolane, depth information has been obtained for approximately 100 locations as reported in the SCR – 2011 (Barr 2012). Screen intervals for private wells were assumed to be relatively discrete and consistent with groundwater zones. Data from these wells have been plotted on the appropriate monitoring zone maps with fourth quarter 2012 sulfolane data from the monitoring wells, as shown on Figures 4-14, 4-15, 4-16, and 4-21. Private well data are shown regardless of sampling date. During the reporting period, new data obtained from wells that were not previously sampled do not have depth information and are not included on plume maps.

Figure 4-14 shows results for private and monitoring wells installed at 10 to 55 feet below the water table. The 14 µg/L isopleth extends north of the intersection of Badger Road and Peridot Street around a few wells with concentrations less than 14 µg/L, to capture a group of private wells with concentrations that exceed 14 µg/L.

Results for private and monitoring wells installed at 55 to 90 feet below the water table are shown on Figure 4-15. The sulfolane plume extends offsite at this depth. Sulfolane was reported in several private wells at this depth; most of these wells are located along Badger Road north of Richardson Highway.

Results from wells installed at 90 to 160 feet below the water table are shown on Figure 4-16. Based on reported construction information, the private well samples with detectable sulfolane appear to be installed below permafrost.

Figure 4-21 shows the results for private wells installed at depths greater than 160 feet below the water table. Based on reported construction information, these wells appear to be installed in the subpermafrost aquifer.

4.9 Geochemical Parameters

Field parameter and geochemical analytical data collected during the reporting period are presented in Tables 4-12 and 4-13, respectively. A PCA and discriminant analysis were

originally presented in the SCR – 2011 (Barr 2012). These analyses were updated with 2012 data and are presented below.

Wells were sampled for geochemical parameters outside of the semiannual monitoring network presented in the SCR-2011 (Barr 2012) for non-routine analyses including Bio-Trap® and University of Alaska Fairbanks studies. The following wells outside of the monitoring network were tested: AS-MW-6, MW-105, MW-105A, MW-109, MW-110, MW-130, MW-161B, MW-166B, MW-169A/C, MW-176A/B, MW-180A/B, MW-182A, and MW-193A/B.

Historical geochemical data are summarized in Appendix C.

4.9.1 Principal Component Analysis

PCA is a multivariate statistical method that compares multiple parameters simultaneously based on the way in which they contribute to the overall variability in a data set. While PCA does not test statistical significance of any observed correlations, it can provide a broad overview of multiple contemporaneous parameters and reveal potential correlations whose statistical significance can be tested via other methods.

Two groups of wells were used for PCA analysis. The groups were selected based on similarity of their screened interval elevations, as well as their proximal arrangement along downgradient transects. Transect 1 runs approximately parallel with the Tanana River, while Transect 2 runs in a more northerly direction:

- Transect 1: MW-142, MW-148A, MW-151A, MW-156A, MW-161A, and MW-165A.
- Transect 2: MW-170A, MW-157, MW-163A, MW-164A, and MW-167A.

Two PCA plots (Figures 4-22 and 4-23) were generated using the data for each set of wells (Tables 4-12 and 4-13), except for nitrate, nitrite, carbonate alkalinity, and hydroxide alkalinity. These parameters did not vary; thus, they did not contribute to variability of the dataset. The PCA plot is a graphical representation of the way in which each parameter (shown as a line emanating from the origin) contributes to the overall variability of the dataset. The axes of the figure are principal components of the dataset variability, and were selected such that the maximum percentage of overall data variability could be viewed on a two-dimensional plot. As with all statistical methods, the results are affected by the number of observations. Parameters whose variability is well-captured by the plot appear as long lines, while those whose variability is not well-captured by the plot appear as short lines. Parameters whose lines are oriented in the same direction correlate positively with one another, while those oriented in opposite directions correlate negatively. Parameters whose lines are orthogonal to one another do not correlate to one another.

Figure 4-22 shows that sulfolane concentration is somewhat negatively correlated with DO concentration, a trend that would be consistent with aerobic sulfolane degradation. Sulfate, an aerobic degradation product of sulfolane, shows a relatively weak positive correlation with sulfolane concentration. However, it is important to note that background sulfate concentrations in the aquifer are large relative to the amount of sulfate that would be produced via sulfolane degradation. Therefore, changes in sulfate concentration due to sulfolane degradation may be difficult to detect. Sulfolane concentrations also correlate positively with manganese species (particularly reduced manganese), and negatively with hardness, alkalinity, and, to a lesser extent, oxidized iron. Testing completed by FHRA around the onsite remediation system operation suggests that changes in the oxidation states of iron and manganese may correspond with sulfolane degradation.

Figure 4-23 shows that sulfolane concentration correlates negatively with DO and, to a lesser extent, hardness, alkalinity, and conductivity. Sulfolane also exhibits a relatively weak positive correlation with pH and total iron. A positive correlation between sulfolane and pH would be expected for aerobic sulfolane biodegradation. As observed in the previous PCA analysis, sulfolane concentrations did not correlate with sulfate concentration.

4.9.2 Discriminant Analysis

Discriminant analysis seeks to separate observations into predetermined categories (in this case, wells exhibiting decreasing, increasing, or stable trends in sulfolane concentration) based on multiple parameters. Figure 4-24 is a discriminant plot performed for those wells determined to exhibit increasing, decreasing, or stable trends via the Mann-Kendall analysis. This analysis is an update to the interpretation originally presented in the SCR – 2011 (Barr 2012). The discriminant factors (or categories) were assigned to each observation as follows:

- Wells that exhibited increasing or probably increasing trends via Mann-Kendall analysis.
- Wells that exhibited stable trends via Mann-Kendall analysis.
- Wells that exhibited decreasing or probably decreasing trends via Mann-Kendall analysis.

Discriminant analysis was then applied to the PCA data (excluding sulfolane concentration) to group the observations into the predetermined categories. This analysis was updated from the previous version to incorporate the 2012 geochemical data, as well as the most current Mann-Kendall trend results for the wells. For this analysis, the Mann-Kendall trend analyses applied were limited to those sulfolane measurements collected after July 2011,

when the analytical method for sulfolane was changed. The analysis was also limited to those wells where sufficient data existed to support the Mann-Kendall analysis.

Figure 4-24 shows that the parameters that most strongly discriminate wells with increasing sulfolane trends from those with stable or decreasing trends are:

- Alkalinity – associated with increasing trends
- Conductivity – associated with increasing trends
- Ferrous or dissolved iron – associated with increasing trends
- Hardness – associated with stable or decreasing trends

Figure 4-24 also shows the parameters that most strongly discriminate between wells with stable and decreasing sulfolane trends. These parameters are:

- Total organic carbon (TOC) – associated with stable trends
- DO – associated with stable trends
- Reduced manganese – associated with decreasing trends

Generally, the outcome of the discriminant analysis is consistent with previous observations that sulfolane degradation may be associated with changes in the oxidation state of iron and manganese.

4.10 Non-Routine Sample Collection

Non-routine sample collection, including COPCs, air sparge pilot test monitoring, site characterization activities, and perfluorinated compounds (PFCs) sampling are discussed in Sections 4.10.1 through 4.10.4.

4.10.1 Chemical of Potential Concern Analysis

COPC analysis was initiated during the third quarter 2011 reporting period and COPCs were evaluated in the SCR – 2011 (Barr 2012), which recommended discontinuation of the sampling for additional COPCs other than sulfolane and BTEX. However, per ADEC email correspondence dated July 20, 2012, iron analysis continued during the reporting period. The SCR – 2011 (Barr 2012) recommended continued annual sampling of gasoline range organics, diesel range organics, and iron, to be conducted during the second quarter of the year. Data collected during 2012 are summarized in Table 4-14. COPC groundwater

concentrations were compared with ADEC groundwater cleanup levels (ADEC 2008; Table C).

Concentrations of total iron ranging from 15.2 to 32.3 milligrams per liter (mg/L) were detected above the USEPA Regional Screening Level (11 mg/L) in wells MW-110, MW-138, MW-139, and MW-176A (Table 4-14). It is expected that the detected concentrations are related to the natural geochemistry of the aquifer, which generally exhibits elevated concentrations of iron. Laboratory analytical reports are included in Appendix D.

4.10.2 Air Sparging Pilot Test

Based on peer-reviewed literature, monitoring results at the Gallery Pond, and bench-scale testing, which indicated sulfolane removal associated with aeration, FHRA commenced an air sparging pilot test to evaluate if aeration will create conditions for sulfolane removal in-situ. A technical memorandum describing the pilot test startup, monitoring results, and data evaluation was included as an appendix to the Interim Remedial Action Plan Addendum (IRAP Addendum; ARCADIS 2013c). A review of the data generated by the air sparge pilot test suggests that air sparging is an effective remediation strategy to enhance in-situ degradation of sulfolane in the impacted groundwater at the site.

Operation of the pilot test system was continued into the first quarter 2013, with two injection points (AS-5 and AS-7) along the south line (Figure 4-25) operating to evaluate the potential minimum air flow rate or DO concentration that is necessary to promote sulfolane removal. Due to freezing of the monitoring wells, no monitoring was conducted in December 2012. FHRA used steam equipment to thaw the monitoring wells and analytical monitoring was completed in January 2013. During the first quarter 2013, FHRA will discontinue operation of the pilot system but will continue monitoring to evaluate sulfolane concentration rebound within the pilot test monitoring well network. Results of this monitoring will be presented in future quarter groundwater monitoring reports.

4.10.3 2012 Site Characterization Activities

Additional site characterization activities were proposed in the 2012 SCWP (ARCADIS 2012a). The majority of proposed field activities was completed during the second and third quarters of 2012 and data were reported in the SCR – 2012 (ARCADIS 2013a). The field activities table (Table 1-1) summarizes site characterization activities conducted during this reporting period. Field activities that were conducted during the reporting period as part of the 2012 site characterization activities included:

- Further delineation of the western boundary of the offsite sulfolane plume, including the completion of monitoring wells MW-322-150 and MW-323-50.

- Further characterization of horizontal and vertical groundwater gradients and their seasonal fluctuations. This included deployment and monitoring of the expanded pressure transducer network.

- Completion of additional biodegradation investigations, including the Bio-Trap and compound-specific isotope analysis (CSIA) studies.

Additional data collected during the site characterization activities will further refine the conceptual site model. Updates on data collection were presented to the ADEC during TPT meetings and Site Characterization Subgroup meetings. The majority of results were summarized in the SCR – 2012 (ARCADIS 2013a). Biodegradation data were presented in the Bio-Studies Summary Report (ARCADIS 2013d).

4.10.4 Perfluorinated Compound Sampling

Lateral and vertical delineation of PFC concentrations in groundwater was completed at the site as part of a two-phase investigation. Phase I activities were completed in October 2012 and consisted of groundwater sampling at seven monitoring wells and six hydropunch locations in the Fire Training Area. Elevated concentrations of perfluorooctane sulfonate and perfluorooctanoic acid were detected at one location near Lagoon C (MW-321-15) during the Phase I investigation, although the analytical results were flagged. The Phase II investigation was completed in December 2012 and consisted of sampling at 29 monitoring wells to confirm detections identified during Phase I and to provide lateral and vertical delineation of PFCs at the site. Results of the Phase I and II investigations showed the original elevated result was inaccurate, and only low levels were present. The summary report was submitted to the ADEC on February 15, 2013 (ARCADIS 2013e).

5. Remediation System Results and Evaluation

This section summarizes and evaluates the operating results for the existing onsite remediation system for the reporting period and on an annual basis for 2012. This section also provides an update on implementation of the interim corrective actions described in the Interim Remedial Action Plan (IRAP; Barr 2010b) and the SCR – 2011 (Barr 2012). FHRA has also provided the ADEC with routine updates on IRAP implementation progress during the ongoing TPT and subgroup meetings.

Ongoing remediation efforts at the site include groundwater recovery and treatment and LNAPL recovery and recycling, as described in Sections 5.1, 5.2, and 5.3. The current components of the remediation systems are described below:

- Groundwater recovery from five recovery wells (R-21, R-35R, R-39, R-40, and R-42).

- 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 layout of the groundwater recovery and treatment system is shown on Figure 5-1 and a process flow diagram of the system is shown on Figure 5-2.

- Pneumatic LNAPL recovery systems are operated continuously when recoverable LNAPL is present at MW-138, R-20R, R-21, R-35R and R-40. Additional pneumatic LNAPL recovery systems are operated seasonally at R-32, R-33, and O-2 in 2012. The LNAPL recovery system installed at O-2 was removed due to low LNAPL recovery and was installed at S-50 in early 2013. FHRA also uses a hand-held product recovery pump at other locations (e.g., R-39) if LNAPL is present and recovery is possible.

5.1 Groundwater Recovery

The objective of the recovery well system operation is to provide capture of the shallow dissolved-phase plume, and enhance LNAPL recovery. Implementation of the corrective actions described in the IRAP (Barr 2010b) included installation of one additional recovery well (R-42). Operation of the groundwater pump and treat system currently involves groundwater recovery from five recovery wells (R-21, R-35R, R-39, R-40, and R-42), as shown on Figure 5-1. Recovery well R-42 began operation on July 26, 2011 upon issuance of an amended temporary water use permit (TWUP [A2011-48]) from the DNR. An additional amendment to TWUP A2011-48 was received on October 3, 2012, which allows increased groundwater withdrawal volume plus withdrawal from proposed additional recovery wells.

Recovered groundwater is treated onsite prior to discharge at the South Gravel Pit in accordance with wastewater disposal permit 2005-DB0012 issued by the ADEC. The treatment system operation and performance is further discussed in Section 5.1.2.

Table 5-1 summarizes the volume and rate of groundwater recovered monthly from 2009 through the reporting period. Annual groundwater recovery totals, measured at the final effluent, are summarized below:

- 2009: 69,200,000 gallons
- 2010: 107,100,000 gallons
- 2011: 136,900,000 gallons
- 2012: 188,300,000 gallons

The groundwater recovery total measured at the final effluent is slightly less than the sum of the total recovery measured at the individual recovery wells, which is likely the result of evaporation across the air strippers and Gallery Pond.

As shown in the groundwater recovery totals above and in Table 5-1, FHRA has continued to optimize the existing remediation system to increase capture of the shallow dissolved-phase plume onsite. An increase in the total groundwater recovery was measured in July 2011 upon initiating operation of new recovery well R-42 (Figure 5-1). An evaluation of system modifications to increase the capacity of the groundwater recovery and treatment systems is included in the Draft Final Onsite Feasibility Study (Draft Final Onsite FS; ARCADIS 2012c) and the installation of additional recovery wells is described in the IRAP Addendum (ARCADIS 2013c).

Pumping rates for the individual recovery wells are measured weekly. The average for the reporting period and the entire year for each well are shown in the tables below. These tables also present the total and percent run times for the reporting period and all of 2012. As shown below, each recovery well maintained high run times during the fourth quarter (99.7%) and throughout 2012 (99.5% or greater).

Location	Fourth Quarter 2012 Average Flow Rate	Fourth Quarter 2012 Runtime	Percent Runtime
R-21	46 gpm	2,201 hours	99.7%
R-35R	87 gpm	2,201 hours	99.7%
R-39	88 gpm	2,201 hours	99.7%
R-40	50 gpm	2,201 hours	99.7%
R-42	116 gpm	2,201 hours	99.7%

Location	Annual 2012 Average Flow Rate	Annual 2012 Runtime	Percent Runtime
R-21	45 gpm	8,760 hours	99.7%
R-35R	88 gpm	8,772 hours	99.9%
R-39	82 gpm	8,739 hours	99.5%
R-40	52 gpm	8,772 hours	99.9%
R-42	116 gpm	8,762 hours	99.7%

Note:
gpm = gallons per minute

As discussed in the SCR – 2011 (Barr 2012), if the LNAPL recovery system is not operating efficiently, some LNAPL is inadvertently entrained into the groundwater recovery system and removed by a coalescer prior to flow through the air strippers. During periods of excessive LNAPL entrainment in 2011, an increase in the dissolved-phase hydrocarbon concentrations was measured in the air stripper effluent. As a result, FHRA continued operation of the recovery system at a reduced pumping rate at R-21 and R-40 during the reporting period to reduce the amount of LNAPL entrained into the groundwater recovery system. FHRA installed a 2-inch-diameter stilling well in R-21 and R-40 to promote more reliable LNAPL recovery. In addition, FHRA is currently evaluating additional methods (including modification of the float assembly on the skimmer pump systems) to increase LNAPL recovery, which will allow higher groundwater pumping rates without overloading the air strippers with increased hydrocarbon concentrations.

During the reporting period, FHRA installed four additional recovery wells (R-43, R-44, R-45, and R-46) to replace R-39 and R-40, and to augment recovery in the R-21 area. Well development and piping installation were suspended due to extreme winter conditions during the reporting period. FHRA anticipates completion of the project in April 2013, as winter conditions subside. The new recovery wells have a greater total depth and diameter than the existing recovery wells, which will allow a higher groundwater recovery rate while maintaining LNAPL-only recovery with a skimmer system. The goal of the upgrades is to optimize groundwater capture using the full capacity of the treatment system. The locations of the new recovery wells are shown on Figure 5-3.

5.1.1 Groundwater Capture Evaluation

As discussed in the SCR – 2011 (Barr 2012), a recovery well pumping test was performed to evaluate the horizontal and vertical capture of the groundwater recovery system and to provide information for updating the groundwater flow model. Using the pumping test information, FHRA completed capture zone modeling of the groundwater recovery system; results were presented in the SCR – 2011 (Barr 2012). Updates to the model are ongoing

as new data are collected. Results will be presented to the ADEC in future reports and are not included in this report.

A site-wide groundwater elevation monitoring event is completed quarterly to evaluate the groundwater elevation. For this report, groundwater elevations were plotted and contoured, with an apparent depression in the potentiometric surface indicated in the area of the groundwater recovery wells (Figure 4-1). The total flow from the groundwater recovery system averaged 349 gpm during this event, which is less than full capacity (estimated at approximately 460 to 480 gpm for the current system). Groundwater recovery rates during 2012 were maintained below full capacity to prevent excessive LNAPL capture by the groundwater recovery system and to minimize LNAPL loading concerns on the air strippers.

A statistical trend analysis of groundwater analytical data to evaluate plume migration and stability is provided in Section 4.7. Trend analysis of the groundwater data is another line of evidence used to evaluate the effectiveness of the groundwater recovery system. With implementation of the IRAP (Barr 2010b) improvements in January 2010, FHRA began to increase the overall groundwater recovery rate (Table 5-1). Groundwater recovery rates further increased in July 2011, following the installation of R-42. Recent sulfolane concentration trends (through the fourth quarter 2012) in monitoring wells located immediately downgradient of the recovery system (and within the sulfolane plume) are summarized below:

- MW-127 (Figure 5-4) is located approximately 350 feet downgradient from the line of recovery wells. The sulfolane concentration has decreased since 2008 with lower concentrations sustained during 2012.

- MW-131 (Figure 5-5) is located approximately 1,000 feet downgradient from the line of recovery wells. The sulfolane concentration has generally declined since monitoring began in 2006. An additional significant decline was observed in late 2010. Sulfolane concentrations continued to decrease throughout 2012, with the lowest concentration detected to date from the fourth quarter.

- MW-139 (Figure 5-6) is located approximately 450 feet downgradient from the line of recovery wells. The sulfolane concentration has generally decreased since early 2009. The concentrations measured in 2011 and 2012 were generally stable, and less than the concentrations measured in 2010.

- MW-142 (Figure 5-7) is located approximately 620 feet downgradient from the line of recovery wells. Since 2009, the sulfolane concentration has fluctuated; however, the peak concentrations measured each year have decreased. A decreasing concentration trend was observed during 2012.

- MW-143 (Figure 5-8) is located approximately 800 feet downgradient from the line of recovery wells. The sulfolane concentration has generally decreased since 2007. A seasonal peak in the concentration has been measured during monitoring conducted typically in March during each of the past 5 years. Since 2007, the peak concentration measured has decreased compared to results of the previous year.

These wells were originally selected for performance monitoring prior to expansion of the onsite monitoring well network. A revised performance monitoring well network was proposed in the IRAP Addendum (ARCADIS 2013c) and is included in the project SAP (Appendix A). The trend at the five wells identified above indicates that the groundwater sulfolane concentration downgradient of the groundwater recovery system is generally decreasing.

Table 4-7 presents sulfolane analytical data from monitoring wells MW-186A/B/C/D/E, a five-well nest located near R-21 that provides vertical contaminant distribution near the groundwater recovery system. MW-186A, which is screened across the water table and was not sampled during previous monitoring events due to the presence of LNAPL, had a sulfolane concentration of 313 µg/L during the reporting period and a decreasing sulfolane concentration trend in 2012. MW-186B, which is screened from 51 to 60 feet bgs, had a sulfolane concentration of 25.2 µg/L (duplicate sample) during the reporting period, which is consistent with the results from other monitoring events conducted during 2012. MW-186C and MW-186D, which are screened from 91 to 100 feet bgs and 130 to 135 bgs, respectively, did not have detectable levels of sulfolane during the reporting period, which is consistent with past monitoring events. MW-186E, which is screened from 71 to 75 feet bgs, had a sulfolane concentration of 16.7 µg/L during the reporting period, which is comparable to the concentration observed during third quarter 2012 (11.2 µg/L).

5.1.2 Mass Recovery

Table 5-2 summarizes the sulfolane mass recovery during sampling events conducted during 2012. The sampling results include routine monthly sampling plus additional sampling completed as part of the IRAP (Barr 2010b) performance monitoring. This additional performance monitoring continued through the second quarter 2012; during the third quarter, a monthly monitoring schedule resumed in accordance with the wastewater disposal permit. During the reporting period, the sulfolane mass recovery averaged 0.40 lb/day. The sulfolane mass recovery for 2012 averaged 0.42 lb/day, which is similar to the recovery rate measured in 2011 (0.49 lb/day). During 2012, FHRA also measured the sulfolane concentration in the recovered groundwater at each active recovery well on a monthly basis; mass recovery rates are shown in Tables 5-3a through 5-3e.

During the reporting period, the maximum mass recovery rate was measured at R-21 (0.18 lb/day), while R-39 had no measured recovery of sulfolane. On an annual basis for 2012,

the maximum mass recovery rate was measured at R-21 (0.24 lb/day) in August, while R-39 had no measured sulfolane recovery during 2012. As previously mentioned, FHRA plans to install replacement recovery wells near R-21 to allow increased groundwater recovery because this location has the highest measured sulfolane concentration of the recovery wells. Although R-39 is outside the sulfolane plume, operation is ongoing to maintain capture of the BTEX plume in this area.

5.2 Light Nonaqueous Phase Liquid Recovery

During the reporting period, FHRA performed LNAPL recovery using skimmer systems at MW-138, R-20R, R-21, R-32, R-35R, and R-40 (Figure 5-1). Additional systems were installed at O-2 and R-33 in 2012; however, these systems were not active during the reporting period due to limited effectiveness. As previously noted, the skimmer system in O-2 was moved to S-50 in early 2013. Manual product recovery was completed during the reporting period with a vacuum truck, portable product pump, or during baildown testing at MW-176A, MW-186A, MW-334-15, O-2, O-10, O-11, O-13, O-19, O-27, R-14A, R-18, and R-32. The recovered LNAPL from the skimmer systems and manual recovery activities is recycled within a refinery process unit.

LNAPL recovery during the reporting period is summarized in Table 5-4. During this period, 137 gallons of LNAPL were recovered. The volume of LNAPL recovered is less than the first and second quarters of 2012 and approximately the same as the third quarter 2012. The majority of the recovery during the reporting period was from recovery wells R-20R, R-21, R-32, R-40, and MW-334-15. As mentioned, FHRA is planning to replace recovery wells R-39 and R-40 and install two additional recovery wells to augment capture near R-21. These four new recovery wells will allow increased groundwater capture, with a subsequent potential for increased LNAPL capture.

Table 5-6 summarizes LNAPL recovery at the site since 1986. From 1986 to present, approximately 393,950 gallons of LNAPL have been recovered.

5.3 Groundwater Treatment Evaluation

As noted in Section 5.1, FHRA operates groundwater recovery wells to provide capture of shallow dissolved-phase contaminants. The recovered groundwater is pumped to an onsite groundwater treatment system, which is operated to remove LNAPL and dissolved-phase contaminants. The recovered groundwater passes through a prefilter for solids removal, a coalescer for LNAPL removal, and a series of air strippers for removal of VOCs before accumulating in the Gallery Pond. The groundwater from the Gallery Pond is then pumped through sand filters and a four-vessel GAC system, which were added as part of the IRAP implementation. The sand filters were added to remove suspended solids and GAC vessels were added to remove organic compounds, including sulfolane. The treated groundwater is

discharged to the South Gravel Pit in accordance with wastewater disposal permit 2005-DB0012, issued by the ADEC. A process flow diagram of the groundwater recovery and treatment system, including the sand filter and GAC vessels, is provided on Figure 5-2.

Since operation of the sand filters and the GAC filter system began on June 9, 2011, additional monitoring has been conducted to evaluate the effectiveness of the sand filters and the GAC filter system following startup. The ADEC approved a 4-month monitoring period (expired September 30, 2011) to evaluate performance of the GAC filter system prior to establishing a discharge limit for sulfolane. At the conclusion of this period, FHRA requested an extension of the monitoring period to continue evaluation of GAC filter system performance. The ADEC extended the monitoring period until the new permit is issued (Smyth 2011).

In accordance with the wastewater disposal permit, FHRA conducted monthly monitoring during the reporting period; results for the reporting period and all of 2012 are summarized in Table 5-7. Analytical laboratory reports are provided in Appendix D.

Only low-level concentrations of BTEX constituents were present in samples collected at the air stripper effluent (prior to discharge to the Gallery Pond) during the reporting period. However, the final system effluent analytical results for each monitoring event indicated that residual contaminants were removed by the GAC vessels (Table 5-7).

As shown in Table 5-7, the sulfolane concentration in the final effluent has been below the LOQ during every monitoring event, showing effective removal of sulfolane from the recovered groundwater. During approximately the first month of the reporting period, Vessels C and D were operated in series and removed sulfolane to non-detectable levels. Vessels A and B were offline for replacement of the GAC during this period. Following completion of the GAC changeout, the treatment lineup resumed with Vessel A as the lead vessel, followed by Vessel B (in series) and then Vessels C and D (in parallel).

As mentioned in the SCR – 2011 (Barr 2012), sulfolane reduction has also been observed across the air strippers, the gallery pond, and the sand filters prior to the GAC vessel inlet. The average reduction of sulfolane across each system component for 2012 is summarized below:

- 40% reduction of sulfolane across the air strippers;
- 55% reduction of sulfolane across the gallery pond;
- 20% reduction of sulfolane across the sand filters;
- 76% reduction of sulfolane from the air stripper inlet to the GAC vessel inlet; and

- 100% reduction of sulfolane across the GAC vessels

FHRA performed additional bench-scale testing to potentially identify the mechanism for this degradation. Bench-scale testing results are provided in the Draft Final Onsite FS (ARCADIS 2012c). Because the sulfolane removal is observed following aeration in the air stripper, FHRA has completed an air sparging pilot test to evaluate if aeration of the aquifer will create conditions for sulfolane reduction in-situ. Monitoring results of the air sparging pilot test were provided to the ADEC as Appendix D to the IRAP Addendum (ARCADIS 2013c), and a summary is included in Section 4.10.2.

5.4 Summary of Non-Routine Repairs, Changes, and Maintenance

The overall groundwater recovery system maintained a runtime of 99.7% during the reporting period and an overall system runtime of 99.9% during 2012. No downtime occurred at the individual recovery wells during the reporting period, other than downtime associated with sand filter maintenance. Changeout of the GAC in Vessels A and B was completed in September/October 2012. However, the groundwater recovery and treatment system remained operational during these maintenance activities.

6. Analytical Quality Assurance and Quality Control

Quality assurance (QA)/quality control (QC) procedures assist in producing data of acceptable quality and reliability. Analytical results for laboratory QC samples were reviewed and a QA assessment of the data was conducted as the data were generated. The QA review procedures provided documentation of the accuracy and precision of the analytical data and confirmed that the analyses were sufficiently sensitive to detect analytes at levels below suggested action levels or regulatory standards, where such standards exist. The laboratory reports for each of the samples for this report, including case narratives describing laboratory QA results and completed ADEC data review checklists, are included in Appendices D and E. SWI conducted QA/QC reviews of the data for this reporting period.

In an email correspondence dated March 20, 2012, the ADEC reduced the requirement for continued submittal of Level IV data packages. Level IV data packages are required for 10 percent of the residential well samples. Level IV data packages and third-party review will continue to be required for monitoring well data if an interference is noted in a groundwater sample from a new well or is identified in an existing well, where no interference was previously identified. Level IV data packages for sulfolane were required for monitoring well data during the reporting period; results are summarized in Section 6.5. Level IV laboratory reports are required for 10 percent of residential well data and are included in Appendix D. Level IV validation reports prepared by Environmental Standards, Inc. (ESI) for the reporting period are included in Appendix J. Additionally, level IV validation reports prepared by ESI for the third quarter 2012 were not available for submittal with the Third Quarter 2012 Groundwater Monitoring Report (ARCADIS 2012b); these validation reports are included in Appendix J.

6.1 Water Sample Data Quality

This section summarizes the results of the QA/QC review of data for this reporting period. Samples were submitted to SGS for analysis of sulfolane, BTEX, other COPCs, and geochemical analysis for select monitoring wells. Samples for geochemical analysis during reporting period were collected in association with Bio-Trap deployment or CSIA sampling.

The COPCs included:

- BTEX
- Sulfolane
- Iron

The geochemistry analyses included:

- Alkalinity, CO_3 alkalinity, HCO_3 alkalinity, OH alkalinity, nitrate, sulfate, and TOC
- For select wells, methane (analyzed by SGS [Wilmington, North Carolina])

Initial water sample sulfolane data collected from the monitoring wells installed during the reporting period were also reviewed. In addition, residential water well sulfolane samples collected during the reporting period were reviewed. ADEC data review checklists are included in Appendix E. The SGS work orders (WOs) reviewed for the reporting period are listed in the table below.

Groundwater Monitoring Sample WO List							
1128486	1128558	1128562	1128563	1128564	1128567	1128575	1128578
1128588	1128589	1128592	1128593	1128597	1128599	1128600	1128601
1128602	1128613	1128616	1128617	1128618	1128623	1128624	1128626
1128627	1128633	1128636	1128637	1128638	1128639	1128640	1128649
1128653	1128654	1128658	1128664	1128665	1128666	1128667	1128683
1128690	1128694	1128695	1128696	1128699	1128657	1128656	1128539

SGS (WOs 1128547 and 1128676 were reviewed for the resampled residential groundwater samples during the reporting period.

The SGS WOs reviewed for the initial residential groundwater samples are listed in the table below.

Initial Residential Water Well Sample WO List				
1128546	1128574	1128577	1128598	1128615
1128614	1128644	1128671	1128670	1128674

Results of the QA/QC analysis are discussed below.

6.2 Sample Handling

Samples were generally hand delivered to the SGS (Fairbanks, Alaska) receiving office and then shipped overnight via Lynden Transport or Alaska Airlines Goldstreak to the SGS laboratory in Anchorage, Alaska to perform the requested analyses, using the methods specified in the COC records. For geochemistry WOs, SGS shipped samples for analysis of methane to the SGS laboratory in Wilmington, North Carolina or ALS Environmental of Simi Valley, California.

Sample receipt forms for each WO for both SGS Alaska locations, and sample receipt information from the SGS (Wilmington, North Carolina) case narratives and COCs, were reviewed and checked to verify that samples were received in good condition and within

the acceptable temperature indicated on the ADEC data review checklist (2 ± 4 degrees Celsius [°C]). The ADEC data review checklist (Appendix E) contains details regarding this review. The ADEC considers temperatures received between 0 and 6 °C acceptable in the absence of ice, as specified by USEPA Method SW-846. Therefore, for this report, temperatures between 0 and 6°C are considered acceptable.

Samples were received within the acceptable temperature range upon arrival at each SGS location during the reporting period sampling event. Samples were received properly preserved and in good condition, with the following exceptions:

- *WO 1128592*. Sample MW-182A may have been outside of acceptable temperatures between October 19 and 22, 2012. The SGS sample receipt form notes the "samples [were] found in a cooler at 12 °C. Samples were chilled and then brought to SGS FBX." Sample MW-182A was delivered to the SGS Fairbanks receiving office on October 22, 2012. The results for this sample should be considered estimated.

- *WO 1128638*. Although the samples arrived at the Fairbanks and Anchorage receiving offices within the acceptable temperature ranges, one bottle for sample MW-183B had ice floating in it. The lab marked the jar and only used it for secondary analysis, if needed. The sample results are considered unaffected.

- *WO 1128656*. One of the sample containers associated with sulfolane sample MW-323-15 was cracked and leaking. The container was not used for analysis; therefore, the results are unaffected.

- *WO 1128664*. The second cooler arrived in Anchorage with a temperature of -0.2 °C. There was no ice present in any of the samples, so the sample results are considered unaffected.

- WO *1128665*. Two coolers reached the Anchorage receiving office below the acceptable temperature, but there was no ice present in any of the samples so results are considered unaffected. One trip blank vial also arrived broken. The other two vials were analyzed, so results are considered unaffected.

- *WO 1128654*. Some of the samples for metals analyses were preserved upon arrival at the Anchorage receiving office. This does not affect data quality or usability. Also, TOC for sample MW-151A was preserved upon arrival at the Anchorage receiving office. Samples for organic analysis that are not properly preserved and analyzed after 7 days are considered estimated, so a "J" flag was applied to this result.

- *WO 1128666*. The cooler arrived at the SGS receiving office in Anchorage, Alaska below the acceptable temperature. However, there was no ice in any of the samples so data quality or usability are not affected.

COC records for each WO were also reviewed to confirm that information was complete, custody was not breached, and samples were analyzed within the acceptable hold time. COC records were complete and correct, with the following exceptions:

- *WO 1128593*. The COC incorrectly listed samples MW-189A and MW-189B. The mistake was discovered during the QA review of the sample sheets and COCs. The laboratory was contacted and told that MW-189A should be MW-182A and MW-189B should be MW-182B; the results were reported with the corrected sample names and therefore are unaffected. In addition, samples MW-193A, MW-193B, and MW-189A were listed on WOs 1128592 and 1128593; these samples were logged and reported under WO 1128593. The samples were analyzed within their hold time; therefore, the results are unaffected.

- *WO 1128558*. Sample MW-166A was written as MW-1668 on the COC. The laboratory correctly reported it as MW-166A after contacting SWI; therefore, the results are unaffected.

- *WO 1128564*. Sample MW-181C was listed on the COC as MW-189C. SWI caught the mistake during review of the COC and the laboratory reported it correctly; therefore, the results are unaffected.

- *WO 1128626*. Sample MW-263A was not written on the COC. This sample was added to the COC and analyzed, and the results are not affected.

- *WO 1128649*. Samples MW-170D and MW-170B were listed on the COC as MW-170-D and MW-170-B. The lab contacted SWI and confirmed the correct sample ID; the results were reported correctly.

Sample ID changes for residential samples collected during the reporting period are addressed in the ADEC data review checklists (Appendix E). To maintain privacy, the homeowner names are not disclosed in this report. No other sample handling anomalies were identified during the reporting period that would adversely affect data quality.

6.3 Analytical Sensitivity

Reported limits of detection for regulated analytes were below ADEC cleanup levels or interim action levels during the reporting period.

Laboratory method blanks were analyzed in association with samples collected for this project to check for contributions to the analytical results, possibly attributable to laboratory-based contamination. Trip blanks were submitted with groundwater samples for BTEX analysis to verify that cross-contamination did not occur during sample handling and transport. Equipment blanks were collected to assess the possibility of cross-

contamination from sampling equipment. There were no method blank, trip blank, or equipment blank detections affecting data quality for the reporting period, with the following exceptions:

- WOs *1128562, 1128602 and 1128592*. TOC was detected in the method blank; however, all sample concentrations were greater than five times the amount found in the method blank, so data are not affected.
- *WO 1128695*. Alkalinity was detected in the method blank; however, all sample concentrations were greater than five times the amount found in the method blank, so data are not affected.
- *WO 1128588 and 1128616*. TOC and alkalinity were detected in the method blanks. For both WOs, associated sample concentrations were more than five times the amount found in the method blanks, so results are unaffected.

6.4 Accuracy

Laboratory analytical accuracy may be assessed by evaluating the analyte recoveries from continuing calibration verification (CCV), laboratory control sample (LCS), and LCS duplicate (LCSD) analyses. LCS/LCSD samples assess the accuracy of analytical procedures by checking the ability to recover analytes added to clean aqueous matrices. In some cases, the laboratory spiked project samples as matrix spike (MS) and MS duplicate (MSD) to assess their ability to recover analytes from a matrix similar to that of project samples. Accuracy was also assessed for organic analyses by evaluating the recovery of analyte surrogates added to project samples. For sulfolane results, the recovery of the internal standard (sulfolane-d8) was also evaluated.

The laboratory did not report CCV or initial calibration verification failures for samples obtained during the reporting period. All LCS/LCSD and MS/MSD results were reviewed from preparatory batches associated with project samples. LCS and LCSD recoveries were within laboratory control limits for each preparatory batch. The MS/MSD recoveries were within acceptable limits, with the following exceptions:

- *WO 1128640*. MS recovery of sulfate was below laboratory control limits using an original project sample. Sample MW-162B should be considered estimated and is flagged “J.”
- WO *1128599 and 1128486*. MS recovery of total nitrate/nitrite is below the acceptable limits. The case narrative refers the reviewer to the LCS for accuracy assessment; LCS was recovered within limits. Results are considered unaffected by the MS failures.

- *WO 1128588*. Methane recoveries for billable matrix spike (BMS) and BMS duplicate (BMSD) were above laboratory control limits. A BMS/BMSD recovery failure occurred for methane, corresponding to sample MW-110. However, the spike concentration was less than two times the native analyte concentration. Therefore, in accordance with the National Functional Guidelines for Organic Data Review (USEPA 2008), the results are not affected.

- *WO 1128601*. Benzene was detected below laboratory control limits in the MS and MSD; LCS/LCSD and surrogates associated with the project sample are within limits. Therefore, the results were unaffected by the MS/MSD failures.

- *WO 1128665*. MSD recovery for o-xylene was above laboratory control limits. The original was not in the project sample set; therefore, data are unaffected.

Recovery of analyte surrogates and the sulfolane internal standard were within laboratory control limits, except for the sulfolane-d8 recovery failures and ion ratio errors discussed below.

The samples listed in the table below were affected by sulfolane-d8 recovery failures:

Work Order	Sample ID
1128618	MW-167B
1128618	MW-169C
1128618	MW-166B
1128618	MW-164B
1128618	MW-164C
1128618	MW-164A
1128618	MW-167A
1128623	MW-165B

Sulfolane results (or limits of detection) associated with internal standard recovery failures were flagged J as estimated. A bias was not imparted because the isotope dilution method theoretically corrects the result for the high or low recovery. However, the low sulfolane-d8 recoveries may indicate matrix interference or extraction inefficiency; therefore, a J-flag was applied to indicate the potential lack of accuracy. For some of these samples, surrogate nitrobenzene-d5 was recovered outside QC criteria as well. However, this surrogate is used for informational purposes only and does not affect sulfolane sample results.

Laboratory CCV, LCS/LCSD, MS/MSD, and surrogate recovery information indicate that the analytical results were accurate, with the exceptions noted above.

The laboratory case narratives noted the following ion ratio errors:

- *WO 1128665*. The laboratory noted that secondary ion response was outside QC criteria for samples O-3 and O-24. A Level IV laboratory report was requested. ESI validated data to determine if the potential interference affected sulfolane results for these samples. ESI's review concluded there was no effect on the data, as summarized in their January 11, 2013 report titled, Fourth Quarter 2012 Analysis of Sulfolane in Monitoring Well Samples Validation Report 1, included in Appendix J.

- *WO 1128699*. The laboratory noted that two of the ion ratios were outside QC criteria for duplicate sample MW-404-80. Because the result for sulfolane in this sample was less than the LOQ and was flagged "J" by the lab, the result is considered unaffected.

6.5 Precision

Duplicate samples were collected at a frequency of at least 10 percent of the overall number of samples collected to evaluate the precision of analytical measurements, as well as the reproducibility of the sampling technique. The relative percent difference (RPD; difference between the sample and its field duplicate divided by the mean of the two) was calculated to evaluate the precision of the data. An RPD can be evaluated only if the results of the analyses for both duplicates are above the LOQ.

During the reporting period, the following duplicate samples were collected:

- Two duplicates for residential water well samples (12 samples total)

- Four duplicates for BTEX samples from monitoring wells (40 samples total)

- Five duplicate for geochemical samples from monitoring wells (43 samples total)

- Twenty-seven duplicates for sulfolane samples from monitoring wells (186 samples total)

- Two duplicates for COPC (iron) analysis (14 samples total)

The collection frequency for sulfolane sample duplicates was approximately 14% of the total samples collected. Results of RPD calculations for these duplicate samples were within the data quality objective of 30%, where calculable.

Laboratory analytical precision can also be evaluated by laboratory QC sample RPD calculations using the LCS/LCSD and MS/MSD, or laboratory duplicate sample results. The results of RPD calculations for LCS/LCSD, MS/MSD, and laboratory duplicate sample pairs were within the laboratory's acceptable range.

Based on a review of the data, the water results associated with the reporting period are considered precise, with the exceptions noted above.

6.6 Data Quality Summary

Based on the methods outlined in the project SAP (Appendix A), the samples collected are considered to be representative of site conditions at the locations and times they were obtained. Based on the QA review, no samples were rejected as unusable due to QC failures. In general, the quality of the analytical data for this reporting period does not appear to have been compromised by analytical irregularities and results affected by QC anomalies are qualified with the appropriate data flags.

7. Conclusions and Recommendations

Groundwater monitoring data collected during the reporting period are generally consistent with data collected during recent quarters. Onsite data are generally consistent with recent monitoring events. Sulfolane concentrations continue to be detected offsite. As is characteristic for this reporting period, severe cold weather limited access to some wells in the monitoring well network; however, the prioritized data collected during the reporting period are representative of the onsite and offsite monitoring plans outlined in the project SAP (Appendix A). FHRA recommends amending the monitoring well networks presented in the project SAP (Appendix A) based on prioritization, when applicable, for future monitoring events. Additionally, FHRA recommends discontinuing analytical sampling of select wells outside of the sulfolane plume and reducing the geochemical parameter monitoring network. Approximately five to eight wells located near the proposed air sparge barrier location will be targeted for routine geochemical parameter analysis. Wells proposed for discontinued analyses and monitoring network revisions will be presented and discussed at Site Characterization Subgroup meetings.

Operation of the sand filters and GAC vessels began on June 9, 2011 and the system continues to successfully treat sulfolane-impacted groundwater collected from the onsite recovery wells. The onsite treatment system has effectively treated a greater volume of sulfolane-impacted groundwater than originally anticipated and recovery and treatment will be continued as outlined in the project SAP (Appendix A). Air sparge pilot testing is complete; however, the system will be shut down following anticipated sampling, and wells will continue to be monitored for potential sulfolane rebound and results will continue to be presented in quarterly reports.

The groundwater monitoring programs proposed in the SCR – 2011 (Barr 2012) and described in the project SAP (Appendix A) are underway for the next reporting period (first quarter 2013). Additional activities will include LNAPL monitoring, remediation system operation and maintenance, sub-permafrost private well sampling, and additional private well sampling, as required. FHR will conduct a second, first quarter, round of sampling in selected wells during first quarter 2013 as requested by ADEC, and facilitate stable isotope sampling being conducted by UAF. FHRA recommends continued mass flux analysis of the VPT on a quarterly basis pending the availability of a complete data set. Mass flux results will be reported in quarterly reports. In addition, FHRA recommends discontinuing the PCA and discriminant analyses for future monitoring reports. Also, as discussed in Section 2.3, a hydraulic gradient evaluation will be submitted as an addendum to this report.

Field activities and performance monitoring proposed in both the IRAP Addendum (ARCADIS 2013c) and additional 2013 Onsite Site Characterization Work Plan (ARCADIS 2013b) will be initiated during the first or second quarter 2013, weather permitting. The performance monitoring program is also summarized in the project SAP (Appendix A).

Design testing for proposed interim remedial actions will also continue during the next reporting period. Data collected as part of these activities will be discussed during ongoing Site Characterization Subgroup meetings and reported in a separate summary report to the ADEC.

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Tables

Figures

Appendices
(on enclosed CD)

Appendix A

Revised Sampling and Analysis Plan

Appendix B

Baildown Testing API Outputs

ARCADIS

Appendix C

Historical Data Tables for Groundwater Elevation and LNAPL Thickness, BTEX, Sulfolane, Geochemical Parameters, Private Wells, COPCs, and Culvert Water Elevations

Appendix D

Analytical Laboratory Reports

ARCADIS

Appendix E

ADEC QA/QC Checklists

Appendix F

Field Data Sheets

Appendix G

Hydrographs

Appendix H

Mass Flux Methods

Appendix I

Mann – Kendall Trend Charts

Appendix J

Level IV Data Validation Reports