Flint Hills Resources Alaska, LLC

SECOND SEMIANNUAL 2015 OFFSITE GROUNDWATER MONITORING REPORT

North Pole Terminal
North Pole, Alaska

DEC File Number 100.38.090

January 29, 2016

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B0081981.0077

Date:

January 29, 2016

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ACRONYMS AND ABBREVIATIONS

AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
AHL	Arctic Home Living
Arcadis	Arcadis U.S., Inc.
Barr	Barr Engineering Company
bgs	below ground surface
bwt	below the water table
city	North Pole, Alaska
CSM	Conceptual Site Model
FHRA	Flint Hills Resources Alaska, LLC
ft/ft	foot per foot
MAROS	Monitoring and Remediation Optimization System
monitoring plan	Deep Private Well Groundwater Monitoring Plan
Offsite RSAP	Offsite Revised Sampling and Analysis Plan
Offsite SCR – 2013	Offsite Site Characterization Report – 2013 Addendum
Offsite SCWP	Revised 2013 Offsite Site Characterization Work Plan
Pace	Pace Analytical Services, Inc.
POE	point-of-entry
QA	quality assurance
QC	quality control
report	Second Semiannual 2015 Offsite Groundwater Monitoring Report
reporting period	third and fourth quarters of 2015
site	Flint Hills Resources Alaska, LLC North Pole Terminal located on H and H Lane in North Pole, Alaska
SOP	standard operating procedure
SWI	Shannon & Wilson, Inc.
USGS	U.S. Geological Survey
µg/L	micrograms per liter

1 INTRODUCTION

On behalf of Flint Hills Resources Alaska, LLC (FHRA), Arcadis U.S., Inc. (Arcadis) prepared this Second Semiannual 2015 Offsite Groundwater Monitoring Report (report) for groundwater located downgradient of the FHRA North Pole Terminal, located on H and H Lane in North Pole, Alaska (site). This report summarizes offsite field activities completed in areas beyond the site boundary during the third and fourth quarters of 2015 (reporting period), as described in Section 3. A separate Second Semiannual 2015 Onsite Groundwater Monitoring Report is being submitted concurrently with this report.

The data, analyses, and conclusions presented in this report are the product of a collaborative effort among FHRA's consulting team members. The team includes qualified professionals in a variety of technical disciplines from three environmental consulting firms: Arcadis, Shannon & Wilson, Inc. (SWI), and Barr Engineering Company (Barr). FHRA engaged these consulting firms to perform various tasks for the project. Pursuant to 18 Alaska Administrative Code (AAC) 75.335(c) (1), this report was prepared and submitted by a Qualified Environmental Professional. Samples were collected and analyzed in accordance with 18 AAC 75.355(a). Point-of-entry [POE] system sampling conducted by Arctic Home Living (AHL) was supervised by FHRA and its consultants, and the resulting sample data were reviewed and used in reports prepared by a Qualified Environmental Professional.

2 SITE SETTING

The site is located inside the city limits of North Pole, Alaska (the city). The city is located approximately 13 miles southeast of Fairbanks, Alaska, within the Fairbanks North Star Borough (Figure 2-1). Groundwater containing sulfolane has migrated offsite. An offsite site plan is presented on Figure 2-2.

The site (both offsite and onsite areas) and the site's physical setting are described in the Conceptual Site Model (CSM; Appendix A to the Offsite Site Characterization Report – 2013 Addendum [Offsite SCR – 2013; Arcadis 2013a]). The CSM (Arcadis 2013a) summarizes how chemicals were historically released to the environment at the site, how those chemicals move through the environment and affect living organisms, and ongoing efforts to protect people from exposure to those chemicals.

3 CURRENT GROUNDWATER MONITORING PROGRAM AND METHODS

The current 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 several iterations of site characterization reports. Table 3-1 summarizes the offsite field activities completed during the reporting period. Table 3-2 summarizes the offsite well construction details. The offsite groundwater elevation and sulfolane monitoring networks used for the reporting period are included in Tables 1 and 2 of the Offsite Revised Sampling and Analysis Plan (Offsite RSAP; Appendix A to the Fourth Quarter 2014 Offsite Groundwater Monitoring Report [Arcadis 2015]), with limited variations. Offsite well locations are shown on Figure 2-2. The offsite groundwater monitoring networks are currently being evaluated for revisions to be presented in a 2016 update to the Offsite Revised Sampling and Analysis Plan.

Groundwater monitoring data are used to monitor offsite dissolved-phase sulfolane concentrations and groundwater nature and movement. Sulfolane is the only offsite contaminant of concern. Groundwater monitoring through the fourth quarter 2015 was completed according to the procedures summarized in the Offsite RSAP (Arcadis 2015).

3.1 Groundwater Elevation Monitoring

The third and fourth quarter 2015 groundwater elevation monitoring events were conducted on August 12 and 13, 2015 and November 19 and 20, 2015, respectively, at an extensive network of offsite wells. Groundwater elevation measurements were also taken from the vertical gradient network and are discussed in Section 4.1 and Appendix F. In addition to manual water-level measurements, automated measurements were collected from a network of wells using pressure transducers to observe hydrogeological conditions in wells screened at various depths within the suprapermafrost and subpermafrost aquifers. Groundwater elevation measurements were downloaded from the deployed offsite transducers on September 15 and 16 and October 1, 2015 during third quarter 2015 and on November 23 and 30 and December 4, 2015 during fourth quarter 2015.

3.2 Groundwater Sampling Priorities

In response to past sampling events where extended cold weather reduced the opportunity to collect groundwater samples, the well networks are evaluated and wells are assigned a priority (one through four). Sampling is conducted in order of priority. Table 2 of the Offsite RSAP (Arcadis 2015) summarizes the priority levels assigned to each well in the offsite sulfolane monitoring network.

The following deviations from the Offsite RSAP (Arcadis 2015) were noted during the reporting period:

- Suprapermafrost monitoring wells MW-349-15 and MW-349-45 are located on the same property as private well PW-1230 and are being sampled on the same schedule as the deep private well monitoring network to minimize disturbance to the property owner. During the third quarter 2015 sampling event, wells MW-349-15 and MW-349-45 were inadvertently sampled for the deep private well network geochemical parameters.

- Monitoring well MW-308-30 was frozen during both third and fourth quarters 2015; therefore, no samples were collected during the reporting period from this well.

3.3 Private Well Sampling

Characterization activities began offsite in 2009. A door-to-door survey was previously conducted downgradient from the site to identify private water-supply wells in Search Areas 1 through 11 (Barr 2014). Private well locations with well identifiers are shown on the figure included as Appendix A. Additional background information about private well sampling is documented in the Alternative Water Solutions Program – Management Plan (Barr 2014) and Alternative Water Solutions Program – 2014 Annual Report (Barr 2015).

Private wells were sampled as part of the 2015 buffer zone and resampling program, where wells within or near the detectable sulfolane plume boundary without previous sulfolane detections were sampled (Barr 2015). Sampling reported during third quarter was completed from May 28 through September 18, 2015. During sampling, FHRA collected initial groundwater samples from three private wells (PW-2068, PW-2220, and PW-2221). Private wells PW-2068 and PW-2221 are located within the search areas. The home located on the property with this private well was previously vacant. Private well PW-2220 is located outside the search areas and the sample from this private wells was collected at the homeowners' request as a "call-in" sample. Sampling reported during the fourth quarter was completed from September 19 through November 14, 2015. FHRA collected an initial sample from one private well (PW-2222) during sampling. Private well PW-2222 is located outside the search areas and a sample was collected on the homeowner's request. The wells sampled for the first time during the reporting period are identified on Figures 3-1, 4-9, 4-13 and 4-14.

During the third quarter 2015, FHRA collected groundwater samples from 178 previously sampled private wells (not including samples collected from POE systems). This includes two call-in samples from outside the search areas (wells were previously sampled in 2010) and one sample from within the search areas (well was previously sampled in 2011). The remaining 175 samples were collected from previously sampled wells as part of the 2015 buffer zone and resampling program (Barr 2015). During the fourth quarter 2015, four previously sampled private wells were sampled as part of the 2015 buffer zone and resampling program.

To date (between November 11, 2009 and November 30, 2015), FHRA has sampled and received results for 671 wells within the search areas (Barr 2014), with many locations sampled several times as part of the annual resampling events, POE treatment system maintenance, and/or the Deep Private Well Groundwater Monitoring Plan (monitoring plan; Arcadis 2012). In addition, 190 private well samples were collected from outside the search areas at locations near the existing search areas or in situations where FHRA was contacted by a landowner, resident, or real estate agent with requests for testing.

3.4 Point-of-Entry Sampling

During the reporting period, FHRA continued to collect POE system maintenance sulfolane samples, including raw water samples (“A” samples). As of November 30, 2015, 179 laboratory packets with POE analytical data for “A” samples were received from Pace Analytical Services, Inc. (Pace) during the reporting period.

Figure 3-1 presents sulfolane sample results for private wells. Well symbols differentiate the wells with and without a POE treatment system. For locations with a POE treatment system, only results from raw influent (“A” samples) are depicted on this figure. POE treatment system monitoring results and a discussion of effectiveness for 2015 will be included in the Alternative Water Solutions Program 2015 Annual Report.

3.5 Deep Private Well Monitoring

Sampling of deep private well network wells continued during the reporting period. Fifteen of the deep private wells have intake intervals reported at depths below permafrost (based on installation logs), with total depths between approximately 89 feet below ground surface (bgs) (PW-0463) and 305 feet bgs (PW-1109). Two of the wells reportedly have shallow intake intervals at approximately 24 feet bgs (PW-0297) and 30 feet bgs (PW-1458) and are located on the same properties as two of the deep wells.

During the third quarter 2015, SWI sampled 14 deep private wells between August 12 and September 1, 2015. Private well PW-1109 was not sampled because the property was vacant and the well was not in service. The two shallow garden wells (PW-0297 and PW-1458) that are part of the deep private well monitoring network were frozen and samples were not collected during third quarter 2015.

After the completion of more than 2 years of monitoring, FHRA reduced the deep private well analyte list to only sulfolane in fourth quarter 2015. During the fourth quarter 2015, samples for sulfolane analysis were collected from 14 deep private wells between October 15 and 31, 2015. Similar to the third quarter 2015 sampling event, private well PW-1109 was not sampled because the well was not in service and the two shallow garden wells (PW-0297 and PW-1458) remained frozen and were not sampled.

The majority of the deep private well network wells are locations with POE systems. The routine collection of raw water data during maintenance at these wells and other POE locations with deep wells based on well logs provides consistent data on the subpermafrost plume (Figures 4-11 and 4-15). Elimination of duplicative sampling of the former deep private well network will be implemented in 2016.

3.6 Well Maintenance Activities

During the reporting period, minor repair was performed on 48 offsite monitoring wells. Previously damaged monitoring wells MW-160A-15 and MW-190B-60 were decommissioned on June 29, 2015. Other minor maintenance was performed on an as-needed basis for the remaining offsite wells during the reporting period.

4 GROUNDWATER MONITORING RESULTS

Offsite groundwater impacts have been characterized, and continue to be monitored through the analysis of water-level gauging data and groundwater samples collected from offsite monitoring, U.S. Geological Survey (USGS), and private wells. This section presents results of water-level gauging and sulfolane analysis of offsite monitoring and private well samples collected during the reporting period. Groundwater monitoring well field parameters and groundwater elevations are presented in Tables 4-1 and 4-2. Tables 4-3 through 4-7 present results of monitoring well sulfolane analysis, private well initial sampling, private well resampling, deep private well field parameters, and deep private well sulfolane results. Historical data for groundwater elevation, sulfolane analyses, geochemical parameters, private well analyses, and culvert measurements are included as Appendix B. Analytical laboratory reports are included in Appendix C. An analytical quality assurance (QA)/quality control (QC) summary, including ADEC QA/QC checklists and Level IV data validation reports for data collected from monitoring wells and private wells (including POE systems and the deep private well network) are included in Appendix D. Field data sheets are included as Appendix E.

4.1 Groundwater Elevation

Depth to water measurements and groundwater elevation data for the reporting period are summarized in Table 4-2. Vertical gradient network groundwater elevations and vertical head differences between nested wells are evaluated in Appendix F.

Depth to water measurements were collected from monitoring wells on August 12 and 13, 2015 and November 19 and 20, 2015 for the third and fourth quarter 2015 groundwater elevation monitoring events, respectively. Potentiometric maps for the third and fourth quarters 2015 monitoring events are included on Figures 4-1 through 4-4 and Figures 4-5 through 4-8, respectively, for each monitoring zone: water table, 10 to 55 feet below the water table (bwt), 55 to 90 feet bwt, and 90 to 160 feet bwt. The average magnitudes of the offsite horizontal hydraulic gradients for groundwater during the third quarter 2015 monitoring event were calculated as follows: water table – 0.0009 foot per foot (ft/ft), 10 to 55 feet bwt – 0.0010 ft/ft, 55 to 90 feet bwt – 0.0012 ft/ft, and 90 to 160 feet bwt – 0.0011 ft/ft. The average magnitudes of the offsite horizontal hydraulic gradients for groundwater during the fourth quarter 2015 monitoring event were calculated as follows: water table – 0.0011 ft/ft, 10 to 55 feet bwt – 0.0010 ft/ft, 55 to 90 feet bwt – 0.0012 ft/ft, and 90 to 160 feet bwt – 0.0009 ft/ft. During the reporting period, the general direction of the horizontal hydraulic gradient was interpreted to be to the north-northwest, which is consistent with historical groundwater data. Vertical hydraulic gradients were also within the range of historical groundwater data as depicted in Appendix F.

In addition to manual water-level measurements, automated measurements were collected using pressure transducers deployed in 39 offsite wells, including 15 well nests. Groundwater elevation hydrographs were prepared in accordance with the standard operating procedure (SOP) for groundwater elevation monitoring (SWI 2013) using the most recent survey data. Error ranges, calculated in accordance with the method outlined in the SOP for groundwater elevation monitoring (SWI 2013), are shown on the well nest hydrographs presented in Appendix G.

A detailed evaluation of transducer data and hydraulic gradients is provided in Appendix 5A to the Offsite SCR – 2013 (Arcadis 2013a). An updated evaluation is presented as Appendix F.

Culvert measurements for third quarter 2015 were recorded on July 9, August 11, and September 2, 2015. Culvert measurements for fourth quarter 2015 were recorded on October 14, November 3, and December 8, 2015. Measurements collected since March 2012 are included in historical tables provided in Appendix B. This data has shown limited variation year to year, and will no longer be collected.

4.2 Sulfolane Distribution in Offsite Groundwater

There are currently 156 offsite monitoring wells (Figure 2-2) to characterize the nature of the aquifer, permafrost depths, and the extent of sulfolane impacts offsite (Arcadis 2013b). In addition, FHRA compiled data from an extensive review of available private well logs, collected information regarding construction of private wells from property owners, and discussed private well depths and the depths to both the top and bottom of permafrost with well drillers. A total of 70 private wells were identified to have been installed through permafrost, within and near the detectable sulfolane plume, at depths ranging from 60 to 353 feet bgs.

During the third and fourth quarter 2015 groundwater monitoring events, samples were collected and submitted for sulfolane analysis from 134 and 112 monitoring wells, respectively, from the offsite monitoring well network. The offsite monitoring well data are presented in Table 4-3. Results from private wells sampled for the first time during the reporting period are presented in Table 4-4 (initial sampling). Results for the buffer zone and resampled private wells are presented in Table 4-5. Offsite sulfolane distribution for the third and fourth quarters of 2015 are included on Figures 4-9 through 4-12 and Figures 4-13 through 4-16, respectively. The approximate extent of sulfolane distribution shown on Figures 4-9, 4-10, 4-13, and 4-14 consider results from monitoring wells sampled during the quarterly monitoring periods (July and August 2015 for third quarter and October 2015 for fourth quarter) and suprapermafrost private wells sampled within the last 12 months (September 18, 2014 through September 18, 2015 for third quarter and November 14, 2014 through November 14, 2015 for fourth quarter). The approximate extent of sulfolane distribution shown on Figures 4-11 and 4-15 consider results from subpermafrost private wells sampled within the last 12 months (September 18, 2014 through September 18, 2015 for third quarter and November 14, 2014 through November 14, 2015 for fourth quarter). Historical sulfolane analytical results are included in Appendix B.

4.2.1 Private Well Sampling Results

During the third quarter 2015, three private wells were sampled for the first time, which included one call-in sample collected from a private well outside the plume area (PW-2220) and two call-in samples collected from within the sulfolane plume area (PW-2068 and PW-2221). Two of the initial private well samples, PW-2068 and PW-2221, contained detectable concentrations of sulfolane at 20.5 micrograms per liter (µg/L) and 14.1 µg/L, respectively, while a concentration below the detection limit (<5.45 µg/L) was reported for the sample collected from PW-2220. FHRA has initiated interim bottled water delivery for the homes associated with PW-2221 and PW-2068. During the fourth quarter 2015, one sample was collected for the first time from a private well located outside the sulfolane plume area (PW-2222). Sulfolane was not detected in the sample from PW-2222.

Initial sample results are presented in Table 4-4. Initial samples collected during the reporting period are highlighted on Figures 3-1, 4-9, and 4-13. Private well locations are also shown on the figure presented as Appendix A.

During the third quarter 2015, 178 previously sampled private wells that are a part of the buffer zone and resampling project or call-in sampling were resampled. No sulfolane was detected in 175 of the samples collected during the third quarter 2015. These results are shown in Table 4-5 and presented on Figures 4-9, 4-10, and 4-11, based on their classification as either suprapermafrost or subpermafrost wells. Only three of the samples (PW-0360 eastern side within the plume, PW-0382 northern near plume front, and PW-0914 north-eastern at plume front) contained estimated sulfolane concentrations below the limit of quantitation at 4.54J, 7.16J*, and 4.29J µg/L, respectively.

During the fourth quarter 2015, four previously sampled private wells were resampled. These results are shown in Table 4-5 and presented on Figures 4-13, 4-14, and 4-15, based on their classification as either suprapermafrost or subpermafrost wells. Only one of the samples (PW-1464 east-central within the plume) contained an estimated sulfolane concentration of 4.73J µg/L. The other three samples collected during the fourth quarter 2015 did not contain detectable concentrations of sulfolane. The most recent data for each private well is shown on Figure 3-1 with color gradation to indicate the concentration.

During the reporting period, 179 raw water samples were collected from locations with a POE treatment system (“A” samples, taken upstream of the treatment system) and were evaluated to identify plume trends. The most recent raw water data for locations with a POE treatment system are also included on Figure 3-1. Historical private well data, including current and historical POE treatment system data for raw water samples, are presented in Appendix B. Laboratory reports and associated ADEC QA/QC checklists reviewed during the reporting period are presented in Appendices C and D, respectively. Data were evaluated for potential sulfolane concentration trends through third quarter 2015; results are discussed in Section 4.3 and included in Appendix H.

4.2.2 Deep Private Well Monitoring Results

As stated in Section 3.5, groundwater samples were collected from 14 private wells that are part of the deep private well monitoring program during the third and fourth quarters of 2015. Sulfolane was not detected in the samples collected from three private wells (PW-0296, PW-0972, and PW-1343) during the third quarter 2015 sampling event. Sulfolane concentrations detected in the remaining private wells ranged from 18.0 JN* µg/L (PW-0932) to 813 µg/L (PW-1230) during the third quarter 2015. The non-detect concentration at PW-296 is not consistent with historical results for this location, which have ranged from 6.90 J* µg/L (September 2011) to 13.4 µg/L (June 2013). The third quarter 2015 result for PW-296 is hence shown as a detection and color-coded accordingly on Figures 4-9, 4-11 and 4-12. Sulfolane was not detected in the samples collected from two private wells (PW-0972 and PW-1343) during the fourth quarter 2015 sampling event. Sulfolane was detected at concentrations ranging from 10.1 J µg/L (PW-0296) to 799 µg/L (PW-1230) during the fourth quarter 2015.

Deep private well field parameter results are included in Table 4-6 and analytical results are included in Tables 4-7a and 4-7b. Sulfolane concentrations for the deep private well network for the third and fourth quarters of 2015 are presented on Figures 4-12 and 4-16, respectively. Historical data are included in Appendix B. Sulfolane statistical trends for the deep private monitoring well network are discussed in

Section 4.3. Laboratory reports and ADEC QA/QC checklists are included in Appendices C and D, respectively.

4.2.3 Subpermafrost and Suprapermafrost Aquifers

Three hundred and twenty six private wells have been identified as being screened within the suprapermafrost aquifer and have been sampled. Seventy private wells have been identified as being installed through permafrost and therefore represent the subpermafrost aquifer system (generally with depths greater than 60 feet) and have been sampled.

Figures 4-9 and 4-13 show the combined sulfolane analytical results from offsite monitoring wells and private wells in both the suprapermafrost and subpermafrost aquifers for the third and fourth quarters of 2015, respectively. This includes private wells that do not have available or reliable well construction information and, therefore, cannot be designated to either the suprapermafrost or subpermafrost aquifer. If the well was not sampled in the third or fourth quarter of 2015, then the most recent result within the preceding 12 months is indicated on the map and was used to estimate the extent of sulfolane. Sections 4.2.3.1 and 4.2.3.2 summarize the analytical data collected during the reporting period from offsite groundwater monitoring and private wells that are designated to the suprapermafrost or subpermafrost aquifer, respectively. The sulfolane detections in offsite monitoring and private wells that were flagged as estimated are discussed in Appendix D.

4.2.3.1 Offsite Sulfolane Distribution in the Suprapermafrost Aquifer

Offsite monitoring wells were sampled throughout the reporting period. A total of 134 offsite monitoring wells were sampled and analyzed for sulfolane during the third quarter 2015 monitoring event. Sulfolane was not detected in 60 samples. In the remaining 74 samples, sulfolane was detected at concentrations ranging from 3.24JL* µg/L (MW-317-15) to 222 µg/L (MW-332-150). Based on the site characterization studies, the following monitoring wells appear to be installed in an area just beyond the edge of a large permafrost body: MW-332-15 (<5 µg/L), MW-332-41 (<5 µg/L), MW-332-75 (<5 µg/L), MW-332-110 (17.4 µg/L), MW-332-150 (222 µg/L), MW-346-15 (11 µg/L), MW-346-65 (28.3 µg/L), and MW-346-150 (<5 µg/L). Sulfolane concentrations in these wells may indicate a “mixing zone” between the subpermafrost and suprapermafrost aquifers (Arcadis 2013a), as shown on Figures 4-9, 4-10, and 4-11 (and similar for fourth quarter Figures 4-13, 4-14, and 4-15). These results are presented in Table 4-3.

A total of 112 offsite monitoring wells were sampled and analyzed for sulfolane during the fourth quarter 2015 monitoring event. Sulfolane was not detected in 52 samples. In the remaining 60 samples, sulfolane was detected at concentrations ranging from 3.34J µg/L (MW-308-15) to 209 µg/L (MW-332-150). Sulfolane concentrations in the inferred mixing zone monitoring wells are as follows: MW-332-15 (<5.10 µg/L), MW-332-41 (<5.10 µg/L), MW-332-75 (<5.10 µg/L), MW-332-110 (16.1 µg/L), MW-332-150 (209 µg/L), MW-346-15 (5.15J µg/L), MW-346-65 (29.4 µg/L), and MW-346-150 (<5.20 µg/L). These results are shown on Figure 4-14 and in Table 4-3.

During the third quarter 2015 sampling event (May 28 through September 18, 2015), 121 private wells screened in the suprapermafrost aquifer were sampled. Suprapermafrost wells sampled during the third quarter 2015 sampling event included POE treatment system maintenance (raw water) samples and 2015 buffer zone and resampling program. Sulfolane was below the detection limit in 78 samples; sulfolane detections in the remaining suprapermafrost samples ranged from 3.30J* µg/L (PW-977) to 167 µg/L (PW-1374). These results are shown on Figure 4-10.

Twenty-two private wells screened in the suprapermafrost aquifer were sampled during the fourth quarter 2015 sampling event (September 19 through November 14, 2015), which consisted of POE system maintenance samples. Sulfolane detections in the POE samples collected from wells screened in the suprapermafrost aquifer ranged from 6.80J µg/L (PW- 1106) to 122 µg/L (PW-598). Sulfolane was not detected in PW-364. These results are shown on Figure 4-14.

4.2.3.2 Offsite Sulfolane Distribution in the Subpermafrost Aquifer

Thirty-eight subpermafrost locations were sampled during the third quarter 2015 sampling event. Subpermafrost wells sampled during the third quarter included wells from the buffer zone and resampling program, deep private well monitoring network, and POE system sampling. Sulfolane was not detected at 16 subpermafrost locations during the third quarter 2015 sampling event. Sulfolane detections in the remaining 22 private wells ranged from 6.28J µg/L (PW-283) to 813 µg/L (PW-1230).

Eighteen subpermafrost locations were sampled during the fourth quarter 2015 sampling event. Subpermafrost wells sampled during the fourth quarter included wells from the deep private well monitoring network and POE system sampling. Sulfolane detections ranged from 10.1J µg/L (PW-296) to 799 µg/L (PW-1230). Sulfolane was not detected at PW-972 and PW-1343 during the fourth quarter 2015 sampling event.

Figures 4-11 and 4-15 present sulfolane data for the previous 12 months (September 18, 2014 through September 18, 2015 for third quarter and November 14, 2014 through November 14, 2015 for fourth quarter), based on the samples collected from private wells installed through the permafrost in the deep aquifer system.

The highest sulfolane concentration in private wells located within the subpermafrost aquifer to date was detected in PW-1230 (813 µg/L on August 12, 2015), which is located approximately 1 mile northwest of the north property boundary. Private well PW-1230 has a total depth of approximately 231 feet bgs and is not used as a drinking water source.

4.3 Statistical Analysis of Offsite Sulfolane Data

The Mann-Kendall trend analysis is a nonparametric statistical method used to determine trends for concentrations of a given constituent at a given monitoring well. The protocol described in the Monitoring and Remediation Optimization System (MAROS) is used to complete the Mann-Kendall trend analysis for sulfolane in select groundwater monitoring wells using data collected through third quarter 2015. Mann-Kendall trend analysis will be completed for the next reporting period using data collected through the first quarter 2016 sampling event.

MAROS is a decision support tool developed by the Air Force Center for Engineering and the Environment in order to use statistical methods based on site-specific data. The use of MAROS for Mann-Kendall trend analysis was applied to offsite groundwater monitoring data collected since 2009 from monitoring wells and private wells.

Statistical and graphical evaluations of sulfolane concentration trends at monitoring and private wells are used to evaluate plume migration and attenuation, and to identify relationships between dissolved-phase concentrations, groundwater elevations, and flow directions.

The analysis trends are expressed as probably increasing, increasing, probably decreasing, decreasing, stable, or no trend. Results of the Mann-Kendall trend analysis for the reporting period are presented in Tables 1 through 2 and Figures 1A through 1D of Appendix H, and are summarized in the table below.

Third Quarter 2015			
Parameter/Trend	**Monitoring Wells**	**Suprapermafrost Private Wells**	**Subpermafrost Private Wells**
No. of Wells	156	326	70
All Results Nondetect [a]	71	190	32
Insufficient Data Points [a]	1	61	6
Probably Decreasing	3	1	0
Decreasing	45	11	3
Probably Increasing	1	3	0
Increasing	16	33	21
Stable	14	13	1
No Trend	5	14	7

Trends associated with private wells with unknown depth information are included in Appendix H, Table 2.

[a] Wells with insufficient data points for the statistical analysis (less than four points) but with all results below detection limits are listed under “”All Results Nondetect.”

Using data from 2009 through the third quarter 2015, sulfolane concentrations in groundwater from 17 monitoring wells and 57 suprapermafrost and subpermafrost private wells were found to have increasing or probably increasing trends. Sulfolane concentrations in groundwater from 48 monitoring wells and 15 suprapermafrost and subpermafrost private wells were found to have decreasing or probably decreasing trends. Wells with increasing and decreasing trends that were screened within the suprapermafrost and the subpermafrost aquifers are discussed below.

4.3.1 Suprapermafrost Aquifer

Offsite monitoring wells in the suprapermafrost aquifer that displayed increasing trends include MW-161A-15, MW-166A-15/B-30, MW-167A-15/B-35, MW-168A-15/B-50, MW-182B-45, MW-185C-120, MW-187-15, MW-194B-40, MW-308-15, MW-316-15, MW-332-150, MW-346-65, MW-347-150, and MW-352-40.

Monitoring wells MW-332-150 and MW-346-65 are located within the inferred mixing zone; therefore, these wells may be influenced by subpermafrost concentrations. Sulfolane was detected in 100 percent of the monitoring events for these wells, at concentrations ranging from 23.4 µg/L (June 2012) to 239 µg/L (October 2014) and from 22.7 µg/L (September 2013) to 28.3 µg/L (July 2015) at MW-332-150 and MW-346-65, respectively. A review of the trend plots for these locations, provided in Attachment 1 of Appendix H, shows stable trends for both wells since 2013.

With the exception of MW-187-15 and MW-316-15, the remaining monitoring wells with increasing and probably increasing trends are located within the detectable sulfolane plume near the center or leading edges of the plume. MW-187-15 is located near the western edge of the plume and has had estimated concentrations ranging from 3.41J (April 2012) to 7.07J (July 2013). MW-316-15 is located near the southeastern edge of the plume and has had estimated sulfolane concentrations ranging from 3.36J* µg/L (May 2012) to 4.47J µg/L (July 2012). Concentrations have been stable or decreased to below the detection limit during the reporting period at these locations.

The maximum sulfolane concentrations within the MAROS datasets for offsite monitoring wells exhibiting increasing trends range from 4.47J µg/L (MW-316-15 in July 2012) to 239 µg/L (MW-332-150 in October 2014). A visual observation of the concentration trend plots (Attachment 1 of Appendix H) show that concentrations at most locations with increasing Mann-Kendall trends are either stable or decreasing. The exceptions include MW-166B-30, MW-167B-35, and MW-168A-15/B-50, which are located near the distal end of the plume. Concentrations at these locations have remained below 100 µg/L since sampling began at these locations.

Thirty-six private wells screened within the suprapermafrost layer displayed increasing or probably increasing trends. These wells are located near the center and along the leading edges of the offsite suprapermafrost sulfolane plume, with the exception of three private wells (PW-620, PW-624, and PW-1374), which are located near the western edge of the sulfolane plume. In the MAROS datasets, maximum sulfolane detections in the private wells located in the suprapermafrost aquifer and exhibiting increasing trends ranged from 7.5J µg/L (at PW-1110 in August 2015) to 167 µg/L (at PW-1374 in August 2015).

Forty-eight monitoring wells displayed decreasing or probably decreasing trends. The maximum sulfolane concentrations within the MAROS datasets for offsite monitoring wells exhibiting decreasing trends range from 3.91J µg/L (MW-193B-60 in October 2011) to 319 µg/L (MW-161B-50 in February 2012). A visual observation of the concentration trend plots show that sulfolane concentrations in these wells are continuing to decrease. The monitoring well locations with decreasing or probably decreasing trends are located throughout the plume with the highest concentration of wells in the central and southern portions of the detectable sulfolane plume.

Twelve private wells displayed decreasing or probably decreasing trends. The maximum sulfolane concentrations within the MAROS datasets for private wells exhibiting decreasing trends range from 10.6 µg/L (PW-1106 in February 2010) to 303 µg/L (PW-161 in January 2010). A visual observation of the concentration trend plots show that sulfolane concentrations in these wells are continuing to decrease. Private well locations with decreasing or probably decreasing trends are concentrated throughout the detectable sulfolane plume, with the highest concentration of wells in the central portion of the plume.

4.3.2 Subpermafrost Aquifer

Sulfolane concentrations in subpermafrost groundwater from 21 private wells screened in the subpermafrost aquifer were found to have increasing trends. These wells include eight wells from the deep private well monitoring network (PW-0463, PW-0464, PW-0466, PW-0658, PW-0932, PW-0943, PW-1155, and PW-1230). As shown on Figure 1D of Appendix H, the locations with increasing or probably increasing trends are primarily located along the leading edge of the offsite sulfolane plume with the exception of PW-1155 and PW-1230, which are located in the central portion and the southernmost extent of the detectable subpermafrost plume, respectively. The available subpermafrost data represent the extended and distal areas of the overall plume, where there are increasing trends both above and below the permafrost.

The maximum sulfolane detections in the MAROS datasets for wells screened in the subpermafrost aquifer and having increasing sulfolane trends ranged from 15.2 µg/L (at PW-1118 in July 2015) to 813 µg/L (at PW-1230 in August 2015). Sulfolane results for well PW-1230 ranged from 517 µg/L (March 2013) to 813 µg/L (August 2015). Attachment 2 of Appendix H indicates an upward concentration trend based on data collected since March 2013.

The sulfolane detected at PW-1230 is believed to have reached the subpermafrost through a talik (Arcadis 2013a). Vertical head differences across the permafrost at the location of PW-1230 have varied from upward to downward (Appendix F); therefore, migration of sulfolane through the talik is expected to be slow and the date of release of the sulfolane detected at PW-1230 cannot necessarily be inferred based on the distance from the site.

Decreasing or probably decreasing trends were observed in three subpermafrost private wells (PW-217, PW-358 and PW-1099). The highest sulfolane concentrations seen at these locations are 217 JL* µg/L in April 2011 (PW-217), 97.9 µg/L in March 2010 (PW-358) and 113 µg/L in December 2013 (PW-1099). The concentration trend plots show that sulfolane concentrations in these wells continue to decrease.

4.4 Geochemical Parameters

Geochemical sampling in the offsite monitoring wells was not conducted in 2015, other than MW-349-15 and MW-349-45 that were sampled in third quarter 2015 along with the deep private well network. Results for geochemical parameter monitoring at these two monitoring wells and deep private wells are consistent with historical results. Further geochemical sampling in the monitoring wells is not proposed at this time. In addition, no further geochemical sampling in the deep private well monitoring network is proposed at this time. These networks will be evaluated with the other offsite monitoring networks and changes will be incorporated in an updated Offsite RSAP (Arcadis 2015).

A summary of the historical geochemical sampling results for monitoring wells and private wells is included as Appendix B.

5 CONCLUSIONS

Quarterly groundwater monitoring events were conducted in the third and fourth quarters of 2015. The events were conducted in general accordance with the Offsite RSAP (Arcadis 2015). The average magnitude of the horizontal hydraulic gradient in offsite groundwater was calculated at approximately 0.001 ft/ft during the reporting period. This result is consistent with historical data.

Based on the consistency of the monitoring data collected throughout the reporting period, the expected plume behaviour is consistent with previous site characterizations. Sulfolane trends in 45 monitoring wells and 14 private wells (including 11 suprapermafrost and three subpermafrost wells) show decreasing concentrations, while 16 monitoring wells and 54 private wells (including 33 suprapermafrost and 21 subpermafrost wells) indicate increasing concentrations. Most of the wells with decreasing trends are located near the site boundary and center of the plume, while wells showing increasing trends are concentrated along the leading edge and distal portions of the plume.

The results from the first and second quarter 2016 monitoring activities will be submitted in a semiannual report in July 2016.

6 REFERENCES

Arcadis. 2012. North Pole Refinery – Deep Private Well Monitoring Plan. June 20.

Arcadis. 2013a. Offsite Site Characterization Report – 2013 Addendum. December 20.

Arcadis. 2013b. Revised 2013 Offsite Site Characterization Work Plan. July 19.

Arcadis. 2015. Fourth Quarter 2014 Groundwater Monitoring Report. January 31.

Barr. 2011. Site Characterization and First Quarter 2011 Groundwater Monitoring Report. May.

Barr. 2014. Alternative Water Solutions Program – Management Plan. October.

Barr. 2015. Alternative Water Solutions Program – 2014 Annual Report. February 25.

SWI. 2013. Standard Operating Procedure for Groundwater-Elevation Monitoring.