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Flint Hills Resources Alaska, LLC

Offsite Site Characterization Report – 2013 Addendum

North Pole Refinery
North Pole, Alaska

December 20, 2013

ARCADIS

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Acronyms and Abbreviations

3-D	three-dimensional
3Q13 GWMR	Third Quarter 2013 Groundwater Monitoring Report
AAC	Alaska Administrative Code
ACL	alternative cleanup level
ADEC	Alaska Department of Environmental Conservation
AEM	airborne electromagnetic
ALS	ALS Environmental
ARCADIS	ARCADIS U.S., Inc.
AS	air sparging
ASTM	ASTM International
AWS	alternative water supply
AWS Management Plan	Final Alternative Water Solutions Program – Management Plan
Barr	Barr Engineering Company
bgs	below ground surface
CCV	continuing calibration verification
cfs	cubic feet per second
city	North Pole, Alaska
cm/s	centimeters per second
COC	constituent of concern
CSM	conceptual site model
Cu	uniformity coefficient
CU #1 Wash Area	Crude Unit #1 Wash Area
CU #2 EU	Crude Unit #2 Extraction Unit

D_{10}	10 percent of the sample is finer than this size
D_{20}	20 percent of the sample is finer than this size
D_{50}	50 percent of the sample is finer than this size
D_{60}	60 percent of the sample is finer than this size
DO	dissolved oxygen
Draft Offsite FS	Draft Offsite Feasibility Study
Ecological CSM	Ecological Conceptual Site Model
ERI	electrical resistivity imaging
FDEM	frequency domain electromagnetic induction
FHRA	Flint Hills Resources Alaska, LLC
ft/day	feet per day
GAC	granular activated carbon
Geomega	Geomega, Inc.
gpm	gallons per minute
GSA	grain size analysis
GVEA	Golden Valley Electric Association
IRAP	Interim Remedial Action Plan
km	kilometers
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LNAPL	light nonaqueous phase liquid
LOD	limit of detection
LOQ	limit of quantitation
mg/L	milligrams per liter
mm	millimeters

monitoring plan	Deep Private Well Groundwater Monitoring Plan
MS	matrix spike
MSL	mean sea level
MSD	matrix spike duplicate
mV	millivolts
NGP	North Gravel Pit
NPB	northern property boundary
NPR	North Pole Refinery
offsite	area located outside the property boundary, primarily in the downgradient north-northwest direction
Offsite Addendum	Offsite Site Characterization Report – 2013 Addendum
Offsite SCWP	Revised 2013 Offsite Site Characterization Work Plan
onsite	area that is located within the property boundary of the FHRA NPR
Onsite Addendum	Onsite Site Characterization Report – 2013 Addendum
ORP	oxidation-reduction potential
POE	point of entry
power plant	electrical generating facility
PPRTV	provisional peer-reviewed toxicity value
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
redox	oxidation-reduction
Revised Draft Final HHRA	Revised Draft Final Human Health Risk Assessment
Revised IRAP Addendum	Revised Interim Remedial Action Plan Addendum
RPD	relative percent difference

RSAP	Revised Sampling and Analysis Plan
SCR – 2011	Site Characterization Report – Through 2011
SCR – 2012	Site Characterization Report – 2012 Addendum
site	FHRA North Pole Refinery, an active petroleum refinery located on H and H Lane in North Pole, Alaska
SPB	south property boundary
SWA	Southwest Former Wash Area
SWI	Shannon & Wilson, Inc.
TOC	total organic carbon
TTA-1	Tracer Test Area 1
TTA-2	Tracer Test Area 2
UAF	University of Alaska – Fairbanks
USBR	U.S. Bureau of Reclamation
USEPA	United States Environmental Protection Agency
USGS	U.S. Geological Survey
VPT	vertical profile transect
WO	work order
WWTP	wastewater treatment plant
µg/L	micrograms per liter
µS/cm	microSiemens per centimeter
°C	degrees Celsius
°F	degrees Fahrenheit

Executive Summary

This Offsite Site Characterization Report – 2013 Addendum (Offsite Addendum) for the Flint Hills Resources Alaska, LLC (FHRA) North Pole Refinery (NPR) presents site characterization data collected in 2013 and the results of technical analyses based on these data. The technical analyses and discussions in this Offsite Addendum are informed by the full data set collected over the total site history and historical findings.

This Offsite Addendum is the last of a series of site characterization reports that collectively present a large body of information that has been gathered to ascertain the physical characteristics of the site, define the primary sources of contamination, and determine the nature and extent of contamination present at the site. The companion reports are:

- Site Characterization Report – Through 2011 (SCR – 2011; Barr Engineering Company [Barr] 2012)
- Site Characterization Report – 2012 Addendum (SCR – 2012; ARCADIS U.S., Inc. [ARCADIS] 2013b)
- Onsite Site Characterization Report – 2013 Addendum (Onsite Addendum; 2013h)

This document and the companion reports, in conjunction with the Revised Draft Final Human Health Risk Assessment (ARCADIS 2012a) are sufficient to support a risk-based evaluation of appropriate remedial alternatives for the site.

This Offsite Addendum outlines results from field activities conducted in 2013, including the technical background and rationale for each activity proposed in the Revised 2013 Offsite Site Characterization Work Plan (Offsite SCWP; ARCADIS 2013d) and additional work agreed to in electronic communication with Alaska Department of Environmental Conservation. It also presents additional interpretations and conclusions based on ongoing private and monitoring well sampling and a review of the full data set for the site. Field activities completed in 2013 were also partially discussed and documented during periodic technical meetings with ADEC. This Offsite Addendum documents the following key characterization initiatives that were completed during 2013, along with related site characterization activities approved in the Offsite SCWP:

- Installation of additional Phase 8 monitoring wells and well nests for further characterization and delineation.

- Collection of routine sulfolane groundwater analytical data from monitoring wells

- Collection of groundwater samples for sulfolane and geochemical parameter analysis from deep private and shallow garden wells in the deep private monitoring program.

- Additional investigation at one deep private well, including down-hole camera examinations, pressure transducer deployment, and installation of two adjacent shallow wells for data collection.

- Collection of soil samples for soil classification and total organic carbon analysis.

- Airborne electromagnetic and ground-based geophysical permafrost imaging.

- Annual sampling of the buffer zone and the addition of private well Search Area 10 on the eastern side of the sulfolane plume.

The scope of the geochemical parameter monitoring program was also revised in 2013; those results will be reported in quarterly groundwater monitoring reports.

The culmination of site characterization activities and evaluations resulted in the following summarized conclusions:

- Groundwater flow and transport at the site is dynamic and extremely complex due to a combination of factors including heterogeneously distributed soil types, discontinuous permafrost, seasonal fluctuations in surface water elevations at the Tanana and Chena rivers, and annual freeze-thaw cycles that extend well below ground.

- Permafrost is generally continuous offsite and at least two probable locations of taliks were identified through the 2013 geophysical investigations and other site data. FHRA concludes that the taliks are primarily responsible for sulfolane flux to the subpermafrost aquifer. Sulfolane transport in the subpermafrost is also affected by bifurcation around permafrost and the possible existence of other taliks.

- Sulfolane releases began in 1985 (Geomega, Inc. [Geomega] 2013a).

- Sulfolane concentration trends in monitoring and private wells in the offsite area near the NPR are decreasing.

- Sulfolane concentration trends are increasing in the northern and western distal ends of the plume.

- Seasonal trends in sulfolane concentrations are observable in a relatively small subset of monitoring wells and are consistent with the decreasing trends near to the NPR.

- There is one currently confirmed private well (PW-1230) that exceeds the 362 micrograms per liter alternative cleanup level. There are also two other potential private wells/locations (PW-0228 and PW-1098) that may potentially exceed the ACL based on historical data, but these wells are either not accessible or abandoned.

- The sulfolane plume is delineated horizontally in the offsite area and potential receptors are protected through the alternative water solutions (AWS) program (Final Alternative Water Solutions Program – Management Plan (AWS Management Plan; Barr 2013c). The adaptive management of the buffer zone allows for ongoing delineation through the use of private wells.

- The AWS programs, which include protection and monitoring of buffer zone sampling, ensure that people will not be exposed to sulfolane-impacted groundwater.

A conceptual site model (CSM) was prepared for the site that summarizes how chemicals were historically released to the environment at the NPR, how the released chemicals move through the environment, how those chemicals affect people and other living things, and ongoing efforts to protect people from being exposed to those chemicals. The CSM is based on extensive environmental assessment activities that have been conducted at the NPR over the past 26 years, with the majority of activities occurring since 2009. The assessment included a thorough review of historical chemical use at the NPR, collection of water and soil samples from the surface and subsurface, monitoring groundwater data through time, hydrologic studies of groundwater gradients and movement, geophysical studies of permafrost in the area, and computer predictions of the movement of contamination in the subsurface. The CSM will support development of the final cleanup plan for the site. The extensive soil and groundwater data collected to date and the CSM will support a risk-based evaluation of appropriate remedial alternatives for the site. The CSM is attached as Appendix 1-A.

1. Introduction

On behalf of Flint Hills Resources Alaska, LLC (FHRA), ARCADIS U.S., Inc. (ARCADIS) prepared this Offsite Site Characterization Report – 2013 Addendum (Offsite Addendum) for the FHRA North Pole Refinery (NPR), an active petroleum refinery located on H and H Lane in North Pole, Alaska (site). The data, analyses, and conclusions in this report are the product of a collaborative effort among FHRA's consulting team members. That team includes qualified professionals in a variety of disciplines from four environmental consulting firms; ARCADIS, Shannon & Wilson, Inc. (SWI), Barr Engineering Company (Barr), and Geomega, Inc. (Geomega). FHRA has engaged these consulting firms to perform various tasks on the project. This report, therefore, encompasses contributions from professionals from each firm in the text and figures presented.

The North Pole Refinery (NPR) was built in 1976 and 77 by Earth Resources Corporation of Alaska and refinery operations began in August 1977. Earth Resources leased the refinery property from the State of Alaska, which owned the refinery land. MAPCO, Inc. acquired Earth Resources Corporation in 1980, and continued operations under a newly formed company, MAPCO Alaska Petroleum, Inc. In 1998, Williams Alaska Petroleum, Inc. acquired MAPCO through a stock purchase, thereby succeeding to MAPCO's operations. Williams and its predecessor MAPCO operated the NPR on State-owned land for almost 25 years, up until 2004. Flint Hills Resources Alaska, LLC (FHRA) purchased the refinery assets from Williams effective April 1, 2004, along with the refinery land, which Williams had acquired from the State of Alaska shortly before the transaction with FHRA. FHRA has owned and operated the refinery since then.

This Offsite Addendum is the last of a series of site characterization reports that collectively present a large body of information that has been gathered to ascertain the physical characteristics of the site, define the sources of contamination, and determine the nature and extent of contamination present at the site. The companion reports are:

- Site Characterization Report – Through 2011 (SCR – 2011; Barr 2012), submitted in December 2012
- Site Characterization Report – 2012 Addendum (SCR – 2012; ARCADIS 2013b), submitted in January 2013
- Onsite Site Characterization Report – 2013 Addendum (Onsite Addendum; 2013h)

The information collected to date and presented in the SCR – 2011 (Barr 2012) and the SCR – 2012 (ARCADIS 2013b) in conjunction with the Revised Draft Final Human Health Risk Assessment (Revised Draft Final HHRA; ARCADIS 2012a) are sufficient to support risk-based evaluation of appropriate remedial alternatives for the site.

Offsite site characterization activities were initiated in 2009 and have been ongoing since that time. The offsite site characterization activities discussed in this Offsite Addendum were proposed in the Revised 2013 Offsite Site Characterization Work Plan (Offsite SCWP; ARCADIS 2013f). The additional field activities were proposed to further refine the Conceptual Site Model (CSM; Appendix 1-A) and were developed based on recommendations presented in previous site characterization reports prepared by FHRA that summarized work completed in the offsite area. In addition, the scope of work includes investigation activities completed at the request of the Alaska Department of Environmental Conservation (ADEC) and provided to FHRA in comments to the work plan (ARCADIS 2013f) and in general communications between the ADEC and FHRA. Throughout the 2013 site investigation activities, FHRA maintained an adaptive management strategy to ensure that site characterization was completed to the necessary extent to support feasibility study development.

It is acknowledged that in 18 Alaska Administrative Code (AAC) 75.990(115), ADEC defines the term “site” as an “area that is impacted, including areas impacted by the migration of hazardous substances from a source area, regardless of property ownership.” For this Offsite Addendum, the term “onsite” is the area that is located within the property boundary of the FHRA NPR, and the term “offsite” is the area located outside the property boundary, primarily in the downgradient north-northwest direction, based on the approximate extent of the dissolved-phase sulfolane plume detected at concentrations above the laboratory detection limit (approximately 3.1 micrograms per liter [µg/L]).

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

FHRA developed a hydrogeologic conceptual site model that describes the distribution of the conductive saturated aquifer, the distribution of permafrost and its influence on groundwater flow, and the sources and sinks of groundwater. Geophysical data were correlated with the monitoring well logs, available private well boring logs and land use information from historical aerial photographs to produce a three-dimensional permafrost model from which generalized cross sections and a depth to the top of permafrost contour map were constructed. The cross sections are presented in Section 4 and the offsite hydrogeology in Section 5. The hydrogeologic conceptual site model is a component of the CSM presented in Appendix 1-A

FHRA submitted an Ecological Conceptual Site Model (Ecological CSM; ARCADIS 2011a) to ADEC in June 2011,. The purpose of the Ecological CSM (ARCADIS 2011a) was to establish whether environmental contaminants related to site operations that are present onsite, or that have migrated offsite, will come in contact with ecological receptors. The Ecological CSM

(ARCADIS 2011a) did not identify complete exposure pathways for ecological receptors and concluded that no further evaluation is warranted.

ARCADIS, Barr, Geomega, SWI, and other technical specialists completed or directed the field activities summarized below during 2013. Field activities were completed by qualified persons as defined by 18 AAC 75.990.

1.1 Purpose

This Offsite Addendum outlines results from field activities conducted in 2013, including the technical background and rationale for each activity proposed in the Offsite SCWP (ARCADIS 2013d) and additional work agreed to in electronic communication with ADEC. It also presents additional interpretations and conclusions based on ongoing private and monitoring well sampling and a review of the full data set for the site. Field activities that were completed in 2013 were also partially discussed and documented during periodic Technical meetings with ADEC. This Offsite Addendum documents the following key characterization initiatives that were completed during 2013, along with related site characterization activities approved in the 2013 SCWP:

- Installation of additional Phase 8 monitoring wells and well nests for further characterization and delineation.
- Collection of groundwater samples from deep private wells and shallow garden wells in the deep private monitoring program for sulfolane and geochemical parameter analysis.
- Additional investigation at one deep private well, including down-hole camera examinations, pressure transducer deployment, and installation of two adjacent shallow wells for data collection.
- Collection of soil samples for soil classification and total organic carbon (TOC) analysis.
- Airborne electromagnetic (AEM) and ground-based electromagnetic permafrost imaging.

The scope of the geochemical parameter monitoring program was also revised in 2013; those results will be reported in quarterly groundwater monitoring reports.

Additional data collected during the 2013 offsite activities were used to validate and refine the CSM presented in Appendix A.

1.2 Proposed Cleanup Levels

In correspondence dated July 19, 2012, the ADEC indicated that FHRA should use an alternative cleanup level (ACL) of 14 µg/L for dissolved-phase sulfolane at the site in the development of remedial action objectives and in evaluation of remedial alternatives. This ACL was based on a provisional peer-reviewed toxicity value (PPRTV) for sulfolane that was derived by the United States Environmental Protection Agency (USEPA) in January 2012, and on exposure assumptions developed by ADEC. In the May 2012 Revised Draft Final HHRA (ARCADIS 2012a), the PPRTV used with the ADEC-selected exposure parameters was called the PPRTV Scenario. The Revised Draft Final HHRA (ARCADIS 2012a) also presented the ARCADIS Scenario, using scientifically supported toxicity value and exposure parameters selected by ARCADIS after data and literature review. The toxicity value and many of the exposure parameters differed between scenarios. Using the ARCADIS Scenario, there were no current or future offsite receptors identified through the risk assessment who exceed the acceptable hazard index or excess lifetime cancer risk, and the resulting sulfolane ACL is 362 µg/L.

FHRA concludes that an ACL of 362 µg/L is the most appropriate and data-supported ACL for the site. Accordingly, sulfolane concentrations in groundwater in the onsite and offsite areas are compared to an ACL of 362 µg/L in this Offsite Addendum, and screening of remedies in the feasibility studies also will be based on this ACL.

2. Site Setting

2.1 Property Description

The 240-acre 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). 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. The site location is shown on Figure 2-1.

Three crude oil processing units are located in the southern portion of the site, making up the process area. Only one of the processing units is currently operating. Tank farms are located in the central portion of the site. Truck-loading racks are located immediately north of the tank farms and a railcar-loading rack is located west of the tank farms. Wastewater treatment lagoons, storage areas, and two flooded gravel pits (the North and South Gravel pits) are located in the western portion of the site. Rail lines and access roads are located in the northernmost portion of the site.

Along the southern site boundary, partially surrounded by the NPR, is an electrical generating facility (power plant) operated by Golden Valley Electric Association (GVEA). FHRA representatives indicated that the power plant burns heavy aromatic gas oil (diesel 4) or 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. Site features are presented on Figure 2-2.

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 residential properties. An undeveloped parcel, owned by the Alaska Department of Natural Resources, lies between the site and the WWTP. The Tanana River is located to the south and west, flowing in a northwesterly direction toward Fairbanks. Surrounding the site is property that is residential or undeveloped. East of the site and crossing the offsite area to the west are the Old Richardson Highway and the Alaska Railroad right-of-way. Current site features are presented on Figure 2-2. Onsite and offsite site plans are presented on Figures 2-3 and 2-4, respectively.

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 River. The site is located on the Tanana River Floodplain. Up to 2 feet of organic soil is typically found in the undeveloped portions of the site. Silt and silty sand layers varying in thickness from 0 to 10 feet typically occur beneath the organic soil. 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 unit, impeding and redirecting the flow direction of groundwater (Glass et al. 1996). Based on regional information (Williams 1970, Miller et al. 1999), permafrost is assumed to be absent beneath the Tanana River.

The aquifer beneath the alluvial plain between the Tanana River and Chena River generally consists of highly transmissive sands and gravels 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 thick near Moose Creek Dam) (Glass et al. 1996). Beyond the zones of influence of the site groundwater recovery system, groundwater flow directions are controlled by discharge from the Tanana River to the aquifer and from the aquifer to the Chena River, as described by Glass et al. (1996). Variations in river stage through time are believed to be the primary cause of variations in flow direction through the aquifer between the rivers (Lilly et al. 1996, Nakanishi and Lilly 1998). Based on data from U.S. Geological Survey water table wells, the flow direction 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 Offsite Constituent of Concern – Sulfolane

Sulfolane is the only offsite constituent of concern (COC). Sulfolane use began at the NPR in 1985. Sulfolane is used to extract high-purity aromatics from hydrocarbon mixtures. Sulfolane in onsite groundwater was first reported to ADEC in 2001. Sulfolane was first detected offsite in a groundwater sample collected from a downgradient monitoring well in October 2009 (Barr 2012). Sulfolane is only present in groundwater offsite.

Sources of sulfolane to the environment are discussed in the History of Sulfolane Releases to the Environment (Geomega 2013a), which was attached as Appendix A to the SCR – 2012 (ARCADIS 2013a). Historical records indicate that there are six primary source locations of sulfolane to groundwater at the NPR. The largest sources have been identified as Lagoon B and the Crude Unit #2 Extraction Unit (CU #2 EU) Area. Other sources include the Southwest Former Wash Area (SWA), South Gravel Pit (SGP), Sump 908, and the Crude Unit #1 Wash Area (CU #1 Wash Area)The data are summarized in the Onsite Site Characterization Report – 2013 Addendum (Onsite Addendum; ARCADIS 2013h). FHRA's current understanding of the offsite nature and extent of sulfolane impacts is discussed in the following sections.

3. Offsite Geology

During 2013, 45 borings were advanced at 21 locations offsite for installation of monitoring wells. This section summarizes the information collected from these borings. In addition, observations and data collected during 2013 were combined with historical information to provide an update and summary of geological conditions at the site.

3.1 Offsite Phase 8 Groundwater Monitoring Well Installation

Offsite Phase 8 wells were installed in 2013 to provide additional characterization of the nature and extent of sulfolane impacts in offsite groundwater as proposed in the Offsite SCWP (ARCADIS 2013d). Offsite Phase 8 monitoring well locations are shown on Figure 3-1 and well construction details are summarized in Table 3-1. Upon installation, monitoring well names were modified from the temporary well name proposed in the Offsite SCWP (ARCADIS 2013d) to permanent well names, as presented in Table 3-1.

Proposed monitoring well locations 8-U and 8-P were not installed due to access restrictions and shallow permafrost, respectively. These locations are also shown on Figure 3-1.

3.1.1 Phase 8 Monitoring Well Construction Methodology

Offsite Phase 8 well construction was completed according to the Revised Sampling and Analysis Plan (RSAP; ARCADIS 2013b) consistent with historical well construction methods. Offsite monitoring wells were generally designed, constructed, and installed in accordance with ADEC’s Monitoring Well Guidance (ADEC 2013a). Monitoring wells were constructed of 2-inch-diameter Schedule 40 polyvinyl chloride (PVC) blank casing from the ground surface to the screened interval.

Monitoring wells screened across the water table were screened from approximately 5 to 15 feet bgs, while wells with submerged well screens were installed with 5-foot well screens placed at the desired depth. Screens were constructed of Schedule 40 PVC 0.01-inch slotted casing. Well construction information for wells at the site is summarized in Table 3-1.

3.1.2 Soil Classification

Soil classification was completed in the offsite area according to the Unified Soil Classification System as summarized in the RSAP. The soil conditions encountered offsite are generally consistent with historical soil classification data at the site, as documented in the SCR – 2011 (Barr 2012) and the SCR – 2012 (ARCADIS 2013b). Soil encountered was consistent with previous observations in that the regional geology consists of alluvial deposits and is highly heterogeneous. Groundwater was observed at approximately 7 to 13 feet bgs in the offsite Phase 8 monitoring wells. Boring logs summarizing the soil types observed during drilling are included in Appendix 3-A.

Soil data show that the site is underlain by a heterogeneous sequence of unconsolidated alluvial deposits. Interbedded discontinuous layers of silt, fine sandy silt, silty fine sand, and poorly graded gravel predominate the upper 10 to 20 feet of the unconsolidated sequence, although layers of silt and sand are still observed in many boring logs at depths greater than 20 feet.

Soil from ground surface to between 1 and 6 feet bgs consisted of sand, gravel, and silt with no apparent bedding. These earth materials are primarily fill material, consistent with development in these areas. The surface fill material was not encountered at well clusters MW-339 and MW-353.

Underlying the surface fill material at most locations was a 1- to 5-foot-thick layer of very fine-grained, low-plasticity silt. This material is considered native, and may represent a low-energy depositional environment such as a floodplain, overbank or slack water. Fine-grained material was not encountered at well clusters MW-338 and MW-340.

Distinct peat layers were not observed in offsite Phase 8 monitoring wells; however, trace organic materials were observed at variable depths and thicknesses between approximately 2 and 7 feet bgs at the following well clusters: MW-160, MW-341, MW-342, MW-350, and MW-352. These well locations trend northwest/southeast and may indicate the deposition from a historical floodplain or slack water.

Beneath the trace organic material and silt layers at many locations, a 3- to 9-foot-thick silty sand layer was observed. This layer consisted of alternating bedding planes of silt and sand. Sand was the predominant constituent (approximately 70 percent sand and 30 percent silt). Silty sand was not observed in well clusters MW-332, MW-338, MW-340, MW-343, and MW-353.

At some locations, ice crystals were observed in shallow soil (less than approximately 10 feet bgs). Due to the shallow interval of these observations, they are likely to be associated with seasonal freezing. Offsite well clusters with shallow frozen soil include MW-160, MW-190, MW-332, MW-339, MW-340, MW-341, MW-342, and MW-346.

Soil below the surficial silt/sand deposits (approximately 20 feet bgs) are interbedded coarse-grained layers of gravel, sandy gravel, sand with gravel, and occasional layers of silt. The gravel is fine to coarse and the sand is commonly fine- to medium-grained with a relatively low fraction of coarse sand. Gravel deposit pore spaces are filled with finer grained soil such as sand and clay-sized particles. Grain size analysis (GSA) data collected in 2013 indicate trace amounts of fine material within the gravel matrix. GSA data are discussed in detail in Section 5.

A geophysical survey conducted in 2013 also indicated a soil matrix of predominantly gravel and sand with little to no observable fine-grained soil from approximately 40 to 150 feet bgs.

Denser zones within the coarse-grained alluvial deposits have been encountered at depths of approximately 130 to 150 feet bgs (Barr 2012). Data collected during offsite drilling activities in 2013 confirmed these data; however, denser material, based on blow counts, was observed as shallow as approximately 40 feet bgs. Select offsite Phase 8 monitoring well logs (MW-190-150, MW-332-110, MW-340-150, MW-346-150, MW-347-150 [Figure 3-1]) indicate discontinuous interbedded layers of denser material generally present 40 to 70 feet bgs, gradually decreasing in density and increasing in density again from 100 to 130 feet bgs. These discontinuous denser layers are consistent with the alluvial depositional environment of braided streams. The boring logs are presented in Appendix 3-A.

Monitoring well logs from select wells (MW-185C-150, MW-328-151, MW-353-100, MW-356-90, and MW-357-150) indicate that the denser zones occur within the alluvial deposits closer to 110 to 130 feet bgs, as previously reported in SCR – 2011 (Barr 2012). The observed variability in the vertical interval where these dense materials occur is reasonably attributable to the alluvial environment when each layer was deposited.

3.1.3 Permafrost Delineation

Permafrost was encountered in six of the 19 offsite Phase 8 monitoring well nest locations. The permafrost conditions that were encountered were generally consistent with historical permafrost delineation at the site (Barr 2012, ARCADIS 2013a), which identified the top of permafrost at depths ranging from near the ground surface to 151.5 feet bgs. Permafrost generally becomes shallower as it extends offsite to the north and northwest. Section 4 discusses permafrost delineation offsite during Phase 8 monitoring well installation.

3.1.4 Soil Sampling

Soil sampling during installation of the offsite Phase 8 wells was completed as proposed in the Offsite SCWP (ARCADIS 2013d) and in subsequent discussions with ADEC. Sampling and documentation were completed according to the RSAP. Soil samples were collected for the following analyses:

- TOC by USEPA Method 9060
- GSA by ASTM International (ASTM) D422-63

3.1.4.1 Total Organic Carbon

Soil samples were collected for TOC analysis to improve characterization of TOC spatially across the sulfolane plume, as proposed in the Offsite SCWP (ARCADIS 2013d). TOC soil samples were collected from six borings at four Phase 8 monitoring well nest locations during installation including:

- MW-347-65

- MW-347-150
- MW-350-50
- MW-352-40
- MW-353-65
- MW-353-100

For each of the borings listed above, one sample was collected from the midpoint of the well screen and one sample from the approximate midpoint between the water table and well screen midpoint. Each sample was collected from at or below the water table. Sampling personnel targeted coarser-grained materials such as silty gravels and poorly graded gravels at each location to represent transport flow paths. Soil sampling locations are shown on Figure 3-2 and TOC data are summarized in Table 3-2. Analytical laboratory reports are included in Appendix 3-B.

TOC concentrations ranged from 0.0301 J percent at MW-347-150 (90.7 to 91 feet bgs) to 0.118 percent at MW-353-65 (62 to 63.5 feet bgs), with an average of 0.064 percent. These data are consistent with onsite soil TOC data collected from the same depth range, which ranged from 0.0321 J to 0.278 percent, with an average of 0.0904 percent as reported in the Onsite Addendum (ARCADIS 2013h). The offsite soil TOC results are generally lower than the TOC data collected from the vadose zone as part of the capillary fringe investigation. This is consistent with the coarser-grained material targeted for sampling offsite, compared to the finer-grained intervals sampled for TOC in the SWA.

3.1.4.2 Grain Size Analysis Results

During Phase 8 offsite monitoring well installation, 110 GSA samples were collected and analyzed. Section 5 presents a detailed analysis of GSA data and estimates of hydraulic conductivity from these data.

3.2 Offsite Geology Summary

Offsite geology is described in the SCR – 2011 and borings advanced in 2012 and 2013 are generally consistent with the description provided in the SCR – 2011 (Barr 2012). A total of 45 monitoring wells were installed to monitor groundwater, classify soil, and delineate permafrost.

General offsite soil classifications of the top 150 feet are shown on the permafrost cross sections discussed in Section 4. These cross sections were previously submitted in the SCR – 2011 (Barr 2012) and SCR – 2012 (ARCADIS 2013a) and were updated to include data from site characterization activities completed in 2013.

Lithologic data collected during offsite characterization demonstrate that soils in the region are generally dominated by a thick sequence of alluvial deposits with significant heterogeneity. Shallow soils (within 10 to 20 feet bgs) consist of interbedded discontinuous layers of silt, fine sandy silt, silty fine sand, and gravel, with occasional lenses of organic material. Soils below approximately 20 feet bgs are generally coarse-grained layers of gravel, sandy gravel, sand with gravel, and occasional layers of silt. GSA data collected in 2013 demonstrate that fine-grained soil is present in gravel pore space. Soil TOC levels in offsite coarse-grained soil are low, averaging 0.064 percent. Denser zones within the coarse-grained alluvial deposits were reported between 40 and 150 feet bgs.

4. Offsite Permafrost Delineation

Permafrost is defined as subsurface soil or ground that is frozen (i.e., below 32 degrees Fahrenheit [°F]) for 2 or more consecutive years (Bates and Jackson 1997). Permafrost has been observed in the subsurface near the NPR during the installation of monitoring wells and private wells. Its presence has also been inferred through the interpretation of geophysical data. Alaska has two primary regions of permafrost (Williams 1970):

1. Continuous permafrost zone, where permafrost is present nearly everywhere, and

2. Discontinuous permafrost zone, where permafrost occurs at significant thicknesses locally, but is broken by unfrozen zones.

North Pole is located within an area of Alaska characterized by discontinuous permafrost (Ferrians 1965). However, this description does not take scale into account, as interpretation of permafrost continuity is directly related to the size of the study area. At the scale of the offsite study, bodies of permafrost in certain areas can be considered continuous.

Because permafrost does not transmit groundwater, it exerts strong control on groundwater flow and COC transport patterns by creating localized regions of converging and diverging horizontal and vertical flow around permafrost bodies (Carlson and Barnes 2011). Defining the extent of permafrost was a primary goal of site characterization at the NPR and is an important component of the CSM.

4.1 2013 Permafrost Delineation Methods

Several of the site characterization activities completed during 2013 included work to further define permafrost. These activities included monitoring well installation and geophysical surveys. Hand auger borings were completed onsite, which helped define the permafrost near the FHRA northern property boundary (NPB). Evaluation of hydrographs from the data logging groundwater pressure transducer (data logger) program provided an additional line of evidence of the interaction of the suprapermafrost and subpermafrost aquifers near a thawed zone (see Section 5.7). Additional work completed by the University of Alaska – Fairbanks (UAF) supported the identification of suprapermafrost and subpermafrost groundwater flow regimes, which further enhanced the understanding of groundwater interactions with permafrost.

The geophysical surveys indicated taliks, which are thawed zones that penetrate the permafrost and connect the suprapermafrost and subpermafrost aquifers. For the purposes of this study, a talik is considered to be thawed ground encircled by permafrost (Williams, 1965), as opposed to broad thawed areas such as those beneath the Tanana River and Badger Slough.

4.1.1 Phase 8 Well Installation

Several of the Phase 8 monitoring wells were advanced either to the top of permafrost or to a maximum depth of 150 feet bgs, whichever was encountered first. The hollow-stem auger drilling method used for site investigations is limited to a total depth of 150 feet bgs. Well installation methods are described in Section 3 and in the RSAP. Phase 8 well locations are shown on Figure 3-1.

When encountered, permafrost was sampled to determine the nature of the frozen soil. The presence of permafrost in soil borings and monitoring wells has been evaluated using several types of information, including direct observation, drill action, and penetration resistance (i.e., blow counts). If frozen soil was suspected, samples were collected from undisturbed soil, then immediately retrieved for visual classification (i.e., the sampler was not floated to the next sample interval before retrieval). Drilling ceased once frozen soil was confirmed.

The permafrost samples were classified using the Alaska Department of Transportation & Public Facilities system, based on ASTM D4083 and Linnell and Kaplar (1966) in accordance with Section 3.2.5 of the RSAP. Depth to permafrost is listed in Table 3-1 and the permafrost encountered during installation of the well borings is described on the boring logs in Appendix 3-A.

If a boring was advanced to a total depth of 150 feet bgs, then permafrost was inferred to be thawed or absent at this location, unless otherwise indicated by geophysical data. Phase 8 monitoring well borings, including onsite and offsite locations, in which permafrost was encountered are summarized below, as are well borings that did not encounter permafrost within 150 feet of the ground surface.

Monitoring Well	Depth to Permafrost (feet bgs)
MW-148-100	110
MW-317-PF	72
MW-338-50	50.5
MW-339-50	52
MW-341-40	42.5
MW-342-65	65.5
MW-343-50	52
MW-349-45	46
MW-350-50	50
MW-352-40	40
MW-353-100	110
MW-363-15	20

Well Borings Completed to 150 feet bgs with no Permafrost
MW-190-150
MW-340-150
MW-346-150
MW-347-150
MW-351-150
MW-358-150
MW-359-150
MW-360-150
MW-362-150
MW-364-150

4.1.2 Geophysical Surveys

Four geophysical surveys were completed to delineate the top and bottom of permafrost within the unconsolidated aquifer materials.

An AEM geophysical survey was completed in five areas near the NPR and was flown between August 21 and 24, 2013 (Figure 1 in Appendix 4-A). The purpose of the survey was to provide supporting evidence for delineation of the top and bottom of permafrost within unconsolidated aquifer materials of the five areas. The total lineal coverage of the five survey blocks was approximately 227 miles (365 kilometers [km]). The flight path of the AEM geophysical survey was limited to undeveloped areas due to Federal Aviation Administration rules.

AEM data were acquired using a RESOLVE electromagnetic system, supplemented by a single high-sensitivity cesium magnetometer. The electromagnetic data collected using the sensors was processed to produce maps and images that display the magnetic and conductive properties of the survey area. A global positioning system electronic navigation system ensured accurate positioning of the geophysical data. A report summarizing the AEM survey is included in Appendix 4-A.

Ground-based frequency domain electromagnetic induction (FDEM) and electrical resistivity imaging (ERI) data were collected from October 2 to 16, 2013 to supplement the AEM survey. A follow-up survey including a down-hole geophysical evaluation was conducted from October 30 to November 5, 2013. The ground-based FDEM survey was performed using a Geonics EM-34. The ERI equipment used during this investigation consisted of an Advanced Geosciences, Inc. (Austin, Texas), SuperSting™ R8/IP earth resistivity system with a 112-electrode switch box, electrode cables with 6-meter connector spacing, and stainless steel electrodes. Equipment for the down-hole geophysical survey included a Mount Sopris Model 5MCA-1000 MGX-II console portable logger mounted to a 4305-1000 mini-winch with 200 meters of ⅛-inch single-conductor cable. Ground-based methodology is described in Appendix 4-B.

Offsite ground-based geophysical data collection was performed using FDEM in several key developed areas that could not be surveyed using the AEM techniques. ERI was unable to be used offsite due to interferences associated with pavement, utilities, driveways, and road crossings. Two main offsite areas were addressed:

1. An area immediately downgradient from the site, north of the Transfer Site Road, positioned along the axis of the main sulfolane plume in the direction of groundwater flow.

2. An area located on Horseshoe Way, Glacier State Road, and Airway Drive, in which sulfolane was detected at elevated concentrations in a residential well known to be completed in the subpermafrost aquifer.

Although ERI was not conducted in the offsite area, data collected from onsite, such as the down-hole geophysical surveys, were used to supplement offsite interpretations of the FDEM data.

The geophysical surveys were successful at delineating the top and bottom of permafrost in many areas. Data from the four geophysical surveys (AEM, FDEM, ERI, and down-hole geophysical) were coupled with private, municipal, industrial, and monitoring well boring log information that described the extent of permafrost and geology. These combined sets of data confirmed areas of known permafrost, and the geophysical data provided additional insight as to the extent and structure of the permafrost in areas without boring log data and facilitated construction of a block model of permafrost.

4.1.3 Hand Auger Borings

Results from the geophysical surveys and the installation of the Phase 8 monitoring wells along the property boundary indicated the potential for a shallow permafrost body in the northern portion of NPR along Transfer Road. Fourteen hand auger borings were advanced in the northern undeveloped portion of the site at locations shown on Figure 4-1, with the goal of confirming the shallow top of permafrost in this area. Eight of the borings met refusal at depths varying from 1.7 to 5.6 feet bgs. Field staff indicated that the sound and action of the hand auger bucket scraping on the refusal surface was consistent with the presence of permafrost based on previous experience. Hand auger logs are included in Appendix 4-C.

4.1.4 Hydrograph Evaluation

The results of an evaluation of monitoring well hydrographs (Section 5) identified two characteristic trends that are exhibited by the vast majority of wells completed in the suprapermafrost aquifer that are monitored using data loggers. One trend, referred to as the “Tanana River” trend consists of groundwater levels that are closely related to discharge and stage variation of the Tanana River. This trend was noted in wells south of the NPR, onsite, and offsite west of Badger Slough. The second trend, referred to as the “Other” trend, consists of a muted response to the Tanana River overprinted with a marked increase in groundwater elevation from December 2012 through April 2013. This second trend was only measured in wells completed in or near the thawed zone beneath Badger Slough. The cause of the increase in groundwater elevation from December 2012 through April 2013 in wells near Badger Slough is inferred to be related to recharge of the suprapermafrost aquifer from the subpermafrost aquifer through the thawed zone. Details of the evaluation are presented in Section 5. Data loggers are located in multiple wells and the data collected from these locations were used in this evaluation.

Average groundwater flow directions for the period of record of each data logger are plotted at the centroid of each group of wells used to calculate the flow directions on Figure 8 of Appendix 5-A. The average flow directions indicate divergence in the mid-plume area near well MW-156A-15 where the plume widens at the water table. The groundwater flow direction in the group of wells including MW 156A-15, MW-157A-15, and MW-158A-15 indicate flow toward MW-157A-15, which may be caused by an inferred talik in that area.

4.1.5 Groundwater Stable Isotope Study

UAF collected and analyzed groundwater samples from approximately 50 monitoring and private wells to evaluate groundwater temperatures and isotopic signatures of different groundwater flow regimes related to the presence and interaction of suprapermafrost and subpermafrost aquifers. Resulting data were used to infer areas of permafrost presence and absence. The study distinguished areas in the suprapermafrost aquifer that are connected with the subpermafrost portion of the aquifer; these areas are near the Badger Slough and the NPB (Barnes and Barnes 2013).

4.2 Permafrost Data Evaluation

The geophysical data were correlated with the monitoring well logs, available private well boring logs (see Section 2.3.3.2 of the SCR-2011 [Barr 2012]), and land use information from historical aerial photographs to produce a three-dimensional (3-D) permafrost model from which generalized cross sections and a depth to the top of permafrost contour map were constructed. The 3-D permafrost model is a visual depiction of the outer surface of the permafrost within the aquifer system and was constructed using the geological modeling software Leapfrog (Cowan et. al. 2002). While many of the private well logs lack soil sampling information, the depths of permafrost indicated on these logs correlate reasonably with the depths noted in the monitoring wells and the depths interpreted from the geophysical survey data.

The depth to permafrost contour map is shown on Figure 4-2 and images of the 3-D permafrost model are included on Figures 4-3 through 4-6. Additional views of the model are provided in Appendix 4-D. Generalized cross-sections showing a schematic representation of permafrost are presented in Appendix 4-E. Cross-section locations are indicated on Figure 4-2. The geophysical data indicate that transitions from frozen to thawed soil can be transitional and can include interlayered zones of frozen and thawed soil; however, these transitions are depicted as sharp contacts on the cross sections. Similarly, permafrost interpreted to be isolated masses is depicted with clean edges and discrete shapes, although the breaks between the masses could be more gradual with zones of interlayered frozen and unfrozen soil. A vertical exaggeration of 25 times has been used on the cross sections because the horizontal distances covered are significantly greater than the vertical distances. This allows subsurface features to be shown with an adequate amount of detail; however, sloped contacts become distorted and appear to be steeper than they actually are.

The sulfolane plume is depicted on the cross sections; sulfolane distribution in groundwater is discussed in Section 7. Transport mechanisms are discussed in Section 8.1.

The 3-D permafrost model supports the overall site characterization efforts and is a useful tool to help understand potential pathways for suprapermafrost and subpermafrost transport mechanisms. The permafrost model will be used as a guide for constructing the permafrost zones within the numerical groundwater flow and transport model.

4.3 Permafrost Occurrence

The extent of permafrost is discussed from southeast to northwest, starting at the site and moving in the downgradient direction (northwest). For simplicity in the following discussion, full monitoring well names are not used, rather, the well designator number is listed (e.g., MW-154 refers to the permafrost results at MW-154B-95).

The edge of a large offsite permafrost mass is located onsite; therefore, a summary of onsite permafrost is included below. Additional information regarding onsite permafrost is included in Section 5 of the Onsite Addendum (ARCADIS 2013h).

4.3.1 Onsite Summary

Permafrost is generally absent under the developed portions of the site. Therefore, separate suprapermafrost and subpermafrost aquifers do not exist in these areas. Small discontinuous masses are present at MW-154, MW-179, MW-301, MW-302, MW-303, and MW-305. The geophysical surveys indicate that these permafrost bodies are isolated masses as shown on Cross-Sections I-I’, II-II’, and IV-IV’ (Appendix 4-E).

A shallow permafrost mass is present in the undeveloped area south of Transfer Site Road (Figure 4-2). No suprapermafrost aquifer exists in that area where the top of this permafrost body extends above the water table.

The edge of a large, relatively continuous permafrost mass is present near the NPB along Transfer Road. The edge of the permafrost body is highly irregular and discontinuous (Figure 4-2 and Cross-Section VII-VII’). The permafrost mass extends to the north and west of the NPB and is present through much of the offsite plume area, although variable in thickness and depth (Section 4.3.2).

As shown on Cross-Sections I-I’, II-II’, and VI-VI’ (Appendix 4-E), the current detectable sulfolane plume extends to a maximum depth of approximately 90 feet bgs at the vertical profile transect (VPT [MW-302]). At this depth, it is possible that the plume encountered the edge of permafrost near the NPB. Advective groundwater flow around the permafrost mass may have caused the plume to bifurcate vertically, leading to separate suprapermafrost and subpermafrost plumes offsite. This mechanism is probable; however, it was not shown on the cross sections based on the plume data because all of the groundwater samples collected at depth in this area were nondetect for sulfolane.

4.3.2 Offsite

Permafrost is present under much of the offsite area as a relatively continuous mass of variable depth and thickness that extends beyond the northern and western extents of the study area (Figure 4-2). This mass has a minimum length (parallel to overall groundwater flow) of approximately 4 miles, and width (perpendicular to overall groundwater flow) of up to approximately 1.7 miles. Permafrost is absent under the Tanana River and the southwestern edge of the permafrost body is roughly parallel to the Tanana River. The permafrost body is truncated on a portion of its eastern edge by a thawed zone beneath Badger Slough that is up to approximately 0.5 mile (0.8 km) wide and approximately 2.8 miles (4.5 km) long. The isotopic study in process by UAF indicates that the groundwater wells in this thawed zone may be in an area of mixing between the suprapermafrost and subpermafrost aquifers, which further supports the conclusion that permafrost is absent in this area. Groundwater elevation data suggest that the subpermafrost aquifer at least seasonally recharges the suprapermafrost aquifer through the thawed zone beneath Badger Slough (Section 5.1.7). The permafrost body appears to extend beneath Badger Slough near the northern limit of the plume and possibly near Hurst Road (Figure 4-2).

The upper surface of the permafrost was encountered from near the ground surface to depths of approximately 150 feet bgs (Figure 4-2). The upper surface generally becomes shallower to the northwest, in the direction of groundwater flow. In some locations, permafrost extends up to the water table as shown on Cross-Sections II-II', XI-XI', XII-XII', and XIV–XIV' (Appendix 4-E). Several of these shallow frozen zones are present in the northern portion of the plume, near the intersection of Badger Road and Peridot Street (Figure 4-2). The configuration of this shallow permafrost may explain the apparent fingering of the sulfolane plume in this area (Section 7.2.1).

The shallow permafrost areas generally correspond to undeveloped tracts of land. Smaller thaw bulbs, expressed as troughs in the upper surface of the permafrost, appear to be present under the north end of Bradley Sky Ranch and near the junction of Old Richardson Highway and Eight Avenue (Figure 4-2), as shown on Cross-Sections II-II', IX-IX', and XI-XI' (Appendix 4-E). The AEM survey indicates a trough in the upper surface of the permafrost under the flood control levee west of the Bradley Sky Ranch (Figure 4-2). Geophysical data (Appendices 4-A and 4-B) and boring logs have also revealed areas where intrapermafrost aquifers can exist, as shown on Cross-Sections VII-VII' and IX-IX' (Appendix 4-E).

The lower surface of the permafrost appears to be highly irregular and is present at depths that range from 100 to greater than 300 feet bgs, based on available boring logs and geophysical data, as shown on the cross sections (Appendix 4-E). Simulated views of the 3-D permafrost shown from below (Figure 4-5 and 4-6) illustrate the irregular nature of the lower surface. These irregularities likely influence subpermafrost groundwater flow and sulfolane migration along the bottom surface of the permafrost.

The permafrost thickness is highly variable based on the irregular nature of the top and bottom permafrost surfaces, potentially exceeding 300 feet in some areas. Cross-Section II-II' (Appendix 4-E) shows that the permafrost begins to thin from the bottom in the area north of MW-164, toward Badger Slough. This thinning also is indicated to the west (near the Tanana River) as shown on Cross-Sections VIII-VIII', IX-IX', XI-XI', XII-XII', and XIV-XIV' (Appendix 4-E).

The geophysical surveys indicate the presence of taliks, or thawed zones that penetrate the permafrost and connect the suprapermafrost and subpermafrost aquifers. The presence of taliks within the permafrost is further supported by the identification of a subpermafrost sulfolane plume downgradient, and observed changes in hydraulic flow patterns in the suprapermafrost aquifer (Section 5.1.6). One talik (Talik A) is located in an area roughly bounded by 3rd Avenue, 4th Avenue, Therron Street, and Rosson's Cross Way (Figure 4-2). The talik is inferred to be a feature plunging (not vertically oriented) to the north, graphically represented on Cross-Sections I-I' and II-II' (Appendix 4-E) between MW-156, MW-158, and MW-157. The orientation of the cross sections relative to the plunge of the talik gives the appearance that the talik does not fully penetrate the permafrost, but it does connect the suprapermafrost and subpermafrost aquifers. At least one other talik (Talik B) may be present approximately where Cross-Section X-X' crosses Richardson Highway (Figure 4-2), and is shown on Cross-Section III-III' (Appendix 4-E). Both taliks are oriented such that impacted groundwater can flow from the suprapermafrost aquifer to the subpermafrost aquifer. Groundwater flow and sulfolane transport though taliks is discussed in Section 8.3.

4.3.3 Summary

In a large portion of the offsite area, discrete suprapermafrost and subpermafrost aquifers are present. The permafrost mass extends to the north and west from the NPR under the offsite plume. Permafrost is largely absent under the developed portions of the site, the Tanana River, and Badger Slough; therefore, one aquifer is present in these areas. This concept is supported by the UAF isotope study and groundwater elevation data. The geophysical surveys have identified taliks in the large permafrost mass that connect the suprapermafrost and subpermafrost aquifers in areas impacted by the sulfolane plume. Therefore, it appears that impacted groundwater may have migrated through the taliks from the suprapermafrost aquifer to the subpermafrost aquifer.

Because permafrost is absent onsite, sulfolane could migrate vertically when vertical gradients are downward (see Section 5.1.7). Advective groundwater flow around the permafrost mass located near the northern refinery property boundary may have enabled the sulfolane plume to bifurcate vertically, leading to separate suprapermafrost and subpermafrost plumes offsite. Fate and transport mechanisms are discussed in Section 8.

5. Offsite Hydrogeology

The site is located east and northeast of the Tanana River and southwest of the Chena River. These rivers act as groundwater sources and sinks to the hydrogeologic system (Figure 5-1). The hydrogeologic system for the North Pole area comprises unconsolidated alluvium and valley fill deposits in the Tanana Valley Basin, and is located between the Yukon-Tanana Uplands and the Northern Foothills of the Alaska Range (Figure 5-1). The Tanana River has a drainage area of approximately 20,000 square miles upstream of Fairbanks (Glass et al. 1996).

Key hydrogeologic concepts for the site are:

- General distribution of the conductive saturated aquifer
- General distribution of permafrost and its influence on groundwater flow
- Sources and sinks of groundwater

5.1 Aquifer Characteristics

The alluvial aquifer material was deposited primarily by a high-energy, braided stream system (Nakanishi and Lilly 1998). Although the uppermost deposits in some areas are finer-grained, consisting of silt and fine sand, the primary aquifer material consists of gravel and sand with a fine-grained silt matrix. The aquifer material is a complex system of alternating lenses of sand, gravel, and silt (Cederstrom 1963). The lenses are thin (typically less than 20 feet thick) and individual units cannot be traced for great distances in the subsurface (Cederstrom 1963, Nakanishi and Lilly 1998). Cederstrom (1963) provides the following evaluation of the heterogeneity of the alluvial aquifer:

> *"The deposits apparently consist of every gradation and combination of fine and coarse material. No lens appears to be more than 15 or 20 feet thick, and ordinarily the lenses are thinner. Apparently no bed can be traced in the subsurface for any great distance, and marker beds of any kind are unknown. In brief, the heterogeneity of the formation is its outstanding characteristic."*

5.1.1 Aquifer Thickness

Saturated alluvial deposits within the area defined by Geomega (2013b) range in thickness from less than 1 foot to more than 600 feet, based on boring log information. In some locations where permafrost extends above the water table, saturated alluvium may not exist. Several discontinuous bodies of permafrost have been identified within the area defined by Geomega (2013b), which limits the lateral and vertical extent of alluvial materials through which groundwater flows. The permafrost bodies divide the aquifer into two or more units: suprapermafrost (above), intrapermafrost (between or within), and subpermafrost (below) aquifers. The presence of permafrost bodies can also significantly influence the groundwater flow directions.

The suprapermafrost aquifer generally consists of highly transmissive sand and gravel under water table conditions (Cederstrom 1963, Glass et al. 1996). In the Tanana Valley, the alluvial aquifer is reportedly more than 600 feet thick (at least 616 feet near Moose Creek Dam [Glass et al. 1996); however, the deepest known well near the site is the GVEA injection well, which is 450 feet deep and did not encounter bedrock. This well is located at the GVEA substation near the south property boundary (SPB) of the refinery [Figure 2-3]).

Isolated, discontinuous masses of permafrost were identified during installation of several well nests north of the recovery system on the NPR property (Figure 4-2). A large mass of permafrost extending above the water table was delineated by recent hand augering and geophysical data (see Figure 4-2 near MW-149B-19 and the eastern end of Cross-Section VII-VII'). Permafrost was also encountered in an isolated area south of the recovery system during installation of well MW-179D-135 at a depth of approximately 140.5 feet below the water table. With the exception of this location, none of 150feet deep borings in the developed portion of the NPR encountered permafrost (from the SPB to areas northeast of the extraction wells [see Figure 4-2]). Northwest of the extraction wells, the tops of identified isolated masses of permafrost were found from depths of 70 to 130 feet bgs (see wells MW-154B, MW-301-70, MW-302-110, MW-303-130, and MW-305-110) to greater than 150 feet bgs near the recovery wells and throughout the developed area (Figure 4-2). Aside from the locations discussed above, permafrost is not known to be present beneath the rest of the NPR.

5.1.2 Hydraulic Conductivity

Hydraulic conductivity estimates from the literature and various site characterization activities are summarized below. The aquifer is heterogeneous based on multiple lines of evidence described below, and is presumed to have similar heterogeneity beneath the permafrost due to similarity in the depositional environment.

5.1.2.1 Literature Values and Previous Studies

Downey and Sinton (1990) estimated the hydraulic conductivity of the alluvial aquifer near the Fairbanks North Star Borough to be 1,000 feet per day (ft/day). Reported hydraulic conductivity values of the suprapermafrost aquifer in the region range from 8 to 2,400 ft/day (Nakanishi and Lilly 1998). These results are primarily from relatively shallow wells. However, the GVEA injection well, which is perforated from 412 to 432 feet bgs, had a specific capacity of approximately 80 gallons per minute (gpm) per foot of drawdown, indicating that relatively permeable materials were present at that depth. No permafrost is known to be present near the GVEA injection well; however, the air rotary drilling method used to drill the well did not allow for positive identification of frozen material. The GVEA well is at a depth similar to the depth of the subpermafrost aquifer identified in residential wells to the north and northwest.

A study in 1987 (SWI 1987) concluded that hydraulic conductivity of the sand and gravel ranged from 100 to 1,000 ft/day based on GSAs of samples collected from the NPR.

A 1995 recovery well optimization study pump test at the NPR found variability in aquifer characteristics over small distances (i.e., tens of feet) based on differences in measured drawdown in wells at similar distances from a pumped well (SWI 1995). The 1995 testing consisted of a step-drawdown test of recovery well R-34. The well was pumped at rates of 50, 100, 150, and 170 gpm for 6 hours at each rate. Quantitative analysis of the 1995 data is not possible because the rate was not constant and drawdowns were calculated only at the end of each step. The steps were not long enough to allow application of the Jacob method for distance-drawdown analysis.

Aquifer testing at the NPR in 2009 indicated a range of hydraulic conductivity values from 130 to 580 ft/day, based on an estimated saturated thickness of 590 feet and pumping of wells penetrating the upper 15 feet of the aquifer (Barr 2010b). These estimates were developed with an understanding that no permafrost was present beneath developed areas of the NPR based on the timing of NPR development, and proximity of the Tanana River. As noted in Section 4, subsequent investigations have encountered permafrost at multiple monitoring well locations beneath the NPR at depths of less than 150 feet. Using the current estimated representative saturated thickness of the suprapermafrost aquifer of 150 feet (see Section 4.1.1), the 2009 aquifer testing results indicate a hydraulic conductivity range of approximately 500 to 2,300 ft/day.

Aquifer testing of the new North Pole water supply wells in July 2010 indicated a hydraulic conductivity ranging from approximately 700 to 1,100 ft/day based on pumping of wells screened from approximately 120 to 150 feet below the water table (Barr 2010c and 2010d).

5.1.2.2 Site Characterization Grain Size Analyses

GSAs were performed on 325 soil samples collected during the site characterization; 216 of these tests were performed on samples collected since completing the SCR – 2011 (Barr 2012b). Sampling methods are described in the RSAP. Both sieve and hydrometer tests were performed to determine the gradations of samples collected from depths ranging from ground surface to 152 feet bgs (Table 5-1). Table 5-1 presents the following information:

- Blow count (the number of hammer blows required to advance the sampler 6 inches).
- Density classification based on the blow count.
- Breakdown of the sample size distribution based on the following size categories:

- Percent gravel (grains greater than 4.75 millimeters [mm] in diameter)
- Percent sand (grains between 4.75 and 0.075 mm in diameter)
- Percent fines (grains less than 0.075 mm in diameter)

· Indications of representative grain sizes as defined below:

- D_{10}, 10 percent of the sample is finer than this size (mm).
- D_{20}, 20 percent of the sample is finer than this size (mm).
- D_{50}, 50 percent of the sample is finer than this size (mm).
- D_{60}, 60 percent of the sample is finer than this size (mm).

· Uniformity coefficient (Cu), an indication of sample heterogeneity, defined as D_{60}/D_{10}.

· Soil type based on ASTM D2487.

· Estimates of hydraulic conductivity of the sample based on up to three different methods:

- Hazen's method (Hazen 1911, Fetter 1988), which is applicable to soil with a Cu of less than 5 and D_{10} ranging from 0.1 to 3 mm. Hazen's method was applicable to 18 samples.

- Prugh's method (as presented on Figures 3.7a, 3.7b, and 3.7c of Powers et al. 2007), which depends on sample density, D_{50}, and Cu. Prugh's method was applicable to 41 samples.

- The Barr (2001) method, which uses all of the gradation information and is applicable to all of the samples.

Ternary plots show the percentage of gravel, sand, and fines (silt) in each sample based on the depth of the sample interval (Figure 5-2). A sample consisting entirely of sand would plot at the top vertex, a sample consisting entirely of gravel would plot at the right vertex, and a sample consisting entirely of silt would plot at the left vertex. The individual plots correspond to the depth ranges used to evaluate groundwater results, assuming a nominal water table depth of approximately 10 feet bgs. Soil samples were collected at depths less than 10 feet bgs. Different symbols are used for samples collected onsite versus offsite. The samples from 20 feet bgs or less have higher silt contents (up to almost 90 percent) than samples from greater depths, where silt content is less than 15 percent. The spread of the samples on all of the grain size subplots demonstrates the heterogeneity of the aquifer materials.

Hydraulic conductivity values were estimated from the sieve samples in Table 5-1 with Cu values less than 5 using Hazen's method with a value of the C coefficient estimated based on the sample description (see Equation 1 below, from Fetter [1988], Equation 4-10, p. 81).

$$K = C(D_{10})^2 \quad \text{Equation 1}$$

Where:

K = hydraulic conductivity in centimeters per second (cm/s)

D_{10} = effective grain size in centimeters (10 percent of the sample is finer than this size)

C = coefficient that accounts for grain size and sample sorting, and represents typical shallow groundwater temperatures, as listed below:

Very fine sand, poorly sorted	40 to 80
Fine sand with appreciable fines	40 to 80
Medium sand, well sorted	80 to 120
Coarse sand, poorly sorted	80 to 120
Coarse sand, well sorted, clean	120 to 150

Hydraulic conductivity was also estimated using the Prugh method (Powers et al. 2007). This involved manually looking up values from the appropriate chart and plot based on relative density, Cu, and D_{50} for each sample.

The Barr method (Barr 2001) relates the surface area of soil particles as determined from GSA data to the coefficient of permeability based on the theory that pressure loss is proportional to viscous resistance and viscous resistance is caused by drag at the particle surfaces.

Hydraulic conductivity values for Hazen's (1911) method versus Barr's (2001) and Prugh's (Powers et al. 2007) methods versus Barr's (2001) method are plotted on Figure 5-3. As shown, the Prugh method (Powers et al. 2007) gives larger values than the Barr method (2001). Hydraulic conductivity of the samples based on Barr's method (2001) is plotted versus the depth of the midpoint of the sample interval on Figure 5-4A. The symbol type on this plot indicates whether the samples are from onsite or offsite, and exhibit similar distributions with depth.

As shown, hydraulic conductivity estimated based on GSAs from samples of aquifer material collected during well installation have a range of more than five orders of magnitude, from 0.1 to 17,000 ft/day (Table 5-1). Hydraulic conductivity values estimated from individual soil samples from a heterogeneous aquifer can show great variability due to the small size of a given sample; the samples are essentially point estimates. A given sample may not be representative of a significant volume of the aquifer. Figure 5-5 shows a histogram of the log (base 10) of the hydraulic conductivity values based on Barr (2001). This histogram approximates a log-normal distribution, which would be expected for hydraulic conductivity that typically exhibits a log-normal distribution in granular porous media (Freeze and Cherry 1979). Results for nearly 70 percent of the samples fall between 10 and 100 ft/day, and approximately 99 percent are less than 1,000 ft/day (Table 5-2).

The lowest hydraulic conductivity values were reported for samples collected from the shallow silty layers located near the water table (see Table 5-1 and Figure 5-4A). Aside from the shallow results, these hydraulic conductivity data do not show an apparent trend with depth (Figure 5-4A).

The Cu of a soil sample is defined as the D_{60} value (60 percent of the grains in the sample have a smaller diameter than this value) divided by the D_{10} value. The sample is more uniform in particle size distribution if the Cu number is smaller. A Cu value of 5 is considered the practical upper limit for typical analyses such as filter pack and screen design (Driscoll 1986), although the charts for soil with intermediate density based on the Prugh method (Powers et al. 2007) apply to soil with Cu values as high as 10.

Thirty-nine of the 326 samples listed in Table 5-1 have Cu values of less than 5. The Cu values were sorted from smallest to largest and plotted on Figure 5-6 along with the corresponding D_{10} and D_{60} values. Based on this plot, the extremely high Cu values are from finer-grained samples, and the vast majority of the high Cu values stem primarily from samples with high D_{60} values. The high amount of nonuniformity for the majority of the samples can be interpreted as the finer fraction of the formation filling the interstices between the coarser grains. This finer-grained matrix creates a material with a lower specific yield, higher specific retention, lower hydraulic conductivity, and lower mobile porosity than more uniform materials. Such nonuniform deposits are formed in fluvial settings during or shortly after deposition through the process of vertical winnowing (the loss of fine particles to the subsurface during transport [Parker and Klingeman 1982]).

5.1.2.3 2011 Recovery Well Pumping Test

An aquifer test was performed on the NPR groundwater recovery system in August 2011 and is described in Sections 2.3.4.3 and 3.5.1.1 of the SCR – 2011 (Barr 2012). The groundwater recovery system was comprised of five wells at that time (R-21, R-35R, R-39, R-40, and R-42). The aquifer testing was completed by turning off all five extraction wells within approximately 4 minutes of each other on August 30, 2011, then turning them back on approximately 24 hours later. The combined recovery and pumping phases were analyzed to evaluate aquifer parameters and system performance.

No indication of a recharge boundary caused by infiltration from the Tanana River or North Gravel Pit (NGP) was noted during the test, and a barrier boundary was not apparent in the aquifer test data. A response indicative of a barrier would be expected if a large mass of shallow permafrost was located close to the extraction system.

Analyses at multiple well clusters were performed using the Moench (1997) solution and are summarized in Table 5-3. Copies of the AQTESOLV analyses are presented in Appendix T of the SCR – 2011 (Barr 2012). The storage coefficient typically went to its lower bound during the parameter estimation process. Variation of the storage coefficient parameter did not appreciably affect the data fitting process if the storage coefficient was set at any value in the allowed range of 1.5×10^{-5} to 1.5×10^{-3}. Some of the analyses produced storage coefficients at the upper bound allowed in the analyses. The elastic response to the testing is apparently rapid and small in magnitude and, therefore, could not be measured.

The specific yield values are relatively low, which reflects the heterogeneity of the aquifer system (Moench 1994) and the influence of silty and sandy material within the gravel deposits at the water table, which retain a significant fraction of water (e.g., Pool and Eychaner 1995).

The estimated hydraulic conductivity near the recovery well system was found to range from 1,000 to 1,500 ft/day. This estimate was based on an assumed saturated thickness of the suprapermafrost aquifer of 150 feet.

5.1.2.4 Single-Well Pumping Test Results

Transmissivity and hydraulic conductivity values were measured during several single-well pumping tests conducted in 2011 (Table 5-4). The AQTESOLV well test analysis summaries are included in Appendix H of the SCR – 2011 (Barr 2012). Hydraulic conductivity values were calculated from the transmissivity and well screen length for each well and varied between 50 and 10,700 ft/day.

The transmissivity and hydraulic conductivity values measured during these short-duration single-well tests demonstrate that significant heterogeneity exists within the geologic formation around the test wells, as indicated by the nearly three order of magnitude range in values estimated.

5.1.2.5 2012 Tracer Test

A tracer test was performed at the site in March 2012 to evaluate the feasibility of in-situ remediation technologies that rely on injection of remediation reagents below the water table (ARCADIS 2013a). As part of the tracer test, step injection testing was performed at the injection well to evaluate a range of possible tracer injection rates and assess hydraulic properties of the water-bearing zone.

The modified Theis Solution for unconfined aquifers was used to analyze the injection test data based on observed water-level responses at the injection and observation wells. These data were used to estimate transmissivity and hydraulic conductivity of the water-bearing zone, using a saturated thickness equal to the well screen interval. Hydraulic conductivity values measured during the step injection test varied between 140 and 1,100 ft/day, and had a geometric mean of 400 ft/day.

5.1.2.6 2013 Recovery Well Pumping Tests

In late May/early June 2013, a pumping test was conducted for the expanded recovery system. As of 2012, the groundwater recovery system at NPR consisted of five wells (R-21, R-35R, R-39, R-40, and R-42). Four new recovery wells were added to the system in 2013 (R-43, R-44, R-45, and R-46) and two of the existing wells (R-39 and R-40) were removed from service upon startup of R-45 and R-46 (which serve as replacement wells for R-39 and R-40) (Figure 2-3).

The startup testing for the 2013 expanded recovery system consisted of a two-day shutdown period, four single-well tests (one well pumping at a time with multiple observation wells), and monitoring of the expanded system restart for three days (Barr 2013b). This testing provided additional aquifer parameter estimates and field measurements of groundwater elevations and drawdown caused by the recovery system.

Well interference was noted in many of the observation wells due to cycling of NPR's production wells NPR-1 and NPR-2 (Figure 2-3). Data logger monitoring frequency was increased to reading every 5 seconds at MW-109. A data logger was temporarily installed in MW-116 and water levels were recorded every 2 seconds for approximately 24 hours to provide better resolution of the aquifer response to pumping cycles near the production wells. These data were analyzed using the methods discussed in Section 3.2 of Evaluation of Recovery Well Replacement, Start-up Aquifer Testing for Recovery System Hydraulic Capture Performance Monitoring (Barr 2013b).

Aquifer properties (transmissivity, storage coefficient, specific yield, and anisotropy [ratio of vertical to horizontal hydraulic conductivity]) were determined using composite analyses for wells screened at differing depths, as recommended by Moench (1994) (Table 5-6). Hydraulic conductivity values for the analyses ranged from 200 to 1,600 ft/day, using an assumed aquifer thickness of 150 feet. Storage coefficient values ranged from 0.0011 to 0.088, which translates to a range of specific storage values of 2.4×10^{-5} m^{-1} to 1.9×10^{-3} m^{-1}. The anisotropy in vertical to horizontal hydraulic conductivity in the solutions ranges from 0.0033 to 0.12.

5.1.2.7 2013 Tracer Tests

Two additional tracer tests were performed in fall 2013 to validate the dual-porosity conceptual model for COC transport and to further characterize site hydrogeologic properties (ARCADIS 2013h). One tracer test was performed at an area of the site containing fine-grained soil, designated as Tracer Test Area 1 (TTA-1). The second tracer test was performed at an area of the site containing coarse-grained soil, designated as Tracer Test Area 2 (TTA-2). As part of the tracer testing procedures, hydraulic conductivity of the soil immediately surrounding the injection and monitoring wells was measured by performing a series of single-well short-duration pumping tests. Hydraulic conductivity values for the fine-grained soil in TTA-1 were found to vary between approximately 19 and 54 ft/day and had a geometric mean of 33 ft/day. Hydraulic conductivity values for the coarse-grained soil in TTA-2 were found to vary between approximately 28 and 455 ft/day and had a geometric mean of 100 ft/day.

5.1.2.8 Hydraulic Conductivity Estimates and Applications

The hydraulic conductivity of saturated soil within the suprapermafrost aquifer has been estimated using numerous techniques presented previously in this section. As would be expected of an aquifer formed primarily in a braided stream depositional environment, and as documented in the literature regarding the region cited above, the hydraulic conductivity estimates varied over several orders of magnitude in both the horizontal and vertical directions, exhibiting an extremely high degree of heterogeneity. Site-specific hydraulic conductivity estimates range from 0.1 to 17,000 ft/day and are summarized below:

- Estimates based on GSAs ranged from 0.1 to 17,000 ft/day. Three of the 324 samples tested had hydraulic conductivity values that exceeded 1,500 ft/day.

- Estimates based on 2009 testing of the recovery well system ranged from 500 to 2,300 ft/day with a geometric mean of 1,100 ft/day.

- Estimates based on the single-well pumping tests ranged from 50 to 10,700 ft/day, with a geometric mean of 270 ft/day.

- Estimates based on 2010 aquifer testing of the new City of North Pole water supply wells ranged from 700 to 1,100 ft/day, with a geometric mean of 880 ft/day.

- Estimates based on 2011 testing of the recovery well system ranged from 1,000 to 1,500 ft/day, with a geometric mean of 1,300 ft/day.

- Estimates based on single-well pumping tests performed during the 2012 tracer test ranged from 140 to 1,100 ft/day, with a geometric mean of 400 ft/day.

- Estimates based on 2013 testing of the recovery well system ranged from 200 to 1,600 ft/day, with a geometric mean of 100 ft/day.

- Estimates based on single-well pumping tests performed during the 2013 tracer tests ranged from 19 to 54 ft/day for finer-grained soil with a geometric mean of 33 ft/day, and 28 to 455 ft/day for coarser-grained soil with a geometric mean of 100 ft/day.

The hydraulic conductivity values listed above were estimated using methods that sample the aquifer at various scales, with long-term pumping tests covering the largest scale (i.e., tens to hundreds of feet), single-well pumping tests covering an intermediate scale (i.e., 5 to 10 feet), and GSAs covering the smallest scale (i.e., pore scale). Results of the various hydraulic conductivity tests demonstrate a more than five order magnitude range of hydraulic conductivity at the site and underscore the extreme heterogeneity of site soil.

Understanding the variability of hydraulic conductivity in the subsurface is critical in the evaluation of many aspects of the site characterization and potential remedial alternatives. To the extent possible, site-specific data have been used in all aspects of the site characterization as summarized below:

- *Mass flux estimates at the VPT*. Data from aquifer tests within and near the VPT were used in these estimates (ARCADIS 2013g)

- *Recovery system capture zone evaluation using the groundwater flow model*. Aquifer testing results and geologic and water-level information available as of the end of 2012 were used to calibrate the groundwater flow model and to evaluate the extent of capture of the groundwater extraction system (Geomega 2013b).

- *Density of available data for the groundwater flow model*, which covers approximately 150 square miles, varies widely with location due to the nature of the investigation and locations of wells installed. Horizontal hydraulic conductivity values in the groundwater flow model range from 85 to 1,530 ft/day (Geomega 2013b [Table 5]). Geomega (2013b [Figures 5-3b 1 to 37]) presents the spatial distribution of hydraulic conductivities in the groundwater flow model. The lowest values in the model represent the silty units found at or near the water table.

- *Recovery system capture zone evaluation based on field measurements*. The lateral extent of the groundwater capture zone was determined based on potentiometric surface maps of groundwater levels measured in monitoring wells. Vertical anisotropy (the ratio of vertical hydraulic conductivity to radial hydraulic conductivity) is used to determine the vertical extent of the capture zone in cross-section view (Barr 2013b [Section 4.3.4]).

5.1.3 2013 Tracer Tests

Two tracer tests were performed at the site in fall 2013 to validate the dual-porosity conceptual model for COC transport in groundwater and the potential influence on plume transport, further characterize hydrogeologic conditions at the site, and to estimate hydraulic conductivity and hydraulic gradients in the tracer test areas. The tracer tests were performed in accordance with the Onsite SCWP (ARCADIS 2013e) at two different areas of the site. The first tracer test was performed in an area with relatively fine-grained soil (TTA-1). The second tracer test was performed in an area with relatively coarse-grained soil (TTA-2). Appendix 6-A of the Onsite Addendum (ARCADIS 2013l) describes the activities conducted during both tracer tests, including well installation, single-well pumping test results, baseline sampling results, step injection testing, tracer injection activities, and groundwater monitoring.

The purpose of the tracer tests was to collect data necessary to validate the dual-porosity conceptual model for COC transport in groundwater and to more thoroughly characterize the hydrogeologic and fate and transport properties of saturated soil beneath the site.

Specific objectives of the tracer tests included:

- Provide additional data to augment the data from the 2012 tracer testing (ARCADIS 2013a). Results of the 2012 tracer testing showed characteristics that suggested rapid transport and tailing of tracer breakthrough curves consistent with dual porosity transport.

- Validate the dual-porosity fate and transport conceptual model and its potential influence on plume transport.

- Obtain quantitative information to estimate mobile porosity, total porosity, and mass transfer coefficient model parameters.

- Determine well-specific injection flow rates to be used during tracer testing.

- Estimate hydraulic conductivity and hydraulic gradients in both areas.

Information collected during the tracer tests provides insights regarding the fate and transport behavior of chemicals in groundwater at the site. The conclusions presented below are based on results of the tracer tests.

Dual-porosity transport of tracers in site groundwater was demonstrated by comparing tracer breakthrough curves at the two areas. In TTA-1, the tracer breakthrough curves show long, gradual increases in concentration through time that indicate significant storage of tracers in the fine-grained soil. Tracer concentrations in almost all TTA-1 monitoring wells were continued to increase at the end of the approximate 2-month monitoring period. The fine-grained soil in TTA-1 represents one porosity regime in which tracers are stored for relatively long periods of time.

In TTA-2, the tracer breakthrough curves show rapid increases and decreases in concentration through time that indicate rapid transport and much less storage of tracers in the coarse-grained soil. Tracer concentrations in almost all TTA-2 monitoring wells decreased to background conditions within approximately 1 to 2 weeks after tracer injection. The coarse-grained soil in TTA-2 represents a second porosity regime in which significant advective transport occurs. Mass transfer of tracers between mobile and immobile porosity regimes due to advection and diffusion provides a primary control on the timing of tracer transport, chemical plume evolution, plume longevity, plume stability, and ultimately, the feasibility of remediation technologies. Furthermore, there is evidence of pore-scale dual-porosity transport associated with presence of immobile porosity (i.e., dead-end pore spaces) within the coarse-grained soil, which is demonstrated by tailing evident in some of the TTA-2 breakthrough curves.

Data collected during the tracer tests were used to estimate dual-porosity transport parameters for each area, including mobile porosity, total porosity, and mass transfer coefficients. For TTA-1, total porosity was estimated between approximately 29 and 36 percent based on laboratory analytical results of three undisturbed soil core samples, and mobile porosity was estimated between approximately 4 and 13 percent. The median mobile porosity estimated at TTA-1 was approximately 9 percent. For TTA-2, total porosity measurements are not yet available. These values will be reported to ADEC in the future. Mobile porosity was estimated between approximately 2 and 21 percent. However, this range is considered to be biased high due to an assumption of strictly two-dimensional tracer transport; a more accurate estimate of mobile porosity likely ranges between 9 and 11 percent, with a median value of 10 percent. The mass transfer coefficient at TTA-2 was estimated between approximately 4×10^{-2} and 2×10^{-7} per day based on quantitative analysis of breakthrough curves using the dual-porosity fate and transport model curve-fitting procedure. The absolute values of these parameters should be used with caution due to uncertainties in the assumptions of the data analysis methods.

Results of the quantitative breakthrough curve fitting procedure indicate that there is a statistically significant basis for accepting the dual-porosity fate and transport model and rejecting the advection-dispersion fate and transport model at two of three locations analyzed. At the third location, there is no statistically significant basis for rejecting either model.

Hydraulic conductivity was measured at seven monitoring wells in TTA-1 and found to vary between approximately 19 and 54 ft/day, indicating the presence of hydraulic heterogeneity within the fine-grained soil in TTA-1. Hydraulic conductivity measurements made using single-well, short-duration pumping tests in this manner result in accurate estimates of the hydraulic conductivity of saturated soil within approximately 5 feet of the well screen, providing a high level of confidence in the results. The hydraulic conductivity measurements at the TTA-1 groundwater monitoring network exhibited a spatial trend that is consistent with an alluvial depositional environment characterized by meandering stream channels. In this environment, the high hydraulic conductivity units are deposited within lower hydraulic conductivity units. This depositional heterogeneity may result in apparent trending in hydraulic conductivity. The TTA-1 hydraulic conductivity measurements result in a horizontal hydraulic conductivity ellipse with a 4:1 ratio that is oriented toward the northwest-southeast.

Hydraulic conductivity was measured at four monitoring wells in TTA-2 and found to vary between approximately 28 and 455 ft/day, indicating the presence of significant geologic heterogeneity within the coarse-grained soil in TTA-2. Hydraulic conductivity measurements made using single-well short-duration pumping tests in this manner result in accurate estimates of the hydraulic conductivity of saturated soil within approximately 5 feet of the well screen, providing a high level of confidence in the results. Similar to TTA-1, the hydraulic conductivity measurements at the TTA-2 groundwater monitoring network also appeared to exhibit a spatial trend that is consistent with an alluvial depositional environment characterized by meandering stream channels. However, the horizontal hydraulic conductivity ellipse at TTA-2 could not be resolved to the same degree of certainty as TTA-1 because fewer measurements were made at TTA-2. Nonetheless, tracer test results suggest that the hydraulic conductivity ellipse at TTA-2 may have a 3.4:1 ratio and be oriented toward the north-northwest to south-southeast.

5.1.4 Sources and Sinks for Groundwater

Sources for groundwater in the Tanana Valley aquifer system include rivers, regional underflow through unconsolidated alluvium, and precipitation. Sinks for the groundwater include rivers, underflow through unconsolidated alluvium, evapotranspiration, and artificial discharge via wells. The recharge from rivers, precipitation, and regional groundwater underflow comprise the major inflows to the groundwater system, while evapotranspiration, rivers, regional groundwater underflow, and well pumping comprise the major outflows.

Precipitation on portions of the Tanana basin at elevations less than 1,000 feet mean sea level (MSL) is estimated to be 12.5 inches per year (Anderson 1970). Actual evapotranspiration over the same area is estimated to be 9.8 inches per year (Anderson 1970). The balance of the precipitation is believed to recharge the shallow water table, and then discharge to rivers within the basin. This portion of the basin (at elevations less than 1,000 feet MSL) has an area of approximately 12,000 square miles. Therefore, the annual average rate of precipitation infiltration is estimated to be 2.7 inches per year. This cycling of recharge to the area rivers occurs above the permafrost. Lakes and swamps in the basin act as flow-through features for groundwater, with some loss to evaporation when they are not frozen.

The major surface water features in the area consist of the Tanana River, Chena River, Badger Slough, and a drainage ditch known as Ditch C. Ditch C is connected to Badger Slough. Shallow groundwater discharges to Ditch C, particularly north of Richardson Highway. The Badger Slough is a tributary to the Chena River, which is a tributary to the Tanana River. Discharge and stage data for the Chena and Tanana rivers were obtained from the U.S. Geological Survey (USGS) water data web site, as described in Geomega (2013b) and summarized in the table below.

River	Mean Annual Discharge (cfs)
Tanana River	20,546
Chena River	814 to approximately 1,300 cfs (increasing in the downstream direction)

Note:
cfs = cubic feet per second

A key characteristic of rivers in the region is the large seasonal variations in flow and stage due primarily to spring snow melt. For example, the Tanana and Chena rivers have spring flows that can be four to six times the October flows, with annual changes in stage of 6 to 10 feet (USGS 2011). When the discharge is high, water from the Tanana River recharges the aquifer and discharges to the Chena River and associated tributaries (Nelson 1978). During seasonal high flows, the Chena River also locally recharges the aquifer. Both the Tanana and Chena rivers gain discharge from the alluvial aquifer when the discharge rates are lower. This seasonal fluctuation influences groundwater flow, as discussed in Section 7.2.1.2.

Two flood-control structures have been built in the study area: the Moose Creek Dam on the Chena River approximately 2 miles upstream from the NPR, and a levee along the northern side of the Tanana River extending from the Moose Creek Dam to Fairbanks (Geomega 2013b [Figure 1-1]). The floodgates on Moose Creek Dam are only used during high flow to ensure that the Chena River flow through Fairbanks is controlled at a maximum of 12,000 cfs. If the Chena River flow is sufficiently high at the dam, water will flow to the Tanana River along a constructed floodway. Between 1979 and summer 1993, the dam was only used during eight periods of high flow and the spillway into the Tanana River was only used once (Glass et al. 1996). The flood control structures have not been demonstrated to have any effect on groundwater flow at the site.

Three basic types of discharge occur via wells in the area:

1. FHRA production and remedial wells
2. Municipal supply and/or industrial wells
3. Domestic wells

5.1.5 Water Table Configuration

The water table at the NPR and offsite is shallow, typically occurring within 5 to 10 feet of the ground surface. The water table typically occurs within the alluvial sand and gravel; however, during seasonal high water conditions the water table may occur within the finer-grained soils above the alluvial sands and gravels.

Onsite, the elevation of the water table ranges from approximately 480 to 490 feet MSL, decreasing from southeast to northwest. Offsite, the water table elevation varies from approximately 460 to 485 feet MSL, and decreases in elevation to the northwest, mimicking the gradually decreasing elevation of the ground surface (ARCADIS 2013g). The elevation of the potentiometric surface associated with deeper portions of the aquifer, as indicated by wells completed in the interval from 15 to 55 feet below the water table, is similar to the water table (ARCADIS 2013g).

The water table fluctuates in elevation seasonally. Historical data indicate that it may fluctuate up to 9 feet at some locations (SWI 2002). This is consistent with values reported by Glass et al. (1996). Hydrographs for well MW-138 (Barr 2012 [Figure 48]) and R-20 (Barr 2012 [Figure 49]) show that the water table has fluctuated up to 4 feet since 2007. The groundwater elevation typically decreases during winter and early spring, with the lowest elevations occurring from late March through May. Groundwater elevations appear to increase during June and July, peaking during late July or August. Groundwater elevations then typically decrease through the remainder of the year. These variations are similar to those observed at three shallow observation wells maintained by the USGS as part of its Active Groundwater Level Network as shown in Appendix 5-C. Water levels in these wells have been observed to fluctuate from 3 to more than 4 feet in the period of record (2001 to 2011). Only one of these wells was monitored by the USGS in 2012 and 2013.

5.1.6 Horizontal Hydraulic Gradient – Magnitude and Flow Direction

Beyond the zones of influence of the NPR groundwater recovery system, groundwater flow directions are controlled by recharge from the Tanana River to the aquifer and discharge 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 groundwater flow direction through the aquifer between the rivers (Appendix 5-B; Lilly et al. 1996). The groundwater flow direction varies up to 19 degrees from a north-northwesterly direction to a few degrees east of north based on data from USGS water table wells (Appendix 5-B). The flow direction trends to the north-northwest in spring and more northerly in the summer and fall (Appendices 5-A and 5-B).

Data from the three USGS wells located near the Tanana River, southeast of NPR, indicate a slope on the water table ranging from 4.5 to 6.5 feet per mile. Data from the USGS Active Groundwater Level Network wells were included in Appendix 5-B.

Groundwater elevations are currently measured using data loggers suspended from the tops of the casings in monitoring wells at the NPR. Details on the data logger program results are presented in Appendix 5-A. Horizontal hydraulic gradients (magnitude and direction of flow) were estimated using groups of three wells completed at similar depths in the suprapermafrost aquifer.

The direction of groundwater flow was determined between 49 triangular groups of groundwater wells screened at or near the water table and monitored with data loggers in shown on Figure 6-7. Variation in groundwater flow directions were calculated throughout the period of record and were plotted in units of degrees counterclockwise from due east (Attachment A of Appendix 5-A). The groundwater flow direction in the suprapermafrost aquifer was found to have the greatest easterly component during summer months when the Tanana River stage is higher, and was found to have a more westerly orientation in other seasons when the Tanana River stage is lower. These findings are consistent with data collected at the USGS wells discussed above.

The groundwater flow direction data are also summarized using rose diagrams (Attachment B of Appendix 5-A). The flow directions are presented with the average value for the period of record plotted at the centroid of each group of wells (Figure 5-8). This figure also includes the extent of the sulfolane plume and contours of the depth to permafrost below ground surface. Significant features in the permafrost distribution include the overall lack of detected permafrost beneath the NPR and the inferred thawed zone beneath Badger Slough where permafrost was not encountered to depths of 150 feet bgs and where geophysical and stable isotope data indicate a connection between the subpermafrost and suprapermafrost aquifers. The relationship between the average groundwater flow direction and the shape of the plume is clear when average flow directions are presented with the sulfolane isopleths (Figure 5-9).

The average groundwater flow directions indicate divergence in the mid-plume area near well MW-156A-15 at the water table where the plume widens. The flow direction measured in the group of wells comprising MW-156A-15, MW-157A-15, and MW-158A-15 indicate flow toward MW-157A-15, which may be caused by taliks or undulations in the permafrost surface in that area (Section 4.2).

The magnitude of the hydraulic gradients was also calculated between the groups of groundwater monitoring wells shown on Figure 5-7 (Attachment C of Appendix 5-A). The gradients are primarily the greatest in the summer when the Tanana River stage is high and recharge from the river to the alluvial aquifer is greatest. Excluding outliers, the horizontal hydraulic gradients range from approximately 0.0004 to 0.002.

5.1.7 Vertical Hydraulic Gradients

Vertical gradients were calculated within well nests for wells that are equipped with water-level data loggers and based on manual measurements. Locations of the well nests with data loggers are shown on Figure 5-9B. Calculated vertical gradients based on the data logger program and on manual measurements are evaluated below.

5.1.7.1 Data Logger Program

The vertical hydraulic gradients were calculated as the water elevation measured in the well with the shallower screen minus the water elevation measured in the well with the deeper screen, divided by the vertical separation between the screen midpoints. Based on this definition, negative vertical hydraulic gradients indicate an increasing hydraulic head with depth in the aquifer and suggest movement of water from deeper in the formation toward the shallower portion of the formation (upward gradient). Conversely, positive vertical hydraulic gradients indicate a decreasing hydraulic head with depth in the aquifer and suggest movement of water from shallower in the formation toward the deeper portion of the formation (downward gradient).

All combinations of nested wells with data loggers were considered in this analysis. Details on the calculation of errors associated with these gradient estimates are presented in Appendix 5-A. The complete set of plots for each well nest with data loggers is shown in Attachment D of Appendix 5-A. Due to the small head difference that typically occurs in nested wells and relatively large errors introduced through using the data loggers and by frost jacking of the well casings, the direction of the gradient is within the margin of error in many cases.

Table 5-7 summarizes nested wells monitored with data loggers in which the vertical gradient is quantified during at least some portion of the period of record. For comparison, the results of manual measurements of the vertical gradient described in Section 5.1.7 are compared with the data logger results. The manual and data logger evaluations agree in terms of the sense of flow (whether it has an upward component or a downward component based on the vertical head differences).

5.1.7.2 Manual Measurements

Manual water-level measurements collected concurrently with surveys of the top elevations of the well casings were recorded at selected nested wells both offsite (Tables 5-8a and 5-8b and Figure 5-10) and onsite (Tables 5-9a and 5-9b and Figure 5-11) since March 2013. This manual measurement program was implemented to obtain information on frost jacking of the well casings and to provide accurate hydraulic head difference calculations for a small number of well nests while the data logger standard operating procedure was under development (SWI 2013, Barr 2013a). The random errors associated with each hydraulic head calculation are the quadratic sum of the water-level measurement error (±0.01 foot) and the top of casing survey error (±0.01 foot), for a total error of ±0.014 foot. The error associated with a calculated hydraulic head difference is the quadratic sum of the random errors associated with the two hydraulic head values, or 0.02 foot.

Significant findings from the offsite vertical gradient observations based on monthly manual measurements are summarized below:

- The vertical head difference between wells MW-148A-15 and MW-148B-30 was downward or within the margin of error on the estimate. The vertical head difference between wells MW 148B-30 and MW-148C-55 was upward or within the estimated margin of error. This is consistent with the concentration trends, which are highest in MW 148B-30. These head and concentration trends likely reflect the preferential flow path of groundwater to a more conductive zone, focusing flow at this location.

- The vertical head difference between wells MW-160AR-15 and MW-160B-90 was upward, except for the May measurement. This is consistent with topography on top of permafrost, which is higher at this location than to the south. Such a sloping surface in the direction of groundwater flow would tend to create an upward gradient. The vertical head difference between MW-160AR-15 and MW-160B-90 is not consistent with the higher sulfolane concentrations measured in MW-160B-90. The lower sulfolane concentrations in MW-160AR-15 likely reflect degradation of sulfolane in the gravel pit south of that well nest and recharge to the shallow portion of the suprapermafrost aquifer.

- The vertical head difference between wells MW-162A-15 and MW-162B-65 were downward when the well could be measured. This is consistent with the relatively higher sulfolane concentrations measured in MW-162B-65.

- The vertical head difference in the MW-318 well nest (the well nest closest to the Tanana River) was oriented downward at all times when the required measurements could be made. This was likely caused by the Tanana River recharging the shallow aquifer. Note that the isotopic signature at this well nest was interpreted to represent a mixture of water types (i.e., was found to be dissimilar from the Tanana River signature) (Barnes and Barnes 2013).

Significant findings from the onsite vertical gradient observations based on monthly manual measurements are as follows:

- Head differences in the MW-186 well nest are consistently upward. This is primarily caused by the location of this well nest in the recovery well network. This is further discussed below.

- Vertical head differences in the MW-304 well nest indicate upward flow between MW-304-15 and MW-304-80. This is consistent with the sulfolane concentrations in these wells. Head differences between MW-304-80 and MW-304-125 and between MW 304-125 and MW-304-150 are within the margin of error of the estimate.

- Vertical head differences in the MW-306 nest indicate a downward hydraulic gradient or head differences within the margin of error of the calculation. This well nest is located east of the sulfolane plume; therefore, sulfolane concentrations are not present and thus cannot be compared.

In addition to the monthly measurements, manual measurements of water levels and top of well casing surveys were made during the 2013 aquifer testing (Barr 2013b). Hydraulic head differences calculated with the onsite groundwater recovery system off (June 3, 2013) and after the recovery system had been pumping for three days (June 6, 2013) are presented in Table 5-10. The changes in head difference between these two dates are due primarily to pumping of the groundwater recovery system. Significant findings in these data are summarized below:

- Head differences in the MW-174 well nest are oriented downward or within the margin of error of the calculation. The downward head difference between wells MW 174-15 and MW-174A-50 without the recovery system pumping (on June 3, 2013) was reduced to less than the margin of error on the calculation by June 6, 2013, likely due to operation of the recovery system.

- Vertical head differences in the MW-186 nest indicated a convergence of flow toward the MW-186E-75 screen from above and below when the recovery system was not pumping, but a continuous upward gradient throughout the well nest when the recovery system was pumping. This suggests that preferential flow might occur toward the elevation of the MW-186E-75 screen, if the recovery well system did not influence flow.

- As noted above, vertical head differences in the MW-306 nest indicate a downward hydraulic gradient with and without the recovery system pumping. No permafrost was encountered in this well nest to a depth of 150 feet bgs although shallow permafrost was observed directly downgradient. This well nest is located east of the sulfolane plume.

- A relatively large, upward head difference of -0.32 ft was measured between MW-310-15 and MW-310-110. This may reflect convergence of flow in the shallower portion of the aquifer toward the NGP. The head difference was still upward, but reduced to -0.21 ft after 3 days of pumping of the recovery system. This likely reflects the discharge of treated water from the recovery system to the NGP, raising the head in the pit and adjacent shallow portions of the aquifer relative to the higher heads deeper in the aquifer.

5.1.8 Analyses of Hydrographs from the Suprapermafrost Aquifer

The continuous records of depth to water measurements recorded by the data loggers from late 2010 through 2013 provide insight into the hydraulic responses of the aquifer system. Overall trends were evaluated along with seasonal variation in responses of groundwater elevations to barometric pressure variations. Results of these evaluations are presented in the following subsections.

5.1.8.1 Overall Hydrograph Trend Evaluation

Methods used to evaluate hydrograph trends are presented in Section 5 of Appendix 5-A. Two characteristic trends were identified that are exhibited by the vast majority of wells completed in the suprapermafrost aquifer. The characteristics that differentiate these trends and the spatial distribution of wells exhibiting the trends are summarized below.

The magnitude of the groundwater elevation rise caused by the 2013 spring breakup event, which peaked in early June, was markedly larger at wells onsite and offsite west of Badger Slough than those wells close to Badger Slough. This is primarily due to the greater distance from the Tanana River to the wells near Badger Slough. In addition, the hydrographs for wells near Badger Slough (e.g., MW-325-18) exhibit marked increases in groundwater elevation from December 2012 through April 2013, whereas the groundwater elevation in wells further from Badger Slough show no such rise in groundwater elevation in the same time period.

The cause of increase in groundwater elevation from December 2012 through April 2013 in wells near Badger Slough is likely related to recharge of the suprapermafrost aquifer from the subpermafrost aquifer through the thawed zone beneath Badger Slough. This is based on the similarity of hydrographs of other wells near the slough to that of MW-325-18 and vertical gradients at the MW-181 well nest (Table 5-8), and is consistent with preliminary stable isotope results that indicate mixing of subpermafrost and suprapermafrost water in this area (Barnes and Barnes 2013).

Three wells have hydrographs that do not fit in the categories described above: MW-166A-15 and MW-194A-15, which resemble each other, and MW-320-20, which does not resemble any of the other wells. Appendix 5-A presents additional information on these three wells. Figure 5-12 shows the spatial relationships between wells with data loggers classified into the three groups described below:

- **T** symbolizes wells that exhibit a trend dominated by the influence of the Tanana River as described above. This group includes wells at the NPR beneath which no permafrost is known to exist.

- **O** symbolizes wells that exhibit increases in groundwater elevation over the winter and are less dominated by the influence of the Tanana River. All of the wells in this group are in or near the area beneath Badger Slough where permafrost was not encountered to depths of 150 feet bgs and where geophysical data indicate a thawed zone potentially connecting the subpermafrost and suprapermafrost aquifers.

- **166/194** indicates wells MW-166A-15 and MW-194A-15, whose hydrographs resemble each other and no other wells. These wells are adjacent to Ditch C, which may explain the observed trends.

5.1.8.2 Barometric Pressure Effects

Seasonal variations in the barometric efficiency are apparent in of many of the wells monitored using data loggers. For example, Figure 5-13 shows the recorded barometric pressure and hydrographs for wells MW 162A-15, MW-325-18, and MW-325-150. Barometric pressure in feet of water is plotted such that changes in groundwater elevation caused by variations in barometric pressure have the same response. The scale of the barometric pressure plot is half of that of the groundwater elevation. Two peaks in barometric pressure are indicated with arrows on Figure 5-13. These events occurred in December 2012 and January 2013, when seasonal frost was present. The hydrographs of the three wells on Figure 5-13 and many other wells with data loggers showed sudden, corresponding drops in water level. This correlation is believed to be a reflection of seasonal frost temporarily creating confined conditions and increasing the barometric efficiency of the suprapermafrost aquifer.

The indication of seasonal frost creating temporarily confining conditions is consistent with the response to pumping noted during the expanded recovery system startup aquifer testing (Barr 2013b). Time-drawdown data from observation wells gathered during the sequential pumping of four separate recovery wells did not show a characteristic unconfined aquifer response. The observed responses are believed to have been caused by seasonal frost penetrating below the water table elevation, creating confining conditions. Downward extension of seasonal frost into the suprapermafrost aquifer is described by Williams (1970). Seasonal frost acting as a confining layer above shallow groundwater is described by Kane et al. (1973).

5.1.9 Analysis of Hydrographs from the Subpermafrost Aquifer

Prior to August 2013, the data logger program consisted entirely of wells installed above permafrost or in areas where no permafrost is known to exist at depth. On August 22, 2013, a data logger was installed in deep privately owned well PW-1230, also known informally as the Tanana Drive well and indicated in the NPR database as PW_ID_1230. This well was installed through and completed below permafrost in 1982. A two-well nest of suprapermafrost monitoring wells was installed adjacent to the Tanana Drive well to track groundwater elevations above the permafrost (MW-349-15 and MW-395-45).

Suprapermafrost monitoring wells MW-349-15 and MW-345-45 were installed in August 2013. The privately-owned well at this residence (PW-1230) was installed in 1982 and penetrated permafrost from 33 to 205 feet bgs. Well PW-1230 has a total depth of 231 feet. Ice was observed in the well in a borehole video, suggesting that the permafrost is intact (a thawed annulus is not believed to exist around the well casing).

Data loggers were installed in all three wells and have been recording groundwater levels since August 22, 2013. Top of casing surveys and manual depth to water measurements were made in all three wells on August 22 and October 21, 2013 (see Table 5-11). Figure 5-14 shows hydrographs of groundwater elevations in wells MW-349-15, MW-395-45, and PW-1230 based on manual measurements and data loggers.

The vertical gradient between suprapermafrost wells MW-349-15 and MW-349-45 was oriented downward during both measurement events. The head difference across the permafrost between wells MW 349-45 and PW-1230 was oriented upward on August 22, 2013 and downward on October 21, 2013. The hydrographs from the data loggers for suprapermafrost wells MW-349-15 and MW-395-45 exhibit strong similarities. In contrast, the hydrograph for the subpermafrost well shows overall similarity but also some differences from those of the suprapermafrost wells. This suggests that the overall controls on the hydraulic heads above and below permafrost are similar but not identical and may change seasonally.

Data from wells MW-349-15, MW-349-45, and PW-1230 and nearby suprapermafrost monitoring wells MW-157A-15 and MW-162A-15 are presented on Figure 5-15. Data from the two latter wells are plotted on a separate Y-axis that is scaled the same as that for the Tanana Drive wells, but offset so the plots can more readily be compared. All of the hydrographs from the suprapermafrost wells are similar. Two particular times are called out on Figure 5-15 with vertical tie lines. Water levels in the suprapermafrost wells rose and then fell at the times indicated by these lines (August 25 and September 14, 2013). The maximum elevation of the latter event was somewhat higher in the suprapermafrost wells, except for MW-157A-15. In contrast, the peaks occurred earlier in PW-1230 and the peak of the second event was markedly lower (0.2 foot) than that of the first event.

Because the vertical gradient in the suprapermafrost wells did not change, the head difference across the permafrost reversed direction, and dissimilarities exist in the hydrographs, it is likely that no hydraulic connection exists across the permafrost near these wells.

6. Offsite Surface Water Investigation Summary

Surface-water samples were collected in August and October 2010 from the North and South Gravel pits (onsite) and from Badger Slough. Laboratory analysis of these samples indicated that sulfolane concentrations were not detected above the detection limit. In 2012, four pore water samples were also collected from locations adjacent to multiple offsite gravel pits. Although sulfolane concentrations in these samples were detectable, it was noted that the adjacent gravel pits were frozen at the time of sample collection; therefore, the results were likely more representative of groundwater than surface water. Measured levels were consistent with shallow groundwater in the vicinity. Locations of historical surface water and pore water samples are shown on Figure 6-1.

Extensive sampling was conducted in the NGP in 2013 as reported in the Onsite Addendum (ARCADIS 2013h). Twenty-six sulfolane samples were collected from the NGP at various locations and depths within the pit, and sulfolane concentrations were not detected in any of the samples (ARCADIS 2013h).

The Ecological CSM (ARCADIS 2011a) determined that the primary exposure pathway for ecological receptors to be exposed to sulfolane is through direct contact with or ingestion of surface water, if surface water is impacted. However, based on surface water samples collected in 2010, the CSM concluded that surface water was not known to be impacted; therefore, the exposure pathway was incomplete. Results of the 2013 surface water sampling further confirm this conclusion, and no further investigation with respect to ecological receptors is warranted.

The Revised Draft Final HHRA (ARCADIS 2012a) evaluated the potential risk to residents who use the offsite gravel pits and other surface water for recreational swimming. For the risk assessment, results from pore water samples collected near the gravel pits were used to represent conservative concentrations of sulfolane in surface water. However, the pore water samples were collected when the adjacent gravel pits were frozen; therefore, the samples were more likely representative of groundwater than surface water (ARCADIS 2012a). Results of the 2013 surface water sampling support this assumption and further confirm that there is no unacceptable risk associated with recreational swimming in offsite surface water bodies.

7. Offsite Groundwater Characterization

This section summarizes analytical data collected from offsite groundwater monitoring wells and private wells within the area of the sulfolane plume. Sulfolane concentrations in groundwater presented in this section are compared to the ACL of 362 µg/L.

7.1 Deep Private Well Groundwater Monitoring

A comparison of geochemical conditions of the suprapermafrost and subpermafrost aquifers near three deep private wells, during a single sampling event, was presented in the SCR – 2011 (Barr 2012). Subsequently, the Deep Private Well Groundwater Monitoring Plan (monitoring plan; ARCADIS 2012b) was submitted to ADEC on June 20, 2012 and an updated monitoring plan was resubmitted in the Offsite SCWP (ARCADIS 2013d). The monitoring plan (ARCADIS 2012b) proposed quarterly collection of sulfolane and geochemical data from a larger network of deep private wells for 2 years. The objectives of the monitoring plan (ARCADIS 2012b) were to:

- Establish a groundwater monitoring network of deep private wells with intake intervals reported to be in the subpermafrost zone.
- Establish a baseline dataset of sulfolane concentrations and geochemical conditions at the deep private well groundwater monitoring network.
- Monitor sulfolane concentrations and geochemical conditions quarterly for 2 years at deep private wells in areas where sulfolane has been previously detected.

The monitoring plan (ARCADIS 2012b) identified private well locations inside the detectable sulfolane groundwater plume (internal plume locations), and along the perimeter of the sulfolane groundwater plume (perimeter locations). The candidate deep private wells had intake intervals reported to be in the subpermafrost zone. Subsequently, it was determined that shallow (suprapermafrost) private wells also existed on the same properties as two deep private wells.

The monitoring plan (ARCADIS 2012b) presented a two-phase implementation approach. The objective of Phase I was to select candidate wells and to obtain access agreements for sampling the selected wells. The objective of Phase II was to sample the selected wells, with access agreements in place, quarterly for 2 years. While homeowners were not always present to allow sampling at some locations during the quarterly events, most of the proposed data were successfully collected during the three quarters of implementation. Details of the finalized 2013 deep private well monitoring network and results from the first three quarters of monitoring are presented in this Offsite Addendum. Sampling locations are presented on Figure 7-1.

7.1.1 Monitoring Network

In 2013, access was obtained for 20 private wells on 18 properties. Eighteen of these wells have intake intervals reported at depths below permafrost (based on installation logs), with total depths between approximately 89 and 305 feet bgs, while two wells have reportedly shallow intake intervals at approximately 24 and 30 feet bgs and are located on the same properties as deep wells. Table 7-1 presents available well construction details for private wells included in the 2013 deep residential monitoring network. Figure 7-2 shows the locations of private wells included in the monitoring network, along with nearby monitoring wells at which geochemical data have been historically collected.

As shown on Figure 7-1, the deep residential monitoring network consists of:

- Four perimeter locations, including:
  - Deep private well PW-0972 and adjacent shallow private well PW-1458, located west of the sulfolane plume, and south of Richardson Highway
  - Deep private well PW-0259, located northwest of the sulfolane plume
  - Deep private well PW-1343, located east of the sulfolane plume, and south of private well PW-0332
  - Deep private well PW-0332, located east of the sulfolane plume, and north of private well PW-1343
- Fourteen internal locations, which may be further subdivided as follows:
  - Two deep private wells, PW-1230 and, if access can be obtained, PW-1626, which are located approximately 1 mile hydraulically downgradient from the NPB. Private well PW-1230 is established in the network and two shallow monitoring wells have been installed on this property for further studies. Private well PW-1626 was identified and initially sampled during third quarter 2013. Efforts are underway to establish an agreement with the owner for ongoing monitoring and to add this well to the network.
  - An arc of four private wells, located approximately 1.7 miles downgradient from the NPB and spanning the lateral extent of detectable sulfolane impacts. From west to east, these wells include PW-1099, PW-0217, PW-1155, and PW-0358.
  - A cluster of eight private well locations approximately 2 to 2.6 miles downgradient from the NPB and east of the centerline of the zone of sulfolane impacts. From south

to north, these wells include PW-0658, PW-0466, PW-0464, PW-0463, PW-0943, PW-0932, PW-1109, and PW-0296 and adjacent shallow private well PW-0297.

Samples were collected during the first (March and April), second (June), and third (September and October) quarters in 2013. Samples were analyzed using the following approved USEPA methods, in accordance with the RSAP:

- Field parameters – Temperature, pH, specific conductivity, dissolved oxygen (DO), and oxidation-reduction potential (ORP) using standard field instruments and procedures
- USEPA Method 1625B with isotopic dilution – Sulfolane
- USEPA Method 200.8 – Total and reduced iron, manganese on both filtered and unfiltered samples
- USEPA Method 200.8 – Calcium, magnesium, potassium, sodium
- USEPA Method 350.1 – Ammonia
- USEPA Method 300 – Nitrate, nitrite, chloride, sulfate
- USEPA Method SM2320B – Alkalinity
- USEPA Method RSK-175 – Dissolved methane
- USEPA Method SM5310 – TOC

Field parameter data are presented in Table 7-2 and sulfolane and geochemical analytical results are presented in Table 7-3.

7.1.2 Private Well Integrity Investigation

A third phase of deep well monitoring was proposed to evaluate the connectivity of, and vertical gradients between, suprapermafrost and subpermafrost water-bearing zones. The Phase III activities included a down-hole camera inspection that was conducted in a residential well (PW-1230) on April 5, 2013 to verify the well construction information detailed on a boring log discovered in the ADEC septic record files. Due to the variations in details in private well logs and sulfolane results from a water sample collected from PW-1230 on March 11, 2013 (558 µg/L), it was valuable to verify the well construction. The boring log indicates that the well that was constructed in 1982 and is cased to 231 feet bgs; permafrost was encountered from 33 to 205 feet bgs at the time of installation and the submersible pump was set to 210 feet bgs. The well was the closest known private well to the NPR that was installed through permafrost until the confirmation of PW-1626 which is slightly closer.

Following pump removal at well PW-1230, a submersible video camera was used to observe the inside casing. Due to buildup on the walls and poor water clarity, a majority of the well casing was not viewable. However, in areas where welded seams were visible, they appeared to be intact and in good condition. Ice was observed along the sides of the wall; the first viewable ice was noted at approximately 74 feet bgs. In addition, large pieces of ice that had been attached to the well casing were pulled out of the well when the camera was removed. The camera could not be lowered deeper than approximately 225 feet bgs due to an obstruction. A perforated screen was not observed at the obstruction. It was concluded that the observed well is the private well noted on the boring log and was installed through permafrost. Monitoring well MW-349-45 was installed in the area of PW-1230 and permafrost was observed at 46 feet bgs.

Well PW-1230 was restored to the original condition for future deep residential sampling events and is secured to prevent use by the tenants of the property. The well is sampled quarterly as part of the expanded deep residential monitoring plan presented in the Offsite SCWP (ARCADIS 2013d).

Additional camera verification work is planned as part of Phase III. Two additional locations within the deep well network are being pursued for camera verification. The results will be provided to ADEC if that work can be completed.

7.1.3 Deep Private Well Sulfolane Results

Groundwater samples were collected in March, June, and September 2013 from 17 residential wells reported to have been installed below permafrost. In addition to the residential water supply wells at PW-0296 and PW-0972, garden wells identified as PW-0297 (installed to 24 feet bgs) and PW-1458 (installed to 30 feet bgs), respectively, were sampled beginning in second quarter 2013. Laboratory analytical results from groundwater samples collected in fourth quarter 2013 were not available for this submittal and will be incorporated into quarterly groundwater monitoring reports. Deep residential private well and garden well results are summarized in Table 7-3 and the latest groundwater result for each location (third quarter 2013) is shown on Figure 7-1, except for one location, which could not be sampled during the third quarter.

Sulfolane was detected at a concentration of 652 µg/L in the groundwater sample collected from deep private well PW-1230 during the third quarter 2013 monitoring event; this was the only offsite location with a concentration exceeding the ACL in third quarter 2013. The sulfolane concentration in the groundwater sample from PW-1230 represents the location with the highest current offsite sulfolane concentration. Private well PW-1492, located upgradient of well PW-1230 did not contain detectable concentrations of sulfolane in the sample collected July 2012. Additionally, sulfolane was not detected in deep private wells at the downgradient distal end of the sulfolane plume (e.g. PW-0389, PW-0976 and PW-1088). Sulfolane distribution in offsite groundwater is described further in subsequent sections.

7.1.4 Geochemical Field Parameter Results

Geochemical field parameter results from deep private wells are summarized below:

- *Groundwater temperature*. Groundwater temperatures between approximately 0.2 and 4.8 degrees Celsius (°C) were measured, with a higher average temperature measured during the second quarter sampling event (1.6 °C) compared to the first quarter (1 °C), and third quarter (1.3 °C) sampling events.

- *DO.* DO concentrations between approximately 0.1 and 2 milligrams per liter (mg/L) were measured, with a higher average DO concentration measured during the third quarter sampling event (0.6 mg/L) compared to the first quarter (0.1 mg/L) and second quarter (0.2 mg/L) sampling events.

- *Specific conductivity.* Specific conductivity values between approximately 172 and 442 microSiemens per centimeter (µS/cm) were measured, with a higher average specific conductivity measured during the second quarter sampling event (239 µS/cm) compared to the first quarter (221 µS/cm) and third quarter (228 µS/cm) sampling events.

- *Acid-Base Indicator.* pH values between approximately 6.7 and 8.2 standard units were measured, with similar average pH values measured in the first quarter (7.3 standard units), second quarter (7.3 standard units), and third quarter (7.1 standard units) sampling events.

- *ORP.* ORP measurements between approximately -296 and 19 millivolts (mV) were measured, with a more-positive average ORP measured during the first quarter sampling event (-144 mV) compared to the second quarter (average of -151 mV) and third quarter (average of -154 mV) sampling events.

7.1.5 Oxidation-Reduction Indicator Parameters

Sulfolane may be degraded in groundwater via naturally occurring oxidation-reduction (redox) reactions that couple sulfolane transformations to the reduction of available electron acceptors. These reactions can be biologically mediated by native soil bacteria or abiotic. The main redox processes that typically occur in aquifers include aerobic respiration, nitrate reduction, metals reduction (e.g., iron and manganese), sulfate reduction, and methanogenesis. FHRA has collected a substantial amount of geochemical data at the site, including several redox indicator parameters that can be used to evaluate the presence and extent of redox reactions in groundwater that may be coupled to sulfolane degradation. These redox indicators include such parameters as ORP and concentrations of DO, nitrate, nitrite, ammonia, manganese species (i.e., Mn II and Mn IV), iron species (Fe II and Fe III), sulfate, and methane. These are described and interpreted below.

Concentrations of electron acceptors (DO, nitrate, and sulfate) and anaerobic reaction products (methane, ammonia, ferrous iron, and reduced manganese) were used to evaluate the redox state of the groundwater. Data are presented in Tables 7-2 and 7-3 and summarized below:

- DO concentrations were generally less than or approximately equal to 1 mg/L, indicating an overall lack of DO and potential presence of reducing aquifer conditions (note, the saturation concentration of DO in water at standard groundwater temperatures measured at the site is approximately 13.5 mg/L).

- Nitrate, nitrite, and ammonia concentrations were low to nondetect and showed little seasonal variability between the first, second, and third quarters 2013. Nitrate concentrations between nondetect and approximately 0.1 mg/L, nitrate concentrations between nondetect and approximately 0.3 mg/L, and ammonia concentrations between nondetect and approximately 0.6 mg/L were measured. The presence of ammonia in some samples indicates the presence of nitrate-reducing geochemical conditions in groundwater near the location where the ammonia-containing samples were collected.

- Dissolved and total manganese concentrations between nondetect and approximately 1.9 mg/L were measured, with manganese occurring predominantly in the dissolved form at an average concentration of 0.8 mg/L during the first, second, and third quarters 2013. The presence of dissolved manganese in some samples indicates the presence of manganese-reducing geochemical conditions in groundwater.

- Dissolved (ferrous) iron concentrations between nondetect and approximately 16.6 mg/L were measured, with a higher average concentration measured in groundwater samples collected during the second quarter 2013 (5.4 mg/L) compared to the first (4.4 mg/L) and third (4.8 mg/L) quarters 2013. The presence of ferrous iron in samples indicates the presence of iron-reducing geochemical conditions in groundwater.

- Total iron concentrations between nondetect and approximately 122 mg/L were measured, with a higher average concentration measured in groundwater samples collected during the second quarter 2013 (11.3 mg/L) compared to the first (7.1 mg/L) and third (9.2 mg/L) quarters 2013.

- Ferric iron concentrations were estimated based on the difference between total iron and dissolved (ferrous) iron concentrations, and ranged from approximately 0 to 117 mg/L, with a higher average concentration measured in groundwater samples collected during the second quarter 2013 (5.9 mg/L) compared to the first (2.8 mg/L) and third (4.4 mg/L) quarters 2013. The estimated ferric iron concentration of 117 mg/L was collected from well PW-1230, which was highly turbid. The presence of ferric iron in groundwater indicates that ferric iron is available as an electron acceptor.

- Sulfate concentrations ranged from approximately 13 to 32.5 mg/L, except for one sample with a nondetect concentration. Sulfate concentrations showed little variability between sampling events, with average concentrations of 23.4, 22.2, and 23.9 mg/L measured in groundwater samples collected during the first, second, and third quarters 2013, respectively. Depleted sulfate concentrations in groundwater indicate the presence of sulfate-reducing geochemical conditions in groundwater.

- Methane concentrations between nondetect and approximately 1.4 mg/L were measured, with a higher average concentration measured in the first quarter (0.13 mg/L) compared to the second (0.05 mg/L) and third (0.06 mg/L) quarters 2013. The elevated average methane concentration during the first quarter 2013 sampling event is largely attributable to an elevated methane concentration measured in private well PW-1230. Elevated methane concentrations in groundwater indicate the presence of methanogenic geochemical conditions.

When private well PW-1230 was sampled during the first quarter 2013, the field sampling technicians reported that gas bubbles and sediment were present in the water soon after the spigot was turned on. The analytical sample collected from this well during this sampling event had the maximum concentration of methane detected within the private well network (1.4 mg/L), elevated concentrations of ammonia (0.289 mg/L) and total iron (37.2 mg/L), high ratios of total to dissolved iron and manganese, and a relatively low sulfate concentration (18.2 mg/L). Additionally, the water sample collected from this well during the first quarter sampling event had the lowest ORP (-295.9 mV) and DO (0.06 mg/L) levels yet observed in the deep residential well network.

During the second quarter 2013 sampling event, black, turbid water was noted in private well PW-1230. The sample collected from this well had the highest concentrations of ammonia (0.615 mg/L) and total iron (122 mg/L) yet measured, high ratios of total to dissolved iron and manganese, along with a relatively depleted sulfate concentration (17.5 mg/L). The methane concentration measured in the second quarter 2013 was substantially lower than that measured in the first quarter 2013 (i.e., 0.009 mg/L in June versus 1.4 mg/L in March). During the third quarter 2013 sampling event, turbid water was noted and a relatively elevated DO concentration (1.6 mg/L) was measured. The groundwater sample collected during the third quarter 2013 event had an elevated total iron concentration (78.9 mg/L), high ratios of total to dissolved iron and manganese, along with a relatively low sulfate concentration (16.6 mg/L). Elevated pH values (7.9 to 8.2) were measured during the first, second, and third quarter 2013 sampling events. This well has also produced samples with the highest offsite sulfolane concentrations detected to date, which varied from approximately 497 to 652 µg/L during the first, second, and third quarters 2013.

The presence of elevated concentrations of methane and ammonia along with low sulfate concentrations in groundwater samples collected from private well PW-1230 suggest that organic carbon is present in soil or groundwater near this well, which is being anaerobically biodegraded in situ or within or along the well screen and casing. During Phase III of the monitoring plan (ARCADIS 2012b), a camera survey of private well PW-1230 was conducted to determine the condition of this well. Results of the camera survey showed that the inside of the well casing was in good condition and did not show visual evidence of corrosion.

Relatively high ratios of total to dissolved iron were measured in samples collected during the first quarter 2013 sampling event at private wells PW-0217, PW-0658, PW-0943, PW-1343, PW-0464, PW-0358, and PW-0932. The difference in the proportion of dissolved to total iron between the first quarter 2013 and the second and third quarters 2013 suggests a seasonal shift in the redox character of groundwater with more oxidizing conditions inferred from data collected during first quarter 2013.

During the first, second, and third quarters 2013, elevated concentrations of TOC (5.4 to 6.6 mg/L) and methane (0.2 to 0.3 mg/L), along with relatively low concentrations of sulfate (13 to 13.5 mg/L) were measured in groundwater samples collected from private well PW-1109. The relatively low concentrations of sulfate suggest that sulfate-reducing geochemical conditions were present in groundwater near this well at the time of sampling.

Taken as a whole, the redox indicator parameters provide evidence of reducing aquifer conditions suggesting some amount of seasonal variability in the concentration and speciation of iron at a subset of private wells. The redox parameter indicator results are consistent with previous analyses of geochemical data collected from suprapermafrost groundwater at the site.

7.1.6 Major Ion Compositions

Differences in major ion compositions in groundwater samples collected from different locations may indicate distinct water sources. Ion concentration data are presented in Table 7-3, and stiff diagrams showing the ion data were created to visually compare major ion compositions between samples. Stiff diagrams are a graphical representation of the ionic composition of a water sample. Anions are plotted to the right of the diagram, and cations are plotted to the left. Measured concentrations are converted from mg/L to millequivalents per liter by multiplying the concentration of each ion by its valence and dividing by the atomic mass of the ion. Major ions plotted on stiff diagrams, in a clockwise direction, include chloride, bicarbonate (as bicarbonate alkalinity), sulfate, ferric iron, ferrous iron, magnesium, calcium, and sodium plus potassium. Stiff diagrams provide an efficient, visual method to analyze and compare the ionic composition of water samples.

Stiff diagrams were generated for each private well with ion concentrations measured during the first, second, and third quarter 2013 sampling events (Appendix 7-A). Major ion concentrations were measured at select monitoring well locations in March 2011 and were presented in the SCR – 2011 (Barr 2012). Stiff diagrams presenting this data on the same scale as private well stiff diagrams are included on Figure 7-2 for direct comparison with private well results.

Except for differences noted in the following section on seasonal variability, concentrations of major ions did not show strong seasonal differences between the first, second, and third quarter 2013 sampling events at private well locations. Stiff diagrams from the third quarter 2013 sampling event are representative of the observed groundwater type at each well, and are presented in map view on Figure 7-2.

A visual comparison of stiff diagrams, as presented in the legend on Figure 7-2, suggests that three distinctive groundwater types are present throughout the site groundwater monitoring network. Distinctions are based primarily on relative concentrations of calcium and bicarbonate alkalinity, but also on total ion concentrations. The average value and standard deviation of temperature, DO, specific conductivity, pH, and ORP values for each of these groups in each monitoring quarter are presented in Table 7-4.

The different groundwater types identified at the site are most likely due to different residence times of groundwater within the suprapermafrost and subpermafrost aquifers, with relatively older groundwater having a longer time to equilibrate with aquifer minerals and relatively younger groundwater having less time to accumulate ions. For this analysis, the different groundwater types have been designated as Type A, Type B, or Type C. Defining characteristics are summarized below:

- *Type A*. Interpreted to be representative of resident groundwater that is older than Type B groundwater, and is characterized by higher concentrations of dissolved ions (e.g., calcium) compared with Type B groundwater. Type A water samples also had higher average specific conductivity values, higher alkalinity concentrations, and relatively positive average ORP conditions compared with Type B groundwater.

- *Type B*. Interpreted to represent younger groundwater that has entered the aquifer more recently than Type A groundwater, and has had less time to equilibrate with aquifer minerals. Type B groundwater is characterized by lower concentrations of dissolved ions (e.g., calcium) compared with Type A groundwater. Type B water samples also had lower average specific conductivity values, lower alkalinity concentrations, and relatively negative average ORP conditions compared with Type A groundwater.

- *Type C*. Interpreted to be indicative of mixing between Type A and Type B groundwater.

As shown on Figure 7-2, these different water types exhibit clustering and other spatial patterns that are approximately correlated with the location of surface water features near the site. For example, available data from monitoring wells (March 2011) indicate that these wells generally fall within the Type A (relatively older groundwater) designation, although mixing is suggested at some locations by the range in ion compositions observed. Private wells PW-

1109 and PW-1343, installed at total depths of approximately 305 and 94 feet bgs, respectively, are also designated Type A (relatively older groundwater). As shown on Figure 7-2**,** private wells designated as Type B (relatively younger) are located adjacent to the Tanana River and Badger Slough, while centrally located private wells are designated Type C (mixing). Shallow private wells PW-1458 and PW-0297 are designated Type C (mixing), and appear to have higher major ion concentrations than adjacent deep private wells.

These groundwater types were also compared with available results from the UAF analysis of stable isotopes in groundwater samples collected concurrently during the first quarter 2013 (Barnes and Barnes 2013). Clustering of well samples with Type A, B, and C ion compositions is also observed on plots of stable oxygen vs. stable hydrogen isotopic compositions, which further supports the designation of these water types. These results indicate distinctive differences in groundwater types in and around the site that may be used to validate the understanding of the fate and transport of sulfolane. For example, at the PW-0972 and PW-1458 private well locations, different water types at these wells demonstrate that permafrost is a vertical barrier to mixing.

7.1.7 Comparison of Deep Private Well and Suprapermafrost Geochemical Data

A direct comparison of suprapermafrost and subpermafrost groundwater can be made at the two private well monitoring locations where both shallow and deep wells are available for monitoring.

Subpermafrost private well PW-0972 and suprapermafrost private well PW-1458 are located west of the zone where sulfolane has been detected, and south of Richardson Highway, near the Tanana River. Groundwater at private well PW-0972 (subpermafrost) is designated Type B (relatively younger), and groundwater at adjacent shallow private well PW-1458 (suprapermafrost) is designated Type C (mixing). Higher DO concentrations were measured in the subpermafrost well relative to the suprapermafrost well during the second and third quarters of 2013 (the suprapermafrost well was not sampled during the first quarter 2013). Additionally, lower ORP values were measured in the subpermafrost well, relative to the suprapermafrost well during the second and third quarters. The suprapermafrost well is characterized by higher temperature and lower pH. This information suggests relatively recent recharge to the subpermafrost aquifer and the presence of waters in equilibrium with aquifer materials in the suprapermafrost aquifer.

Subpermafrost well PW-0296 and suprapermafrost private well PW-0297 are located east of Badger Road in the northern portion of the plume. Groundwater in private wells PW-0296 and PW-0297 is designated Type C (mixed), and groundwater collected from the suprapermafrost well has higher ion concentrations than groundwater collected from the subpermafrost well, again suggesting that the subpermafrost aquifer has received recent recharge from a source with a low ionic composition.

7.1.8 Seasonal Variability in Deep Private Wells

As illustrated on the stiff diagrams presented in Appendix 7-A, little seasonal variability was observed at most private well locations; however, a few notable changes were identified.

Private wells PW-0332 and PW-1343 are located east of the sulfolane plume. Private well PW-0332 is located approximately 0.5 mile northwest of private well PW-1343. Private well PW-0332 is reported to have been completed to a total depth of approximately 266 feet bgs, while private well PW-1343 is reported to have been completed to a total depth of approximately 94 feet bgs. Seasonal variability was observed at both of these wells. Specifically, during the first and third quarters, groundwater at private well PW-1343 was designated Type A (older). During the second quarter, substantial decreases in calcium, iron, manganese, magnesium, and potassium concentrations along with a dramatic increase in sodium concentration were observed. During the first quarter, a geochemical signature was observed at private well PW-0332 similar to that observed during the second quarter at private well PW-1343, with a highly elevated sodium concentration. During the second and third quarters, groundwater in private well PW-0332 was designated Type B (relatively younger).

Additional seasonal changes identified by changes in the shape of stiff diagrams include: changes in iron concentrations and speciation between monitoring events, as discussed in Section 7.1.5, and sulfate depletion at private well PW-1099 during the second quarter.

7.1.9 Deep Private Well Summary

Based on the geochemical evaluation of deep private wells, preliminary conclusions include:

- Geochemical conditions in both the suprapermafrost and subpermafrost aquifers are generally reducing. Although DO concentrations were slightly higher at deep private wells during the third quarter 2013, concentrations in both the suprapermafrost and subpermafrost aquifers generally remain below 1 mg/L.

- Iron concentration and speciation appears to be seasonally variable to some extent.

- Unique biogeochemical conditions including elevated methane, elevated ammonia and elevated ratios of total to dissolved metals were found in groundwater samples collected from private well PW-1230. In particular, elevated methane concentrations at this private well during the first quarter sampling event indicate strongly reducing (methanogenic) conditions. This well has also produced samples with the highest detected offsite sulfolane concentrations, approximately 497 to 652 µg/L, during the first, second, and third quarters 2013. This well will continue to be monitored in the future according to the monitoring plan (ARCADIS 2012b).

- Different groundwater types can be identified at the site based on the difference in ionic composition of samples that are most likely due to different residence times of groundwater within both the suprapermafrost and subpermafrost aquifers. Relatively older groundwater has had a longer time to equilibrate with aquifer minerals and relatively younger groundwater has had less time to accumulate ions. These differences may be used to validate understanding of the offsite fate and transport of sulfolane.

Suprapermafrost wells are generally characterized by higher alkalinity and ion concentrations, while alkalinity and ion concentrations at subpermafrost wells are spatially variable with lower concentrations adjacent to surface water features. This mixing is due to the presence of thawed zones (thaw bulbs or taliks) beneath surface water and seasonal hydraulic heads may be sufficient to cause a downward vertical gradient. Additional data collected as part of the monitoring plan (ARCADIS 2012b) will be incorporated into the analysis presented above.

7.2 Sulfolane Distribution in Offsite Groundwater

Sulfolane was first detected in offsite groundwater in October 2009. In November 2009, FHRA began conducting a door-to-door private well survey. Permanent buildings within the search area were visited and residents were surveyed to determine the presence or absence of private 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 nondetect for sulfolane. A total of approximately 800 private wells had been sampled as of September 20, 2013, with the majority of those located within or adjacent to the plume (sampling has included wells significantly outside the plume in response to requests by property owners and realtors). The AWS Management Plan (Barr 2013c) was initiated in October 2009 and includes 158 private wells with dedicated point of entry (POE) treatment systems that are sampled during maintenance activities. Samples are also collected annually from private wells in the buffer zone (Barr 2013c).

FHRA installed 165 offsite monitoring wells including 43 new monitoring wells (Phase 8 monitoring wells) during 2013 (Figure 3-1), to characterize the nature and extent of sulfolane impacts and permafrost depths offsite. In addition, FHRA completed an extensive review of available private well logs, knowledge of property owners, and discussions with well drillers for data concerning well depths and the depths to both the top and bottom of permafrost. These data have identified 45 private wells reportedly installed beneath permafrost and located throughout the detectable sulfolane plume that range in depths from 30 to 353 feet bgs. This list of wells includes the 18 deep private wells in the monitoring plan (ARCADIS 2012b). Wells installed within the suprapermafrost aquifer include offsite monitoring wells and private wells known to be installed above permafrost. Sulfolane analytical results from offsite monitoring wells and private wells of all depths are shown on Figure 7-3. Sulfolane distribution in the suprapermafrost and subpermafrost aquifers is described below. However, 569 private wells do not have known well construction information and, therefore, cannot be designated to either aquifer; sulfolane results at these wells are discussed below. Historical analytical results for both monitoring and private wells are included in Appendix 7-B. Phase 8 laboratory reports are included in Appendix 7-C.

7.2.1 Sulfolane Distribution in Suprapermafrost Groundwater

As proposed in the Offsite SCWP (ARCADIS 2013d), 43 Phase 8 monitoring wells were installed in the suprapermafrost aquifer (Figure 3-1):

- Ten monitoring wells were advanced to the top of permafrost, ranging in depths from 42.5 feet bgs (MW-352-40) to 100 feet bgs (MW-353-100).

- Five monitoring wells were advanced to a depth of 150 feet bgs, which suggests that permafrost was not present at these locations.

- Twenty-eight monitoring wells were completed at shallower depths, ranging in depths from 15 to 110 feet bgs.

Additionally, well construction information from well logs and other sources for multiple private wells noted the presence of permafrost at the bottom of the boring, indicating that the wells were installed above permafrost:

- Seven private well logs showed that the wells were advanced to the top of permafrost, ranging in depths from 24 feet bgs (PW-0297) to 70 feet bgs (PW-0973).

- One private well (PW-1098) failed and was decommissioned. During decommissioning, well PW-1098 was observed to have been installed in the suprapermafrost aquifer, to approximately 20 feet bgs. A new subpermafrost well (PW-1099) was installed adjacent to PW-1098 to a total depth of 140 feet bgs and is part of the deep private well monitoring program (Figure 7-1). The top of permafrost was noted at 23 feet bgs and the bottom at 105 feet bgs. The third quarter 2013 groundwater sample collected from PW-1099 exhibited a detectable sulfolane concentration (Table 7-3).

Based on data collected from monitoring wells during third quarter 2013, initial samples from newly installed monitoring wells and two private wells, sulfolane has been detected in the suprapermafrost aquifer at concentrations ranging from 5.10 J µg/L (MW-352-15) to 367 J µg/L (PW-1098). Private well PW-1098 was the only offsite suprapermafrost well (monitoring or private) that contained a concentration of sulfolane that exceeded the calculated ACL of 362 µg/L in suprapermafrost groundwater. The groundwater sample collected from decommissioned private well PW-1098 was collected in August 2012 and is shown on Figure 7-3 with a pink halo, indicating that the most recent sample was collected prior to October 2012 (i.e., 12 months prior to preparation of this Offsite Addendum). Well PW-1098 was installed to approximately 20 feet bgs and is located approximately 1.7 miles hydraulically downgradient from the NPB. The groundwater sample collected from upgradient well MW-342-15, installed to 15 feet bgs, contained a sulfolane concentration of 122 µg/L. Downgradient well MW-161A-30, installed to 15 bgs, contained a sulfolane concentration of 226 µg/L. An increasing sulfolane concentration trend has been established at well MW-161A-30.

As shown on Figure 7-4, the detectable sulfolane plume is represented by a nondetect contour line separating wells with a detectable concentration from wells where sulfolane has not been detected. The detectable sulfolane plume in the suprapermafrost groundwater extends beyond the site boundary to approximately 3.6 miles downgradient. At the NPB, the detectable sulfolane plume is estimated to be approximately 1,000 feet wide. Due to the local hydrogeology (i.e., presence of permafrost and seasonal hydrogeologic cycles), the width of the detectable sulfolane plume increases to approximately 1.5 miles (7,900 feet) at the widest point. The detectable sulfolane plume is currently delineated by offsite monitoring wells located east/northeast between the plume and Badger Slough and west/northwest between the plume and the Tanana River. Groundwater analytical data for newly installed Phase 8 wells are summarized in Table 7-5.

Groundwater sampling data from suprapermafrost monitoring wells indicate that the majority of sulfolane detections are found in the upper 55 feet of the suprapermafrost aquifer; however, sulfolane is detected to depths of 100 feet bgs (MW-353-100) near the center of the plume and 150 feet bgs (MW-332-150), which is the maximum depth of monitoring wells at the site, near the eastern edge of the plume (Figure 7-4). As discussed in Section 4.3.2 and shown on Figure 4-2, a thaw bulb, expressed as troughs in the upper surface of the permafrost, appears to be present under the north end of Bradley Sky Ranch and the Old Richardson Highway between its junctions with North Pole High School Boulevard and Perimeter Drive, which is just upgradient from well MW-353-100. This thaw zone appears to extend to depths between 50 and 100 feet bgs (Cross-Section II-II'; Appendix 4-E).

In addition, a talik (Talik A) appears to be present north of well cluster MW-158 and permafrost begins to thin from the bottom in the area north of well cluster MW-164, toward Badger Slough. This talik is also shown on Figure 4-2 and Cross-Sections I-I' and II-II' (Appendix 4-E). An additional talik (Talik B) may be present between well clusters MW-184 and MW-171 (Figure 4-2; Cross-Section III-III' in Appendix 4-D). It appears that deep suprapermafrost groundwater flows beneath a more shallow discontinuous mass of permafrost at this location. The shallow mass of permafrost appears to abruptly become thawed just upgradient from well cluster MW-332 where the suprapermafrost and subpermafrost aquifers meet. This location is along the eastern edge of the detectable sulfolane plume in the suprapermafrost aquifer; therefore, shallower wells in the MW-332 well cluster do not encounter sulfolane-impacted groundwater like the well screened at 150 feet bgs, which is impacted by the subpermafrost plume.

7.2.1.1 Sulfolane Concentration Trends

Mann-Kendall statistical analysis of sulfolane concentration trends in groundwater samples from monitoring and private wells is performed quarterly and was most recently reported in the Third Quarter 2013 Groundwater Monitoring Report (3Q13 GWMR; ARCADIS 2013g). Sulfolane concentration trend maps based on third quarter 2013 data are attached to this Offsite Addendum as Appendix 7-E. These trends were reevaluated as discussed below to enhance the evaluation of the distribution of sulfolane offsite.

The figures indicate which groundwater monitoring wells within the sulfolane plume are increasing and possibly expanding, or decreasing to stable sulfolane concentration trends. Based on areas with similar trends and evaluation of the sulfolane Mann-Kendall trend figures, the following observations were made about sulfolane concentrations in groundwater offsite:

- Sulfolane concentration trends are generally stable to decreasing to the south, near the NPR; however, the trends appear to be increasing further north and west at the distal end of the plume.

- Sulfolane concentrations are stable to decreasing in deeper groundwater zones with the exception of one monitoring well identified to have an increasing sulfolane concentration trend (MW-332-150); however, groundwater north and east of this location is nondetect.

Only six of the private monitoring wells where sulfolane was sampled have had historical concentrations above the ACL. For various reasons including well decommissioning, property access limitations, and the short duration of the monitoring period, a trend evaluation could not be completed on four of these wells. No trend was observed for the two wells (PW-1096 and PW-1098) where a Mann-Kendall analysis could be performed.

7.2.1.2 Seasonality

Temporal sulfolane concentration trend analyses for groundwater samples in suprapermafrost monitoring wells have been completed using the Mann-Kendall method as described by ARCADIS (2013i). This section presents conclusions based on qualitative analyses intended to augment the Mann-Kendall analyses to evaluate temporal trends in sulfolane concentrations in offsite, suprapermafrost aquifer monitoring wells. Details on the evaluation of sulfolane concentration trends are presented in Appendix 7-D.

Sulfolane concentration data were evaluated with respect to seasonal variations in such factors as the horizontal hydraulic gradient (magnitude and direction of groundwater flow) and groundwater elevation. Seasonal trends that are repeated year after year that cannot be related to the factors listed in the previous section are also described. This evaluation serves to identify wells at which concentration trends were masked by seasonal variations.

Spatial trends were also considered, such as concentration trends in nested monitoring wells and the overall concentration trends in monitoring wells throughout the plume.

Possible influences of longer-term spatial and temporal trends were also considered, including concentration trends that may be related to multiyear trends in maximum groundwater elevation, expansion of the recovery well system, sulfolane release history, and source controls.

7.2.1.2.1 Evaluation of Seasonal Trends in Sulfolane Concentrations in Wells

Sulfolane concentration trends in samples from all wells with sufficient data (approximately four or more data points) and a period of record of 2 years or more were reviewed in light of available groundwater flow direction data. Locations of the offsite wells evaluated are shown on Figure 7-6. The database of sulfolane concentrations in groundwater dates back to 2001; however, frequent measurements are only available since 2006 and the pre-2006 MDL was significantly higher (2 mg/L). A gas chromatograph/flame ionization detector and direct inject analytical method were used to analyze sulfolane from 2001 to 2005. Only data since 2006 were used because this data set was analyzed using a consistent analysis method of gas chromatography/mass spectrometry (GC/MS).

Groundwater elevation data from the USGS wells described in Appendix 5-B and groundwater elevation data from the NPR monitoring wells equipped with data loggers described in Appendix 5-A were used to develop horizontal plots of the direction and magnitude of horizontal hydraulic gradient (gradient plots) at or near NPR since 2006. The time-concentration plots for 79 monitoring wells were compared with the gradient plots to qualitatively determine if the plots were correlated. This includes 37 onsite and 42 offsite wells. In the context of this evaluation, correlation means “timing of the peaks and valleys matches up” or the change in concentration is offset to a later time than the observed change in the gradient plot. Additional information regarding these data are included in Appendix 7-D.

Trends were categorized with respect to the question of whether the data exhibit a correlation between recorded seasonal variations in flow direction, magnitude of hydraulic gradient, or other unidentified factors. The following categories were used:

- “Yes” means that a correlation was identified.
- “Possible” means that a correlation is noted in some but not all years.
- “Inconclusive” means that the data appear to show seasonality one year but not another year or, in the case of a nested well included with other wells in the nest, too few data points are available to draw a conclusion.

- "No" means that sufficient data are available to lead to the conclusion that no correlation with known factors or other seasonal trend is apparent in the data. Such data sets are typically from wells that are nested with wells in which more data are available.

Of the 42 offsite suprapermafrost monitoring well time-concentration data sets evaluated, seven show an apparent seasonal variation in sulfolane that can be related to variations in horizontal hydraulic gradients, 19 show a possible seasonal variation, and six are inconclusive or show no apparent seasonal variation (Figure 7-7).

Seven offsite wells show a definite seasonal trend (MW-150A-10 and MW-150B-25 are located near the site, the rest are located in the mid- to distal portion of the plume: MW-161A-15, MW-163A-15, MW-163A-15, MW-194A-15, and MW-194B-40).

7.2.1.2.2 Overall Temporal Trends

The concentration-time plots were evaluated to determine if they exhibit an overall increasing or decreasing trend based on visual inspection of the graph. This evaluation takes seasonality and other factors into account to identify trend indications that would not be detected by the Mann-Kendall analysis; that is, the seasonal fluctuations lead to a "no trend" determination. The following categories were established; symbols indicated in the list below are posted on Figure 7-8:

- Decreasing trends:
  - D = Plots that show a steadily decreasing trend through time.
  - Ds = Plots that show a seasonal maximum concentration that decreases through time.
  - Di = Plots that show a steadily decreasing trend through time if the initial value(s) are not considered.
- Increasing trends:
  - I = Plots that show a steadily increasing trend through time.
  - Is = Plots that show a seasonal maximum concentration that increases through time.

The majority of offsite wells evaluated (29 of 42) fall into the decreasing categories. The decreasing concentration trends are likely due to several factors:

- Influence of source control over time. Due to the development of better refinery operation practices over time, the majority of sulfolane releases occurred prior to 2004 (Geomega 2013a).

- Influence of the onsite recovery system. Most wells downgradient of the groundwater recovery system and south of the road leading to the waste transfer station show decreasing concentrations over time due to capture of contaminated groundwater by the groundwater recovery system.

- Natural attenuation.

Offsite wells that show an increasing trend through time are summarized below:

- MW-153B-55 shows an overall increasing trend in a range far below the ACL (see Figure 22). The nested water table well MW-153A-15 shows an overall decreasing trend. Trends in MW-166A-15, MW-166B-30, MW-194A-15, and MW-194-40 are likely due to movement of sulfolane with groundwater near the front of the plume.

- Trends in MW-161A-15 and MW-161B-50 are increasing, but neither of these wells show increases above the ACL.

7.2.1.2.3 Other Sulfolane Concentration Trends

Other findings are discussed below; additional information is presented in Appendix 7-D.

Ten of the 42 offsite wells evaluated exhibited trends in which a peak concentration that was markedly higher than other values within the same year occurred each year. These peak concentrations occurred at different times of the year. Wells exhibiting the yearly peak concentration in winter, prior to breakup, are located both onsite and offsite in all portions of the plume.

Sulfolane concentration trends in nested monitoring wells show a decrease with depth in many well nests in the upgradient and mid-portion of the site (see Figure 48 of Appendix 7-D). This would be expected for a solute that enters the suprapermafrost aquifer at or near the water table. Nests that exhibit an increasing sulfolane concentration with depth are distributed throughout the site (see Figure 49 of Appendix 7-D). Those in the distal portion of the site likely reflect the influence of recharge, which displaces groundwater and sulfolane downward. Those nests at and near the NPR that exhibit increasing sulfolane concentrations with depth (such as wells MW-154B-95 and MW-178B-50), likely reflect downward vertical gradients, causing transport of sulfolane deeper in these areas*.* This may contribute to vertical bifurcation of the sulfolane around permafrost masses north of the source areas and represents a mechanism for sulfolane transport from source areas at the NPR to the subpermafrost aquifer. Increasing concentrations at depth in the suprapermafrost aquifer offsite likely contribute to the mechanism of transport of sulfolane to the subpermafrost aquifer through taliks.

7.2.2 Sulfolane Distribution in Subpermafrost Groundwater

As described in Section 4 and shown on the cross sections in Appendix 4-A, permafrost is present under much of the offsite area as a relatively continuous mass that extends beyond the northern and western extents of the study area as defined in Geomega (2013b). Permafrost is absent under the Tanana River and is truncated on a portion of its eastern edge by a thawed zone beneath Badger Slough. The permafrost body appears to extend beneath Badger Slough near the northern limit of the plume and possibly near Hurst Road.

The highest sulfolane concentrations measured at private wells known to be within the subpermafrost aquifer were measured at private well PW-1230 (652 µg/L), located approximately 1 mile northwest of the NPB. Well PW-1230 was the only well known to be screened below permafrost that contained a sulfolane concentration that exceeded the calculated ACL of 362 µg/L. Private wells PW-1230 and PW-1626 have total depths of approximately 231 and 305 feet bgs, respectively. Sulfolane concentrations observed at PW-1230 are greater than concentrations detected in groundwater samples collected at other private wells. Sulfolane was not present above the laboratory detection limit of approximately 6.20 to 6.74 µg/L during the first, second, or third quarters 2013 in samples collected from perimeter private well locations PW-0972, PW-0259, PW-1343, and PW-0332.

Talik A was identified in the area upgradient from well PW-1230 that likely allows transport of groundwater impacted with sulfolane from the suprapermafrost aquifer to the subpermafrost aquifer (Figure 4-2). This talik is described in Section 4.3.2. Based on boring logs and geophysical data, the base of the permafrost formations appear to have a more abrupt and angular profile than the more gently undulating surfaces of the top of the permafrost formations. This variability in the surfaces of permafrost is believed to have a significant influence on the distribution of sulfolane when looked at on a localized scale in both the subpermafrost and suprapermafrost aquifers. Therefore, the location and concentration of sulfolane below the permafrost may not be the same as the suprapermafrost in some areas. This difference is observed at well PW-1230, where sulfolane concentrations in the subpermafrost (652 µg/L) do not directly correlate with sulfolane concentrations in the suprapermafrost (MW-349-15; 59.3 µg/L). Additionally, as stated above, sulfolane concentrations in shallower wells in the MW-332 well cluster are inconsistent with sulfolane concentrations in the well screened at 150 feet bgs, which is impacted by the subpermafrost plume. The fate and transport of groundwater from the suprapermafrost aquifer to the subpermafrost aquifer is described in Section 8.4.

The detectable sulfolane plume shown on Figure 7-5 is represented by a non-detect contour line separating wells within the sulfolane plume from wells where sulfolane has not been detected. In some cases, wells with no detectable concentrations are near those with detectable concentrations, and therefore are included within the non-detect contour line. The zone of detectable sulfolane concentrations is currently delineated by private wells located east/northeast to Badger Slough and west/southwest to the Tanana River dike.

7.2.3 Sulfolane Occurrence in Private Wells with Unknown Depths

Well construction information is not available for 569 of the private wells that have been sampled for sulfolane. Based on data obtained since October 2012 and historical data (prior to October 2012), 272 wells contain detectable concentrations of sulfolane. One well, PW-0228, exceeded the ACL of 362 µg/L; however, this well has not been recently sampled. Two additional private wells, PW-1095 and PW-1096, have historically had sulfolane concentrations exceeding the ACL of 362 µg/L; however, recent samples collected in 2013 have had concentrations below the ACL. These data are included in the historical data tables attached in Appendix 7-B. The most recent groundwater sample from private well PW-0228 was collected in 2009 and exhibited a sulfolane concentration of 443 µg/L. Well PW-0228 has not been recently sampled because FHRA does not have access to the property. This detection exceeding the ACL is shown on Figure 7-3 with a pink halo, indicating that the most recent sample was collected prior to October 2012 (i.e., within 12 months of production of this Offsite Addendum).

7.3 Total Organic Carbon

As noted in the Offsite SCWP (ARCADIS 2013d), a sufficient amount of TOC in groundwater data are available from historical and ongoing groundwater monitoring activities. A total of 387 samples have been collected since 2010 for TOC analysis from offsite monitoring and private wells. While these data were collected for a variety of other purposes described below, the data are synthesized here to provide a broader context for observed TOC at the site.

1. Offsite monitoring well geochemical monitoring program (38 locations; Table 7-6). TOC data were collected as part of this program for the purposes of characterizing geochemical conditions throughout the offsite sulfolane plume.

2. POE treatment systems during in-home pilot testing (five locations) and accelerated pilot testing trials 1 and 2 (both accelerated testing trials were completed at a single location) and additional monitoring to evaluate copper issues (five locations; Table 7-7). TOC data were collected in conjunction with the POE treatment systems for operational and maintenance purposes.

3. Private wells monitored as part of the deep private well monitoring program (23 locations; Table 7-8). TOC data were collected in conjunction with deep private well monitoring in accordance with the Deep Private Well Monitoring Plan (ARCADIS 2012b).

Locations of the wells sampled for TOC are shown on Figure 7-10.

FHRA conducted additional TOC groundwater monitoring onsite; results are presented in the Onsite Addendum (ARCADIS 2013h). A total of 496 groundwater samples have been collected from onsite and offsite for TOC analysis since 2010.

This section summarizes and evaluates available TOC data in groundwater. In addition, as previously requested by ADEC in comments to the Onsite SCWP (ARCADIS 2013c), the POE TOC data are evaluated to identify any potential impacts of TOC concentrations on POE treatment system performance.

7.3.1 Total Organic Carbon Data from Offsite Monitoring Wells

TOC monitoring in groundwater was accomplished by collecting and analyzing samples from offsite monitoring wells as part of a geochemical evaluation (2011 to 2013). TOC results for monitoring wells screened across the water table ranged from 1.80 to 34.4 mg/L (Table 7-6). Concentrations were lower in the deeper wells, ranging from 1.42 to 11.2 mg/L in wells screened 10 to 55 feet and 55 to 90 feet below the water table. The majority of the deeper well results were between 1 and 6 mg/L; 11.2 mg/L was the only result greater than 6.3 mg/L (Table 7-6). As expected, higher concentrations and variability were measured in the monitoring wells screened across the water table because localized and seasonal infiltration has a greater influence on shallow groundwater. TOC data are summarized in Table 7-6.

7.3.2 Total Organic Carbon Data from Point of Entry System Pilot Test Homes

As described in the SCR – 2011 (Barr 2012), FHRA installed and monitored the operation of POE treatment systems at five pilot test homes in 2010 and 2011. The monitoring program included sample collection at a high frequency, including weekly and monthly monitoring. Samples collected from the raw water inlet were analyzed for TOC; results ranged from 1.6 to 5.7 mg/L (Table 7-7), with the highest concentrations measured at PW-0657. The sulfolane breakthrough data for the first and second granular activated carbon (GAC) vessels in the five pilot test systems were reviewed with respect to TOC data to determine if TOC affected system performance. Review of the data indicated that the POE system at PW-0657 experienced sulfolane breakthrough consistent with the other test homes when considering the sulfolane concentration and water usage (Barr 2012). This location has a duplex system (two primary treatment vessels followed by a redundant vessel) and did not exhibit sulfolane breakthrough in the second vessel through 1 year of use and treatment of more than 91,000 gallons. This indicates that the variability in TOC concentration in the raw water did not affect sulfolane treatment performance in the five pilot test homes.

Results of TOC monitoring completed during two accelerated pilot testing trials of the POE system (referenced as Accelerated Pilot 1 and 2) are presented in Table 7-7. The data include a high frequency of sample collection for a short duration (i.e., 41 samples over 6 weeks). The TOC results ranged from 2.1 to 3.6 mg/L.

As part of an investigation to resolve copper corrosion issues in select residences (AWS management Plan, Barr 2013c), FHRA completed additional monitoring, collected samples from various locations within each residence on December 15 and 16, 2011, and submitted the samples for TOC analysis. The results ranged from below detection limits to 13.6 mg/L (Table 7-7). At locations PW-0504, PW-0648, and PW-1315, samples were collected from multiple locations within the POE treatment system. Consistent with the monitoring port descriptions provided in the AWS Management Plan (Barr 2013c), Port A refers to a raw water sample, Port B refers to a water sample collected after the sediment filters and a softener, Port C refers to a water sample collected after the primary GAC vessel, and Port D refers to a water sample collected after the redundant GAC vessel. As shown in Table 7-7, the sediment filter and softener were successful in removing TOC from the location with the highest TOC concentration (PW-0504 raw water-"Port A"). This is evidenced by the significantly lower TOC concentration in Port B.

7.3.3 Total Organic Carbon Data from Deep Residential Wells

As part of the deep residential monitoring program, samples were collected from deep private wells and analyzed for TOC. Results are summarized in Appendix 7-B. The TOC concentrations in the deep private wells ranged from 1.6 to 5.7 mg/L (Table 7-8).

7.3.4 Point of Entry System Performance and Summary

Sampling and analysis to monitor performance of installed POE systems was completed prior to scheduled changeout of the GAC at each system (Barr 2013c). Results of this monitoring were provided to ADEC via the SharePoint website and will be summarized in annual reports as described in the AWS Management Plan (Barr 2013c). To date, breakthrough of sulfolane has not been detected in any of the 156 POE treatment systems prior to changeout. Thus, any variability measured in raw water TOC concentrations has not impacted the performance of the POE systems based on the current operation and changeout frequency. Additionally, the private wells using POE treatment systems are installed at a variety of depths; therefore, the variations in TOC measured with depth have not affected performance of the POE systems.

Ongoing monitoring of the POE system performance has demonstrated that variability in raw water TOC concentration has not lead to breakthrough of sulfolane prior to scheduled GAC changeout events. In addition, the variability of TOC values noted in the aquifer (except for monitoring wells screened across the water table) is consistent with values measured during pilot testing periods. The high-frequency monitoring conducted during the pilot testing periods showed effective sulfolane removal.

7.4 Summary

The following conclusions are based on a review of offsite groundwater data:

- Sulfolane is below the ACL of 362 µg/L in offsite monitoring wells and was above the ACL in the most recent sample (August 2012) collected from one decommissioned private well installed in the suprapermafrost aquifer.
- Sulfolane exceeds the ACL of 362 µg/L in one private well known to be installed below permafrost.
- Sulfolane exceeded the ACL of 362 µg/L in the most recent sample (November 2009) collected from one private well with unknown well construction.
- The intersection of the sulfolane plume with taliks through permafrost is the primary mechanism that has been identified to account for the detection of sulfolane below permafrost.
- Seasonal changes in groundwater flow directions are also responsible for the distribution of sulfolane offsite.
- Geochemical conditions in both the suprapermafrost and subpermafrost aquifers are generally reducing.

As described in Section 4, permafrost distribution at the site has a large influence on sulfolane concentrations in groundwater due to its influence on a variety of geologic, hydrologic, and groundwater transport elements. An extensive review of all of the site characterization data generated to date concluded that the intersection of the sulfolane plume with taliks through permafrost is the primary mechanism identified to account for the migration of sulfolane-impacted groundwater beneath permafrost. Investigations regarding the lateral and vertical extents of discontinuous permafrost in this area have shown it to have an irregularly shaped surface that will direct the flow of sulfolane-impacted groundwater around and beneath it.

Based on the boring logs and geophysical data, the differences in the surface of the base of the permafrost compared to the surface of the top of the permafrost is believed to have an influence, at a localized level, on the distribution of sulfolane in the supra- versus subpermafrost groundwater. Generally, the extent of the sulfolane plume is consistent in the subpermafrost and suprapermafrost aquifers. Some localized variability has been observed. For example, concentrations observed in subpermafrost well PW-1230 and the Horseshoe Way area near the MW-332 well nest do not directly correlate with sulfolane concentrations in the suprapermafrost. The lateral extent of the subpermafrost sulfolane plume is less than the current lateral extent of the suprapermafrost sulfolane plume.

Cross-Section I-I' (Appendix 4-E) shows the extent of permafrost and sulfolane concentrations near PW-1230. As discussed in Section 4.3.2, a talik (Talik A) is present upgradient from PW-1230, allowing suprapermafrost groundwater to flow into the subpermafrost aquifer, which explains the localized sulfolane concentration exceeding the ACL of 362 µg/L at a depth of 230 feet bgs at PW-1230. Private well PW-1230 is not in use as a source of drinking water and is part of the ongoing deep private well monitoring program. Sulfolane concentrations from well PW-1230 will continue to be evaluated for trends in future groundwater monitoring reports.

Geochemical parameters provide evidence of reducing aquifer conditions in shallow and deep groundwater in the subpermafrost aquifer. Unique geochemical conditions appear to characterize private well PW-1230. In particular, elevated methane concentrations at this private well during the first quarter 2013 sampling event indicated strongly reducing (methanogenic) conditions. These results are consistent with previous analyses of geochemical data at the site.

8. Fate and Transport Mechanisms

This section discusses the relevant fate-and-transport mechanisms governing COC transport in the offsite portion of the affected area. As discussed in greater detail below, offsite COC transport is limited to fully saturated groundwater flow below the water table because the only offsite COC (sulfolane) is non-volatile, does not occur as a gas in the vadose zone, does not adsorb readily to soil, and its occurrence is therefore limited to the dissolved, aqueous phase.

8.1 Summary of Constituent of Concern Sources

As described in the Onsite 2013 Addendum and Appendix A to the 2012 Site Characterization Report, Williams' predecessor, MAPCO, began releasing sulfolane in October 1985, almost immediately after the refinery began using sulfolane (Geomega 2013a). Refinery documents and former Williams and MAPCO personnel describe a long history of sulfolane spills and mismanagement at NPR, which caused persistent releases of sulfolane to the environment throughout the entire period that Williams and MAPCO operated the refinery. Those spills and releases include:

- Discharge of sulfolane from Lagoon B through numerous holes, rips and tears that were documented in the lagoon in the 1980's and 1990's during Williams' and MAPCO's operations. Williams/MAPCO stored wastewater with high concentrations of sulfolane in the lagoon over the course of its use, and in 2000, documented that the lagoon was "loaded with sulfolane" at 1,650,000 µg/L, which equated to 1500-2000 gallons of sulfolane in the lagoon.

- The chronic release of sulfolane beginning in the 1990's from refinery sumps, including salt dryer sump 908 and extraction unit sump 02/04-2, both of which were found to be corroded through in inspections performed in the 1990's. Extraction unit sump 02/04-2 was documented in 1997 to have holes in the bottom that permitted the direct discharge of sulfolane to groundwater. Other significant surface spills of material containing sulfolane were documented during the several large-scale turnaround maintenance events in the Williams/MAPCO period, including up to 800 gallons of material reported to contain 66% sulfolane that was spilled to dirt in April 2002.

- Releases in the Southwest Area from overspray and overflow of sulfolane-contaminated wastewater during the cleaning of extraction unit equipment, which a former Williams/MAPCO employee described as a "messy job and created lots of water that quickly filled the containment area." Extraction unit equipment was initially cleaned in the CU#1 Wash Area, which is also impacted with sulfolane, until the Southwest wash area was constructed in about 1990. In 2000, Williams tested the wastewater from its cleaning operations in the Southwest Area and found that it contained 97,000,000 µg/L sulfolane.

The collective impact of these and other sulfolane releases in the Williams/MAPCO period has resulted in the 3.5 mile long and 1.5 mile wide plume that the site characterization process has defined (Figure 8-1). This equates to a transport distance of almost 20,000 feet since the initial 1985 spills, resulting in an average sulfolane transport velocity of approximately 2 ft/day, which is also consistent with the findings of the site characterization process.

8.2 Offsite Constituent of Concern Fate and Transport Mechanisms

Offsite COC fate and transport mechanisms are limited to migration in groundwater due to a combination of mechanisms including advection, dispersion, diffusion, hydrophobic sorption, and degradation. These transport mechanisms are more fully described below.

8.2.1 Transport of Sulfolane via Groundwater Advection

Advection refers to the transport of COCs dissolved in groundwater by the bulk movement of flowing groundwater. Advection is the primary transport mechanism that controls the direction of COC migration in groundwater; it also controls the velocity of COC migration to some extent. Groundwater flow is controlled primarily by hydraulic gradients and variations in hydraulic conductivity in the subsurface, as described by Darcy’s Law. FHRA has devoted considerable resources to collecting detailed measurements of horizontal and vertical hydraulic gradients and hydraulic conductivity throughout the site. These measurements have been documented in the various site characterization reports that have been prepared for the site. The site hydraulic head and hydraulic conductivity information have also been used along with many other sources of information to develop a detailed numerical groundwater flow model for the site that simulates groundwater flow rates and directions. Thus, groundwater flow has been well characterized at the site and provides a solid basis for evaluating COC fate and transport via groundwater advection.

Hydraulic conductivity of onsite soil has been measured during six different site evaluations and found to vary between approximately 0.1 and 17,000 ft/day, with an average (geometric mean) of approximately 600 ft/day (Section 5.0). It is reasonable to expect that the offsite soil has hydraulic conductivity characteristics that are similar to those of onsite soil because offsite soil was deposited in the same depositional environment as onsite soil.

Hydraulic gradients have been measured at the offsite monitoring well network and have an average (arithmetic mean) of approximately 0.001 ft/ft (Appendix 5-A). Mobile porosity was estimated during three onsite tracer tests (Section 6). Mobile porosity represents the portion of total porosity that contributes to advective groundwater flow and transport. Mobile porosity was estimated to vary between approximately 2 and 21 percent with an average of approximately 10 percent (Section 5). It is reasonable to expect that the offsite soils have mobile porosity characteristics that are similar to those of onsite soils because offsite soils were deposited in the same depositional environment as onsite soil.

The average linear groundwater velocity can be estimated using this information based on a form of Darcy's Law, which states:

$$V = \frac{KI}{n_m}$$

Where:

V = average linear groundwater velocity
K = hydraulic conductivity
I = hydraulic gradient
n_m = mobile porosity

Based on this information, the estimated linear groundwater velocity varies between 0.1 and 30 feet per day, depending on the local soil characteristics. An average linear groundwater velocity of 1 foot per day was observed in a medium-grained sand layer during site tracer testing (Appendix 6-A of the Onsite Addendum). The upper end of the estimated groundwater velocity is for gravels at tracer TTA-2. This range of local linear groundwater velocities is lower and higher than the average sulfolane transport velocity of 2 feet per day over the length of the plume estimated in Section 8.1. The sulfolane transport velocity is also influenced by the dual-porosity fate and transport mechanism discussed in Section 8.3.3, which retards the sulfolane transport velocity relative to the average linear groundwater velocity.

8.2.2 Dispersion

Dispersion is a pore-scale COC fate-and-transport mechanism that results in mixing of groundwater with and without COCs in soil pores, and can cause spreading COCs both vertically and horizontally. The extent of COC dispersion may be enhanced by heterogeneities within aquifer materials.

Offsite dispersivity values have been estimated to vary between approximately 0.1 meter and 8.2 meters through the completion of onsite tracer tests (ARCADIS 2013e) and 10 and 50 meters through calibration of the site groundwater flow model (Geomega 2013b). Dispersivity is known to be scale-dependent (Gelhar 1992) and increases with time and distance. The tracer tests were performed over a scale of approximately 10 to 50 feet, whereas the groundwater model considers transport over a scale of approximately 20,000 feet.

8.2.3 Diffusion into and out of Low-Permeability Zones

Diffusion is a chemical process where COCs move from areas of high concentration to low concentration. In heterogeneous soil, such as the soil found offsite, COCs may be transported into or out of the pore spaces of relatively low-permeability zones via diffusion at rates depending on the concentration gradient and advection. These low-permeability pore spaces represent the immobile porosity of a soil mass. Soon after COCs reach the water table, COC concentrations will be higher in the pore spaces of higher permeability materials , referred to as mobile porosity, and will naturally diffuse into the immobile porosity of lower-permeability materials where COC concentrations are low. As the concentrations equilibrate between the mobile and immobile porosities, lower-permeability zones may come to store a significant amount of COC mass depending, in part, on the nature of the soil heterogeneities. After the high concentrations of COCs have been reduced in the mobile porosity of higher-permeability zones due to natural aquifer flushing or enhanced flushing due to the groundwater extraction system, the direction of diffusion reverses and COC mass diffuses from the immobile porosity zones back into the mobile porosity zones.

One implication of diffusion is that, in time, most of the COC mass will eventually be stored in the low-permeability zones. Because most of the advective and dispersive groundwater flow and COC transport occurs in 2 to 21 percent of the total pore space that represents the mobile porosity, the amount of COC mass stored in high-permeability zones will be relatively low. A second implication of the diffusion mechanism is that COC migration rates can be significantly retarded relative to the average linear groundwater velocity because COC mass entering the mobile pore spaces will depend on contrast between the low- and high-permeability zones, and diffusion-derived retardation factors ranging between approximately 5 and 25 are possible. A third implication of the diffusion mechanism is that diffusion into and out of low-permeability zones can cause COC mass to be stored for relatively long periods of time in the subsurface and cause significant tailing of COC concentrations measured in groundwater monitoring and extraction wells. A fourth implication of the diffusion mechanism is that the reverse-diffusion process can cause rebound of COC concentration in groundwater during and after remedial operations.

Diffusion and advection into and out of low-permeability zones onsite, and its control on COC migration in onsite groundwater, was demonstrated by three independent, site-specific datasets as reported in the Onsite Addendum (ARCADIS 2013h). It is reasonable to expect that the offsite soils have dual-porosity characteristics that are similar to those of onsite soils because offsite soils were deposited in the same depositional environment as onsite soils.

8.2.4 Hydrophobic Retardation

Some organic COCs can be sorbed into solid organic particles that are naturally present in soils due to their hydrophobicity. This is another COC partitioning process and can result in retarding the velocity of COCs in groundwater relative to the average linear groundwater velocity. The extent to which hydrophobic sorption influences the fate and transport of COCs in groundwater depends on the amount of naturally occurring solid organic carbon in the soil and the chemical properties of the COCs. The range of TOC in 32 onsite soil samples collected in 2013 has been measured to vary between approximately 0.104 and 8.1 percent (ARCADIS 2013h). The average was 0.767 percent. It is reasonable to expect that the offsite soils have a TOC content very similar to that of onsite soils because offsite soils were deposited in the same depositional environment as onsite soils.

The extent to which a specific COC is influenced by hydrophobic retardation may be evaluated through use of the COC-specific retardation factor, which can be estimated using the following equation (Freeze and Cherry 1979):

$$R_{coc} = 1 + \frac{K_{oc} f_{oc} \rho_b}{n}$$

Where:

R_{coc} = retardation factor for the COC
K_{oc} = COC-specific organic-carbon water partition coefficient
f_{oc} = fraction of organic in the soil
n = total porosity
ρ_b = soil bulk density

The K_{oc} value for sulfolane is approximately 0.08 liter per kilogram, which indicates that sulfolane does not readily partition to TOC particles in soil (ARCADIS 2013e). Using this information, the retardation factor for sulfolane is calculated to be approximately 1.0, which indicates that sulfolane migration in groundwater will not be affected by hydrophobic sorption.

8.2.5 Degradation

Sulfolane is used at the NPR in the refining process as detailed in the SCR – 2011 (Barr 2012). Sufficient scientific studies have been performed to prove that sulfolane is degradable under natural conditions. Aerobic biodegradation is a primary attenuation mechanism.

FHRA prepared an evaluation of the fate of sulfolane during the degradation process. The results of this work were submitted to ADEC in a memorandum that summarized methods, results, assumptions, and conclusions (ARCADIS 2013e). This evaluation demonstrated that potential sulfolane intermediate compounds are, by their very nature, unstable and transient, and would be difficult to measure if present. In most cases, chemical standards are not available, and analytical methods to detect the compounds have not been developed. More importantly, there is no indication that intermediate compounds would persist or accumulate.

8.2.6 Surface Water – Groundwater Interaction

In areas with shallow water tables, groundwater can interact with surface water features such as rivers, streams, and gravel pits. Groundwater-surface water interactions may influence groundwater flow rates and patterns as well as COC transport. Surface water features may be gaining when groundwater discharges to the surface water feature, or losing when surface water recharges groundwater. Surface water bodies may be gaining or losing at different locations along the surface water feature, and both gaining and losing at different times of the year depending on the hydraulic gradient between the surface water feature and groundwater. Variations in river stage through time are therefore believed to be the primary control on pressure gradients, and ultimately groundwater flow directions, in the aquifer between these rivers (Lilly et al. 1996, Nakanishi and Lilly 1998).

Groundwater-surface water interactions are important at the site because the site is near the Tanana River, Badger Slough, Chena River, Ditch C, gravel pits, and ponds; and numerous wetlands are present within the affected area. In terms of COC fate and transport, flow-through surface water features, such as the NGP and other gravel pits offsite, may collect and/or receive COCs from the groundwater, where they can be subject to biologic and abiotic processes unique to surface water features (e.g., volatilization to the atmosphere, biodegradation, abiotic degradation, sorption to sediment). Losing surface water features, such as the Tanana River during periods of higher stage, can create pressure gradients in the aquifer that control groundwater flow and COC transport and can function as important geochemical boundaries such as sources of oxygen and nutrient influx to aquifers.

8.3 Influence of Permafrost on Offsite Constituents of Concern Fate and Transport

Permafrost will exert a strong control on groundwater flow and COC transport patterns because, where it is present, it acts as an aquitard and does not transmit groundwater. This fate and transport mechanism was documented in a detailed study of groundwater flow conducted near Fairbanks, which found that permafrost exerted a strong control on groundwater flow patterns by creating localized regions of converging and diverging flow around permafrost bodies (Carlson and Barnes 2011). The study found that, as groundwater encounters discontinuous permafrost bodies, the flow would split and divert around the permafrost bodies. A portion of the groundwater would flow over the permafrost through the suprapermafrost aquifer, and a different portion would flow under the permafrost through the subpermafrost aquifer. This process can be visualized analogous to an airplane wing, where some air passes over the wing and some air passes under the wing.

As discussed in Section 5, the extent and distribution of permafrost in the subsurface offsite has been investigated through several site characterization activities completed during 2013, including monitoring well installation, geophysical surveys, and hand-auger borings. Information regarding the depth and extent of permafrost is also present in numerous historical geologic logs and was used to delineate the extent of permafrost. Evaluation of hydrographs from the data logger program provided an additional line of evidence of the interaction of the suprapermafrost and subpermafrost aquifers in the vicinity of a thawed zone. Further, work completed by the UAF identified suprapermafrost and subpermafrost groundwater, which furthered the understanding of the permafrost extent. The methods, results, and conclusions of these evaluations are discussed in Section 5.

In a large portion of the offsite area, due to the large permafrost mass, discrete suprapermafrost and subpermafrost aquifers are present. The permafrost mass extends to the north and west throughout the offsite plume. Permafrost is largely absent under the developed portions of the FHRA property, the Tanana River, and Badger Slough; therefore, only one aquifer is present in these areas. The geophysical surveys have identified taliks in the permafrost that connect the suprapermafrost and subpermafrost aquifers in areas that where sulfolane has been detected. The connection between the sub- and suprapermafrost aquifers is supported by other site data, including the UAF isotope study. A "talik" is defined as a zone of unfrozen ground within a permafrost area. Taliks may provide a hydraulic connection between the suprapermafrost and subpermafrost aquifers. Downward vertical gradients from the suprapermafrost to the subpermafrost aquifer are due to a combination of natural groundwater recharge-discharge relationships, interactions with permafrost bodies, hydraulic conductivity contrasts, pumping from the subpermafrost aquifer, and density-driven gradients. These downward vertical gradients from the suprapermafrost aquifer to the subpermafrost aquifer would enable migration of sulfolane-containing suprapermafrost groundwater into the subpermafrost aquifer through taliks. A downward vertical hydraulic gradient across the permafrost between wells MW 349-45 and PW-1230 was measured in October 2013 (Section 6).

Based on interpretation of multiple lines of evidence, one talik (Talik A) has been identified in an area roughly bounded by 3rd Avenue, 4th Avenue, Therron Street, and Rosson's Cross Way (Figure 4-2). This talik is a feature plunging (not vertically oriented) to the north, graphically represented on Cross-Sections I-I' and II-II' (Appendix 4-E) between MW-156, and MW-157. The orientation of the cross sections relative to the plunge of this talik gives the appearance that it does not fully penetrate the permafrost, but it does connect the suprapermafrost and subpermafrost aquifers. At least one other talik (Talik B) may be present between MW-163 and MW-171, as shown on Cross-Sections III-III' and X-X' (Appendix 4-E). The site data suggest that these taliks are the most probable transport pathways for sulfolane to migrate from the suprapermafrost aquifer to the subpermafrost aquifer near the site. Both taliks are oriented such that impacted groundwater can flow from the suprapermafrost aquifer to the subpermafrost aquifer.

8.4 Potential for Vertical Constituent of Concern Transport through Improperly Sealed Boreholes

A possible transport pathway for sulfolane to enter the subpermafrost aquifer involves downward migration through improperly sealed boreholes associated with historical private water well drilling practices. It has been hypothesized that the installation of private wells through permafrost could to a greater or lesser extent permanently melt permafrost around well boreholes due to heat associated with standard drilling practices, for example by the friction of spinning augers against soil, friction of advancing well casings through soil, heat generated during curing of grout, heat introduced with drilling fluids such as mud and development water, or the use of heating elements inside wells. These processes could potentially create a breach in the permafrost that would result in a hydraulic connection between the sub- and suprapermafrost aquifers around private residential wells. Downward vertical gradients from the suprapermafrost to the subpermafrost aquifer could potentially cause migration of sulfolane-containing suprapermafrost groundwater into the subpermafrost aquifer through improperly sealed boreholes. Another potential mechanism along these lines involves leakage of sulfolane-containing suprapermafrost groundwater into wells through corroded well casings or leaky casing joints and subsequent downward transport to the subpermafrost aquifer inside the well casing.

To evaluate the potential for sulfolane-containing suprapermafrost groundwater to be transported to the subpermafrost aquifer via downward vertical migration through improperly sealed private well boreholes, Darcy's Law was used in Appendix 8-A to test the hypothesis that suprapermafrost groundwater migrating vertically downward along improperly sealed boreholes under natural gradient or pumping conditions will mix with groundwater flowing through the subpermafrost aquifer. This groundwater mixing phenomenon would result in dilution of sulfolane concentrations present in subpermafrost groundwater in direct proportion to the amount of dilution.

As discussed in Appendix 8-A, results of the analysis demonstrate that transport of suprapermafrost groundwater vertically downward along improperly sealed boreholes into the subpermafrost aquifer results in mixing of waters, producing a dilution factor of at least 50. The implication of this finding is that, if groundwater migration through improperly sealed boreholes was the primary transport process for sulfolane to enter the subpermafrost aquifer, sulfolane concentrations detected in subpermafrost groundwater sample should be at least 50 times lower than sulfolane concentrations detected in suprapermafrost groundwater samples. The fact that sulfolane concentrations detected in subpermafrost groundwater samples are similar to sulfolane concentrations detected in suprapermafrost samples allows rejection of the hypothesis that groundwater migration through improperly sealed boreholes is a primary transport process for sulfolane to enter the subpermafrost aquifer.

9. Ongoing Corrective Actions

As required in AAC 75.335 (c) (5), a site characterization report will propose cleanup techniques for the site. Corrective actions for sulfolane began at the site in 1985 or 1986 and substantially increased in scope beginning in 2009 as FHRA responded to the identification of sulfolane impacts in groundwater beyond the site boundary. As described in this section, FHRA has implemented an alternative water supply (AWS) program and an enhanced groundwater extraction and treatment system to exert hydraulic control over the source areas on the NPR. This section also discusses ongoing corrective actions and the planned feasibility study to address sulfolane-impacted groundwater at the site.

9.1 Alternative Water Solutions Program

Upon detection of sulfolane in an offsite monitoring well in October 2009, FHRA immediately began sampling private wells of residents and businesses near the NPR and providing AWSs to those with impacted wells (Barr 2013c). As of September 20, 2013 and since monitoring began, 800 private wells have been sampled and 354 have yielded detectable concentrations of sulfolane.

To address potential drinking water risks associated with offsite dissolved-phase sulfolane impacts, the following mitigation activities have been completed:

- Replaced the city's existing municipal wells.
- Provided AWSs to residences and businesses with wells exhibiting detections of sulfolane.

As described in the Alternative Water Solutions Program – Management Plan (Barr 2013c), three long-term AWS options have been provided to homeowners within the plume boundary and the buffer zone:

1. An in-home water treatment system that uses the existing well water and treats for sulfolane before water is distributed throughout the residence (POE treatment system).
2. A bulk water tank option where water would be delivered by a water delivery company from another site to the tank, and that water would be distributed throughout the residence.
3. Long-term bottled water delivery, consisting of 3- or 5-gallon bottles of water, for drinking and cooking, delivered to the residence weekly.

In addition, in response to the ADEC's recommendation for well-water use within the sulfolane plume area, FHRA offered to collect samples from garden wells for property owners and properties within the plume area that were offered an outside hose spigot connected to the property's city water system for gardening and other potable water activities.

During 2013, 158 POE treatment systems and 113 bulk water tanks have been installed, 32 properties have chosen ongoing bottled water service as their permanent solution, and 48 garden tanks have been installed for those outside the city's water main system. Some properties required more than one alternative solution because of multiple dwellings on one property. Long-term AWSs have been provided or offered to all properties with a detection of sulfolane. Additionally, properties within or near the known plume boundary area but without a detection of sulfolane have been provided an AWS on a case-by-case basis in response to specific concerns or circumstances. As described in the AWS Management Plan (Barr 2013c), FHRA has also established a buffer zone around the known contamination plume where private wells have been sampled and bottled water is being provided as a precautionary measure to prevent exposure to sulfolane.

9.2 Current Onsite Remedial Operations

FHRA is currently remediating groundwater by extracting and treating groundwater onsite, as summarized in the Third Quarter 2013 Groundwater Monitoring Report (ARCADIS 2013g). The layout of the current extraction well network is shown on Figure 9-1.

Extraction operations have undergone continued optimization since 2009. Groundwater recovery is currently ongoing at seven recovery wells (R-21, R-35R, R-42, R-43, R-44, R-45, and R-46).

FHRA is currently completing the design and permitting necessary to complete the implementation of the interim corrective actions described in the Interim Remedial Action Plan (IRAP; Barr 2010a), SCR – 2011 (Barr 2012), and Revised Interim Remedial Action Plan Addendum (Revised IRAP Addendum; ARCADIS 2013f), including an expansion of the groundwater recovery and treatment system to the west of the current layout. This includes installation of new treatment infrastructure and two additional wells: R-47 and R-48. These corrective actions expand and optimize the existing groundwater extraction and treatment remediation system to address remaining sulfolane source areas that were identified through the completion of the site characterization process and provide full capture and treatment of the sulfolane across the transect of recovery wells.

9.3 Potential Cleanup Techniques

FHRA believes that the site characterization data presented this document and its companion reports, in conjunction with the Revised Draft Final Human Health Risk Assessment (ARCADIS 2012a) are sufficient to support a risk-based evaluation of appropriate remedial alternatives for the site. The interim remedial actions, including the AWS program and the existing groundwater extraction and treatment systems are considered applicable cleanup techniques for the site.

There are other potential remedial techniques that may also warrant further consideration in the development of a final cleanup plan for the offsite affected area, however, further consideration of those alternatives will be reserved until approval of this document is received from ADEC along with ADEC's acknowledgement that the Site Characterization requirements under AAC 75.335 have been met.

10. 2013 Site Characterization Data Quality

The RSAP provides quality assurance (QA)/quality control (QC) procedures to ensure that analytical data are of an acceptable quality and reliability. Analytical results for laboratory QC samples were reviewed, and a QA assessment of the data was conducted. The QA review procedures produced 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. Laboratory reports, including case narratives describing laboratory QA results and completed ADEC data review checklists, are included in Appendix 10-A of this addendum. SWI conducted QA/QC reviews of the data and applied data quality flags, where applicable, as summarized with the analytical data in Tables 3-2, 7-3, and 7-5.

10.1 Water Sample Data Quality

This section summarizes the results of the QA/QC review for soil and groundwater data collected from the offsite Phase 8 wells, and groundwater data collected from deep residential wells during the third quarter of 2013. Phase 8 well installation soil samples and groundwater samples were submitted to SGS for analysis of TOC and sulfolane, respectively. Groundwater samples collected from deep residential wells were submitted for analysis of sulfolane, TOC, alkalinity, ammonia, and metals. ADEC data review checklists are included in Appendix 10-A.

The SGS work orders (WOs) reviewed for the Phase 8 initial groundwater samples are listed in the table below.

Phase 8 Initial Groundwater Sample Work Orders						
1137761	1137757	1137774	1137782	1137806	1137833	1137980
1138524	1138545	1138559	1138635	1138669	1138299	

The SGS WOs reviewed for the Phase 8 TOC soil samples are listed in the table below.

New Phase 8 Initial Soil Sample Work Orders			
1138213	1138300	1138375	1138413

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

Deep Residential Water Well Sample Work Orders					
1138397	1138398	1138420	1138418	1138426	1138427
1138433	1138434	1138435	1138441	1138442	1138443
1138453	1138505	1138515	1138522	1138621	

Results of the QA/QC review and any issues that affected data quality (i.e., resulted in applying data qualifiers) are summarized below. The data review checklists included in Appendix 10-A provide additional details regarding QA/QC for each WO.

10.2 Sample Handling

Phase 8 soil, Phase 8 initial groundwater, and third quarter 2013 deep residential groundwater samples were hand delivered to the SGS receiving office in Fairbanks, Alaska and then shipped overnight via Lynden Transport or Alaska Airlines Goldstreak to the SGS laboratory in Anchorage, Alaska for analyses, using the methods specified on the chain of custody records. Deep residential groundwater samples analyzed for methane were shipped by SGS to ALS Environmental in Simi Valley, California (ALS) for analysis.

Sample receipt forms for each WO for SGS Fairbanks and Anchorage and for ALS were reviewed to verify that samples were received in good condition and within the acceptable temperature range. The ADEC data review checklists (Appendix 10-A) contain details regarding this review. 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 addendum, temperatures between 0 and 6°C are considered acceptable.

Samples were received within the acceptable temperature range upon arrival at each laboratory, and were received properly preserved and in good condition, with one exception. For deep residential WO 1138522, ALS received methane samples above the acceptable temperature range (see checklist for exact temperatures). Methane results are considered biased low due to the elevated temperature and are flagged ‘JL.’ Sample names are included in the data review checklist.

Chain of custody records for each WO were also reviewed to confirm that information was complete, custody was not breached, and samples were analyzed within the acceptable holding time. Chain of custody records were complete and correct, except for several minor naming or sample time discrepancies that did not affect data quality or usability (see checklists for details). Samples were analyzed within holding times.

No other sample handling anomalies were identified that would adversely affect data quality.

10.3 Analytical Sensitivity and Blanks

Reported limits of detection (LODs) for regulated analytes were below the 362 µg/L ACL for non-detectable results.

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. Equipment blanks were collected to assess the possibility of cross-contamination from sampling equipment. There were no blank detections that affected data quality, with the following exceptions:

- *Deep residential WOs 1138427, 1138443, 1138505,* and *1138621.* TOC was detected in the method blanks at an estimated concentration. Sample results for TOC in these WOs were considered non-detectable and were flagged 'UB', where the analyte was detected at less than five times the concentration in the method blank. Samples with detections above the limit of quantitation (LOQ) were flagged at the reported concentration; samples with detections below the LOQ were flagged at the LOQ. Sample names are included in the data review checklist.

- *Deep residential WO 1138505*. Nitrate was detected in the method blank at an estimated concentration. The affected sample results were considered nondetect and were flagged 'UB' at the LOQ. Sample names are included in the data review checklist.

10.4 Accuracy

Laboratory analytical accuracy was assessed by evaluating the analyte recoveries from continuing calibration verification (CCV), laboratory control sample (LCSs), 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 or soil matrices. In some cases, the laboratory spiked project samples as matrix spike (MS) and MS duplicate (MSD) samples 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 evaluated.

There were no CCV or initial calibration verification failures affecting data quality for samples obtained. Recovery information was reviewed for LCS/LCSDs and MS/MSDs associated with project samples. LCS and LCSD recoveries were within laboratory control limits for each preparatory batch. Recovery of analyte surrogates and the sulfolane internal standard were within laboratory control limits.

Laboratory CCV, LCS/LCSD, MS/MSD, and surrogate recovery information indicated that the analytical results were accurate, with one exception. For deep residential WO 1138515, the

MS recovery for chloride was above QC criteria. The affected sample results were considered estimated and biased high, and were flagged 'JH.' Sample names are included in the data review checklist.

10.5 Precision

Duplicate samples were collected at a frequency of 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 is evaluated only if the results of the analyses for both duplicates are detected quantitatively (above the LOQ). The following duplicate samples were collected:

- Two duplicates for deep residential analyses (19 samples total)
- Five duplicates for Phase 8 initial groundwater samples (40 samples total)

Results of RPD calculations for each of the duplicate samples were within the data quality objective of 30 percent for water data and 50 percent for soil data (laboratory duplicate), where calculable. No duplicate samples were collected for Phase 8 TOC soil samples; laboratory duplicate information suggested adequate precision at the analytical level.

Laboratory analytical precision was also evaluated by laboratory RPD calculations using the LCS/LCSD, MS/MSD, and laboratory duplicate sample results. There were no RPDs above laboratory control limits that affected data quality.

Based on review of the data, the results associated with this addendum are considered precise.

10.6 Data Quality Summary

Based on the methods outlined in the RSAP, the samples collected were considered 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 collected during the 2013 field season did not appear to have been compromised by analytical irregularities and results affected by QC anomalies are qualified with the appropriate data flags (Tables 3-2, 7-3, and 7-5.).

11. Conclusions

This Offsite Addendum is the last in a series of site characterization reports that collectively present a large body of information that has been gathered to ascertain the physical characteristics of the site, define the sources of contamination, and determine the nature and extent of contamination present at the site.

FHRA completed the following offsite site characterization activities in 2013:

- Installation of 43 additional monitoring wells in the offsite area. FHRA has installed a total of 165 monitoring wells in the offsite area.
- Collection of soil samples for soil classification and TOC analysis and evaluation of previously collected TOC groundwater samples.
- Initiation of deep private well sampling to characterize sulfolane impacts below permafrost and evaluate geochemical parameters.
- Completion of three geophysical surveys to evaluate the distribution of discontinuous permafrost in the offsite area.
- Annual sampling of the buffer zone and the addition of private well Search Area 10 on the eastern side of the sulfolane plume.

The culmination of site characterization activities and evaluations resulted in the following summarized conclusions:

- Groundwater flow and transport at the site is dynamic and extremely complex due to a combination of factors including heterogeneously distributed soil types, discontinuous permafrost, seasonal fluctuations in surface water elevations at the Tanana and Chena rivers, and annual freeze-thaw cycles that extend well below ground.
- Permafrost is generally continuous offsite and at least two probable locations of taliks were identified through the 2013 geophysical investigations and other site data. FHRA concludes that the taliks are primarily responsible for sulfolane flux to the subpermafrost aquifer. Sulfolane transport in the subpermafrost is also affected by bifurcation around permafrost and the possible existence of other taliks.
- Sulfolane releases began in 1985 (Geomega2013a).
- Sulfolane concentration trends in monitoring and private wells in the offsite area near the NPR are decreasing.

- Sulfolane concentration trends are increasing in the northern and western distal ends of the plume.

- Seasonal trends in sulfolane concentrations are observable in a relatively small subset of monitoring wells and are consistent with the decreasing trends near to the NPR.

- There is one currently confirmed private well (PW-1230) that exceeds the 362 µg/L ACL. There are also two other potential private wells/locations (PW-0228 and PW-1098 that may potentially exceed the ACL based on historical data, but these wells are either not accessible or abandoned.

- The sulfolane plume is delineated horizontally in the offsite area and potential receptors are protected through the AWS program (Barr 2013c). The adaptive management of the buffer zone allows for ongoing delineation through the use of private wells.

- The AWS programs, which include protection and monitoring of buffer zone sampling, ensure that people will not be exposed to sulfolane-impacted groundwater.

Groundwater flow and transport at the site is dynamic and complex due to a combination of factors including heterogeneously distributed soil types, discontinuous permafrost, seasonal fluctuations in surface water elevations at the Tanana and Chena Rivers, and annual freeze-thaw cycles that extend well below ground. Eight phases of site investigations have been performed that have focused on characterizing groundwater flow and the fate and transport of site-related COCs. These hydrogeologic investigations resulted in the installation of 165 offsite groundwater monitoring wells, and the collection and analysis of 4,332 groundwater samples from offsite monitoring and private wells. Hydrogeologic investigations have also included measuring hydraulic conductivity at more than 50 well locations, performing three tracer tests, performing several geophysical surveys, collecting many years' worth of high-resolution water-level monitoring data, and constructing and calibrating a 3-D mathematical groundwater flow model.

Results of these investigations have enabled the creation of a detailed hydrogeologic conceptual site model that encompasses the complexities encountered at the site and accurately accounts for the fate and transport of site-related COCs.

Of particular importance is the identification and characterization of off-site taliks, which are year-round zones of unfrozen ground within the permafrost area and provide a hydraulic connection between the supra- and subpermafrost aquifers. One talik (Talik A) is located in an area roughly bounded by 3rd Avenue, 4th Avenue, Therron Street, and Rosson's Cross Way. Another potential talik (Talik B) is located near monitoring well MW-160. Both of these taliks are within the sulfolane plume. Multiple lines of evidence demonstrate that these taliks are probable transport pathways for sulfolane-containing suprapermafrost groundwater to have entered the subpermafrost aquifer. Other taliks may be present, but the sulfolane plume is delineated.

It is concluded that the site hydrogeologic and fate and transport conceptual site model is within a reasonable degree of accuracy necessary to evaluate potential risks associated with groundwater transport and remediation alternatives. The CSM will support development of the final cleanup plan for the site.

Site characterization of the offsite area is sufficiently complete to define the nature and extent of sulfolane in the groundwater, characterize the associated risk, and provide the basis for preparation of risk-based cleanup alternatives for the offsite area.

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Tables

Table 3-1
Well Construction Details

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well	New Well Name	LocationNdx	Proximity	Boring Completion Date	Survey Date	Riser Elevation (feet MSL)	Riser Stickup* (feet)	Ground Surface Elevation (feet MSL)	Well Depth (feet BGS)	Well Bottom Elevation (feet MSL)	Depth to Top of Permafrost (feet BGS)	Well Diameter (inches)
MW-101	MW-101-60	8c6933da-5b95-4b6c-8309-bea55309be88	On-site	3/19/1987	Nov-2012	494.59	3.45	491.1	61.00	430.14	—	2.00
MW-101A	MW-101A-25	c4675dab-3f5d-4b60-a525-174cc6cd4d26	On-site	3/28/1987	Nov-2012	495.01	4.00	491.0	23.00	468.01	—	2.00
MW-102	MW-102-70	6f9cbe39-0966-482c-b75a-8eb43ef13d20	On-site	4/4/1987	Nov-2012	496.02	3.46	492.6	71.50	421.06	—	2.50
MW-104	MW-104-65	ec38e78a-67b2-4bc4-aa9f-a01bf06be14c	On-site	4/2/1987	Nov-2012	496.02	2.99	493.0	67.00	426.03	—	2.50
MW-105	MW-105-65	e68ad9b8-65d9-470c-8710-a309c94f7e16	On-site	3/21/1987	Nov-2012	497.66	2.46	495.2	63.00	432.20	—	2.00
MW-105A	MW-105A-25	80d77aae-0d1a-4eef-8d89-622541a27567	On-site	3/21/1987	Nov-2012	499.21	3.58	495.6	23.00	472.63	—	2.00
MW-106	MW-106-25	c33d535e-505d-4b33-90ad-467f531db826	On-site	9/14/1987	Nov-2012	499.28	1.51	497.8	23.00	474.77	—	2.00
MW-109	MW-109-15	dd7599e8-23ef-4279-886b-8cf29aa95e21	On-site	8/9/1988	Aug-2013	495.16	0.32	494.8	14.00	480.84	—	2.00
MW-110	MW-110-20	c885097c-4b0b-4bdd-bd54-fca010186534	On-site	8/10/1988	Nov-2012	496.73	3.26	493.5	18.00	475.47	—	2.00
MW-110-65	MW-110-65	aad4add7-6453-4b0a-a483-9bdb01bf05fl	On-site	8/23/2013	Nov-2013	496.38	2.70	493.9	65.87	428.05	—	2.00
MW-113	MW-113-15	e1e85c3a-02ba-48d2-9a61-6bc09cc41709	On-site	9/19/1988	Sept-2013	494.50	3.11	491.4	16.00	475.39	—	2.00
MW-115	MW-115-15	3e8beaaa-c956-4e99-9a85-4cb8479a23b6	On-site	9/20/1988	Nov-2012	495.84	2.55	493.3	17.00	476.29	—	2.00
MW-116	MW-116-15	5449f925-cc12-4424-b8ee-5bd0346876a9	On-site	9/22/1988	Nov-2012	496.17	2.91	493.3	17.00	476.26	—	2.00
MW-118	MW-118-45	f92339d0-5845-4777-9490-bee15733a26f	On-site	3/9/1990	Nov-2012	496.90	4.26	492.6	43.00	449.64	—	2.00
MW-124	MW-124-25	9d4146c4-2288-4174-973e-9968db5ffa36	On-site	6/6/1990	Nov-2012	497.39	3.36	494.0	24.50	469.53	—	2.00
MW-125	MW-125-25	936c4ce9-759f-4c03-984a-218d1c3eb2e6	On-site	6/6/1990	Sept-2013	496.19	3.16	493.0	24.00	469.03	—	2.00
MW-126	MW-126-25	9e272cdf-aead-4230-a1fc-d5c774f1bff3	On-site	6/4/1991	Nov-2012	495.53	3.72	491.8	24.50	467.31	—	2.00
MW-127	MW-127-25	3c8b2299-30e8-4953-b53b-e4618996b1c4	On-site	6/4/1991	Nov-2012	496.53	3.68	492.9	24.50	468.35	—	2.00
MW-129	MW-129-40	3f653a34-8d89-4c0d-b564-a014a0e113c7	On-site	10/21/1996	Nov-2012	496.05	3.12	492.9	41.50	451.43	—	2.00
MW-130	MW-130-25	adb8abca-656d-4275-a122-7eb6dfa177e2	On-site	4/22/1997	Sept-2013	496.92	3.09	493.8	23.00	470.83	—	2.00
MW-131	MW-131-25	648918db-c579-4123-a2ac-6d7e45d3c2db	On-site	8/5/1988	Nov-2012	495.75	2.00	493.8	24.50	469.25	—	2.00
MW-132	MW-132-20	50f5cc49-a244-4c3b-a7d6-e94da455bbf7	On-site	9/1/1999	Nov-2012	499.41	2.69	496.7	22.00	474.72	—	2.00
MW-133	MW-133-20	cfe03169-8621-499f-a766-d5422d7ef2b6	On-site	9/1/1999	Nov-2012	498.34	2.59	495.8	22.00	473.75	—	2.00
MW-134	MW-134-20	5c263c87-677b-4b39-99f7-431d09f73f86	On-site	9/2/1999	Nov-2012	497.76	2.56	495.2	21.50	473.70	—	2.00
MW-135	MW-135-20	e8d8040f-9f30-41db-b114-12fd3df3e687	On-site	3/8/2001	Sept-2013	496.93	3.74	493.2	19.50	473.69	—	2.00
MW-136	MW-136-20	63d04061-0bfc-4b91-8b32-9327af1ef389	On-site	3/8/2001	Sept-2013	496.90	3.46	493.4	19.10	474.34	—	2.00
MW-137	MW-137-20	75bb3a9d-018d-4e24-b946-097f1b039e12	On-site	3/8/2001	Sept-2013	497.41	3.17	494.2	19.30	474.94	—	2.00
MW-138	MW-138-20	09218cf6-c842-44b0-9103-be0e9b75d23e	On-site	4/12/2001	Nov-2012	496.34	3.14	493.2	18.10	475.10	—	2.00
MW-139	MW-139-25	11a10f6f-293a-43ed-9810-3a99a9801c82	On-site	5/29/2001	Nov-2012	497.25	1.96	495.3	25.00	470.29	—	2.00
MW-140	MW-140-25	120cd6b1-99f9-4658-807f-026fd882b362	On-site	5/30/2001	Nov-2012	494.90	2.83	492.1	23.50	468.57	—	2.00
MW-141	MW-141-20	aa3c73fc-28fd-4450-910b-beb741379567	On-site	10/5/2001	Nov-2012	492.38	2.17	490.2	22.40	467.81	—	2.00
MW-142	MW-142-20	d936bcfb-3bb8-46ca-8941-e3deda411e8e	On-site	8/10/2001	Nov-2012	495.73	2.73	493.0	19.40	473.60	—	2.00
MW-143	MW-143-20	c053326a-ce4a-496c-ba5a-ab0285db6231	On-site	8/15/2005	Nov-2012	495.37	3.36	492.0	19.50	472.51	—	2.00
MW-144A	MW-144A-25	2073119e-a978-415d-b462-79c6778f4875	On-site	9/15/2005	Nov-2012	495.35	2.95	492.4	24.70	467.70	—	2.00
MW-144BR	MW-144BR-90	74d7d402-6600-4c48-baec-8043d9f97581	On-site	9/21/2011	Nov-2012	494.98	2.88	492.1	90.52	401.58	—	2.00
MW-145	MW-145-20	a68360ec-cb7c-4e71-bc92-f81f25c0fe97	On-site	8/15/2005	Nov-2012	495.61	2.76	492.9	19.00	473.85	—	2.00
MW-146A	MW-146A-15	a153e041-db13-4815-a3f0-a7b3aa194f2f	On-site	9/29/2008	Nov-2012	495.09	2.52	492.6	16.00	476.57	—	2.00
MW-146B	MW-146B-30	35df5d2a-e57f-49e0-966f-a29193e18278	On-site	9/29/2008	Nov-2012	494.98	2.39	492.6	28.00	464.59	—	2.00
MW-147A	MW-147A-15	e21730cb-7d79-46cf-ae91-8be7df137d9f	On-site	10/1/2008	Nov-2012	491.93	2.26	489.7	13.00	476.67	—	2.00
MW-147B	MW-147B-25	43d14a64-0135-4ef9-bc09-12a9a1a8da87	On-site	9/30/2008	Nov-2012	492.59	2.90	489.7	26.00	463.69	—	2.00
MW-148A	MW-148A-15	c863983f-2f4f-4113-ad84-0f8272f9b4b2	Off-site	10/2/2008	Sept-2013	493.07	2.17	490.9	15.00	475.90	—	2.00
MW-148B	MW-148B-30	c574206f-5e58-4fff-a65a-2933780336da	Off-site	10/2/2008	Sept-2013	492.86	2.60	490.3	29.00	461.26	—	2.00
MW-148C	MW-148C-55	e25814ff-b3b3-49d7-9d8b-899a805bd295	Off-site	9/27/2011	Sept-2013	493.33	2.74	490.6	55.74	434.85	—	2.00
MW-148D	MW-148D-150	c6693a5f-dd7d-437d-95d4-76d167d43ff3	Off-site	9/26/2011	Sept-2013	493.36	3.01	490.4	150.96	339.39	151.5	2.00
MW-148-100	MW-148-100		Off-site	10/3/2013	Oct-2013	493.04	2.72	490.1	100.40		—	2
MW-148-80	MW-148-80		Off-site	10/9/2013	Oct-2013	493.20	2.96	490.5	80.54		—	2

Table 3-1
Well Construction Details

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well	New Well Name	LocationNdx	Proximity	Boring Completion Date	Survey Date	Riser Elevation (feet MSL)	Riser Stickup* (feet)	Ground Surface Elevation (feet MSL)	Well Depth (feet BGS)	Well Bottom Elevation (feet MSL)	Depth to Top of Permafrost (feet BGS)	Well Diameter (inches)
MW-149A	MW-149A-15	cb2e6f70-db70-4032-bd7c-d5c24a756757	On-site	10/3/2008	Aug-2013	493.72	2.81	490.9	14.00	476.91	—	2.00
MW-149B	MW-149B-20	d4cbb151-c1a4-4cd9-aced-0623e6e7ee19	On-site	10/3/2008	Nov-2012	493.38	2.32	491.1	21.00	470.06	19.0	2.00
MW-150A	MW-150A-10	bb50bc4d-6401-41d3-9861-696370680d01	Off-site	10/2/2009	Nov-2012	487.14	-0.43	487.6	11.58	475.99	—	2.00
MW-150B	MW-150B-25	83c37284-76b4-4384-bb48-333ec07b1a23	Off-site	10/2/2009	Nov-2012	486.95	-0.57	487.5	24.64	462.88	—	2.00
MW-150C	MW-150C-60	744ba0c5-b6fd-45dd-af82-8e44bb0c445c	Off-site	5/12/2012	Nov-2012	486.41	-0.56	487.0	60.51	426.46	63.5	2.00
MW-151A	MW-151A-15	6472319f-ab90-4ae5-a9f6-aec78497a44d	Off-site	10/7/2009	Mar-2013	487.27	-0.23	487.5	15.50	472.00	—	2.00
MW-151B	MW-151B-25	cde41833-053d-4233-9371-074d867381f9	Off-site	10/2/2009	June-2013	487.22	-0.40	487.6	23.60	464.02	—	2.00
MW-151C	MW-151C-60	1370ecf0-782c-472f-87fe-16464098f678	Off-site	2/18/2010	June-2013	491.14	3.57	487.6	57.70	429.87	65.0	2.00
MW-152A	MW-152A-15	dbff8efb-8352-4146-93a0-05ff923ce646	Off-site	10/7/2009	Aug-2013	488.35	-0.28	488.6	16.00	472.63	—	2.00
MW-152B	MW-152B-25	0eb80aa1-7d5a-40c0-8a91-a8070d8a7eb9	Off-site	10/7/2009	Aug-2013	488.13	-0.35	488.5	25.40	463.08	—	2.00
MW-152C	MW-152C-65	131fa3db-b2f5-4a20-af1d-102e754c79a6	Off-site	9/28/2011	Aug-2013	488.17	-0.53	488.7	65.17	423.53	67.5	2.00
MW-153A	MW-153A-15	f7edf3d9-f361-4bdb-9fd5-2314b04bff4c	Off-site	10/7/2009	Aug-2013	490.11	-0.40	490.5	16.00	474.51	—	2.00
MW-153B	MW-153B-55	3d1d3c74-cfca-42a5-9592-3d1c1d22bf7f	Off-site	4/20/2010	Aug-2013	489.78	-0.50	490.3	56.65	433.63	59.0	2.00
MW-154A	MW-154A-75	6b3e69b9-1a05-4fea-b43f-887e876aa695	On-site	10/5/2009	Nov-2012	498.04	2.56	495.5	75.50	419.98	—	2.00
MW-154B	MW-154B-95	fa3ffb61-9bc7-402a-9ca9-80ba980c1980	On-site	2/20/2010	Nov-2012	497.76	2.70	495.1	95.00	400.06	102.0	2.00
MW-155A	MW-155A-15	19457422-9ed5-4d15-9e3d-c648f8a46f1e	Off-site	11/11/2009	Nov-2012	488.19	-0.40	488.6	15.50	473.09	—	2.00
MW-155B	MW-155B-65	ac168cd7-f9ef-440c-811e-71b85463dd3b	Off-site	9/11/2010	Nov-2012	488.25	-0.45	488.7	65.80	422.90	67.0	2.00
MW-156A	MW-156A-15	d6afa1bc-65e8-441c-8962-d93590ea2511	Off-site	11/11/2009	Sept-2013	485.80	-0.33	486.1	15.50	470.63	—	2.00
MW-156B	MW-156B-50	f0ea807b-3999-4835-b358-766fdef01961	Off-site	2/17/2010	Nov-2012	489.36	2.87	486.5	50.40	436.09	51.5	2.00
MW-157A	MW-157A-15	cba4e6c6-dba6-438b-b519-39772d4ea37a	Off-site	11/13/2009	Aug-2013	485.06	-0.21	485.3	15.50	469.77	—	2.00
MW-157B	MW-157B-30	26ec3cf5-cb09-40b7-96bf-1947c5fbfa5b	Off-site	9/30/2011	Aug-2013	484.74	-0.52	485.3	30.73	454.53	40.0	2.00
MW-158A	MW-158A-15	c1b5076c-8e3e-4b4a-bf4e-80b6fe6f8fef	Off-site	11/13/2009	June-2013	488.07	-0.04	488.1	15.60	472.51	—	2.00
MW-158B	MW-158B-60	29aea756-0983-4744-9696-d1ca2057e2ec	Off-site	9/23/2010	Nov-2012	487.46	-0.49	488.0	60.61	427.34	65.0	2.00
MW-159A	MW-159A-15	d81c04b3-15c3-4d1b-841e-93795e73becf	Off-site	11/13/2009	Nov-2012	488.52	-0.37	488.9	15.60	473.29	—	2.00
MW-159B	MW-159B-45	b8ef50c5-4697-4b23-9257-a96b6226c20a	Off-site	10/12/2011	Nov-2012	488.22	-0.77	489.0	46.20	442.79	—	2.00
MW-159C	MW-159C-70	ee856537-f0a8-404b-b2db-af9983b67093	Off-site	9/29/2011	Nov-2012	488.70	-0.38	489.1	72.30	416.78	72.5	2.00
MW-160AR-15	MW-160AR-15	757debee-b964-479d-812e-45ed3f32201a	Off-site	4/16/2013	Sept-2013	485.51	-0.42	486.0	15.27	470.68	—	2.00
MW-160B	MW-160B-90	80debeec-8345-4d7f-af15-85a351ce7095	Off-site	2/19/2010	Sept-2013	485.46	-0.34	485.8	90.73	395.07	91.0	2.00
MW-161A	MW-161A-15	83a1130f-71d5-4a40-9d37-3917df391445	Off-site	12/9/2009	Sept-2013	479.51	-0.67	480.2	15.60	464.58	—	2.00
MW-161B	MW-161B-50	b2616abb-dfd0-424d-9a00-edd16bfac373	Off-site	9/10/2010	Nov-2012	479.60	-0.34	479.9	50.44	429.50	54.0	2.00
MW-161-30	MW-161-30	8bdd00d1-c1b4-4b5d-9441-861cd6c8ace2	Off-site	4/23/2013	Sept-2013	479.62	-0.51	479.8	30.19	449.64	—	2.00
MW-162A	MW-162A-15	858392a1-38eb-4f06-a0e5-82ff1d909661	Off-site	11/25/2009	Sept-2013	484.02	-0.47	484.5	15.60	468.89	—	2.00
MW-162B	MW-162B-65	9457f288-c784-4216-8d18-0c365d5d579e	Off-site	11/25/2009	Sept-2013	484.20	-0.22	484.4	65.38	419.04	67.5	2.00
MW-163A	MW-163A-15	b910d35b-c2f0-45ac-986d-fd8b1b17795c	Off-site	12/9/2009	Nov-2012	485.02	-0.78	485.8	15.60	470.20	—	2.00
MW-163B	MW-163B-40	438df18a-ab13-4309-a5b1-3331fa88f2af	Off-site	9/13/2010	Nov-2012	484.80	-0.93	485.7	39.55	446.18	40.0	2.00
MW-164A	MW-164A-15	7cbec488-f8f7-4eec-ad8b-6858cba234c6	Off-site	12/10/2009	Sept-2013	480.09	-0.59	480.7	15.60	465.08	—	2.00
MW-164B	MW-164B-50	bc4b92c6-94c9-49ce-8af7-37bb4eb8d8ea	Off-site	9/9/2010	June-2013	479.85	-0.33	480.2	50.67	429.51	—	2.00
MW-164C	MW-164C-60	85dc25cb-443f-4f85-a00c-d70112552fc1	Off-site	8/17/2011	June-2013	479.90	-0.44	480.3	62.44	417.90	63.0	2.00
MW-165A	MW-165A-15	73dd9d61-5434-4b1a-921e-9f07f0fce24a	Off-site	1/18/2010	Nov-2012	474.79	-0.46	475.3	15.40	459.85	—	2.00
MW-165B	MW-165B-50	7aacb690-eca4-4beb-ab2a-e12427ba7fe6	Off-site	9/28/2010	Nov-2012	474.64	-0.62	475.3	50.88	424.38	—	2.00
MW-166A	MW-166A-15	206d095c-1583-4c5a-81fb-673ce91fdef6	Off-site	1/8/2010	Sept-2013	475.08	2.38	472.7	15.60	457.10	—	2.00
MW-166B	MW-166B-30	c1c48e00-7fde-465f-bfa8-d929db2f4301	Off-site	3/15/2010	July-2013	475.51	3.24	472.3	32.10	440.17	33.0	2.00
MW-167A	MW-167A-15	e1ff3df0-be30-4411-ae47-689fcaf01bb8	Off-site	1/7/2010	July-2013	475.70	-0.32	476.0	15.80	460.22	—	2.00
MW-167B	MW-167B-35	5bfc3b82-de6b-4d32-89c4-a35b7ad24ceb	Off-site	3/23/2010	Nov-2012	475.57	-0.52	476.1	33.27	442.82	33.5	2.00
MW-168A	MW-168A-15	10b43fff-61db-483a-a9fa-10f28b4597c7	Off-site	1/8/2010	Mar-2013	478.25	-0.41	478.7	15.50	463.16	—	2.00
MW-168B	MW-168B-50	fb777856-a6f9-458d-819b-3c12e5ac82bb	Off-site	10/1/2011	Nov-2012	478.34	-0.28	478.6	51.45	427.17	55.0	2.00
MW-169A	MW-169A-15	e711bc9e-2ba8-484b-8156-66db4530d16f	Off-site	2/25/2010	Sept-2013	486.12	2.94	483.2	15.15	468.03	—	2.00

Table 3-1
Well Construction Details

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well	New Well Name	LocationNdx	Proximity	Boring Completion Date	Survey Date	Riser Elevation (feet MSL)	Riser Stickup* (feet)	Ground Surface (feet MSL)	Well Depth (feet BGS)	Well Bottom Elevation (feet MSL)	Depth to Top of Permafrost (feet BGS)	Well Diameter (inches)
MW-169B	MW-169B-50	9aa9bf82-4e2f-460f-9cfb-7edb6f51e92c	Off-site	10/21/2010	Nov-2012	485.95	3.05	482.9	49.20	433.70	—	2.00
MW-169C	MW-169C-60	11c1f256-db61-406a-bed8-9e984c9d438e	Off-site	9/1/2011	June-2013	482.52	-0.47	483.0	59.94	423.05	69.0	2.00
MW-170A	MW-170A-15	5399b88d-fac3-419a-a9a6-3b42b9ff8b56	Off-site	2/24/2010	June-2013	490.69	-0.42	491.1	14.90	476.21	—	2.00
MW-170B	MW-170B-75	c6116c19-04a8-4ab7-9457-1447a1f6aad3	Off-site	3/6/2010	Nov-2012	490.74	-0.27	491.0	74.79	416.22	—	4.00
MW-170C	MW-170C-130	ab1f0c2b-3785-4d7f-aad5-950c9e2b18ee	Off-site	3/4/2010	Sept-2013	490.84	-0.46	491.3	130.90	360.40	135.0	2.00
MW-170D	MW-170D-50	b977bbde-8c66-4fcf-8938-2181173fb50b	Off-site	10/13/2010	Nov-2012	490.41	-0.55	491.0	50.62	440.34	—	2.00
MW-171A	MW-171A-15	3a686f73-8a7d-428f-86d1-892b7ce412f4	Off-site	2/25/2010	Sept-2013	484.89	-0.70	485.6	15.20	470.39	—	2.00
MW-171B	MW-171B-40	ecba7d43-fdde-4fdd-92a0-f24475320dc4	Off-site	3/16/2010	Nov-2012	484.83	-0.40	485.2	40.28	444.95	42.0	2.00
MW-172A	MW-172A-15	cc74169f-0255-4386-8627-180ad05b89da	Off-site	3/24/2010	June-2013	475.67	-0.15	475.8	15.47	460.35	—	2.00
MW-172B	MW-172B-150	b4e68ce9-85df-48eb-83d6-fe7ef818032a	Off-site	3/27/2010	Sept-2013	475.78	-0.31	476.1	150.37	325.72	150.5	2.00
MW-173A	MW-173A-15	d38c1929-95b9-4dfe-8a3f-f031749c79b3	On-site	3/3/2010	Aug-2013	496.10	3.12	493.0	14.60	478.38	—	2.00
MW-173B	MW-173B-150	6f17c038-1032-4b3c-a84b-994d64a0da3c	On-site	3/30/2010	Aug-2013	496.41	3.34	493.1	150.82	342.25	—	2.00
MW-174A	MW-174A-50	8d6cd868-99e3-4192-b4ee-9afbc9547848	On-site	9/16/2010	Aug-2013	494.40	3.06	491.3	50.17	441.17	—	2.00
MW-174B	MW-174B-90	fe67b0d8-ae5c-4f12-922e-0ad31c91dec6	On-site	9/15/2010	Aug-2013	493.53	2.11	491.4	90.37	401.05	—	2.00
MW-174-15	MW-174-15	36c45018-9e6f-4399-b75e-e4bcd146c19e	On-site	3/16/2013	Aug-2013	494.66	3.33	491.3	13.62	477.71	—	2.00
MW-175	MW-175-90	eeb725bf-8bd1-416e-8a63-3b457d4e8f48	On-site	9/30/2010	Sept-2013	497.09	3.31	493.8	90.82	402.96	—	2.00
MW-176A	MW-176A-15	8f8fd70b-ccfa-4e24-8d6b-38789e6e794a	On-site	10/4/2010	Nov-2012	497.02	3.20	493.8	14.83	478.99	—	2.00
MW-176B	MW-176B-50	604b04e0-8a0f-4f67-88d0-d75e316ee652	On-site	10/4/2010	Nov-2012	496.93	3.21	493.7	50.61	443.11	—	2.00
MW-176C	MW-176C-90	50c0f2bb-a6b2-4ba0-b42b-29339e859a06	On-site	10/1/2010	Nov-2012	496.86	3.15	493.7	90.49	403.22	—	2.00
MW-177	MW-177-90	81f2535c-945c-42a4-bf2f-25cb555ab202	On-site	9/22/2010	Nov-2012	497.92	3.01	494.9	89.71	405.20	—	2.00
MW-178A	MW-178A-15	b9eeb43a-dedb-4099-b400-3b4e64d82051	On-site	9/18/2010	Nov-2012	496.48	2.32	494.2	16.06	478.10	—	2.00
MW-178B	MW-178B-50	128a2b63-39bf-48c5-b5bb-5d3cdb4227a0	On-site	9/18/2010	Nov-2012	496.10	2.19	493.9	51.17	442.74	—	2.00
MW-178C	MW-178C-90	89476783-9371-468f-b5ca-5d00ff586e68	On-site	9/17/2010	Nov-2012	497.27	3.03	494.2	90.15	404.09	—	2.00
MW-179A	MW-179A-15	217cdccb-aae5-402d-903d-42e6a55d302b	On-site	9/21/2010	Aug-2013	496.96	3.05	493.9	15.61	478.30	—	2.00
MW-179B	MW-179B-50	8191320f-d376-4d7e-a44e-43a9f3eafa74	On-site	9/21/2010	Aug-2013	496.75	2.68	494.1	50.82	443.25	—	2.00
MW-179C	MW-179C-90	3ed4c681-a78b-4a12-b1e2-76c620c4b20a	On-site	9/20/2010	Aug-2013	497.26	2.85	494.4	90.43	403.98	—	2.00
MW-179D	MW-179D-135	f59efef3-a7eb-45db-87c8-aa9ee6c2c605	On-site	8/12/2011	Aug-2013	497.06	3.08	494.0	134.05	359.93	140.5	2.00
MW-180A	MW-180A-15	edc01ed2-a0fa-4b01-a6d9-753ca8ee8712	On-site	9/27/2010	Nov-2012	497.42	3.09	494.3	15.39	478.94	—	2.00
MW-180B	MW-180B-50	929744be-c316-4939-a7ba-299144cc8cfa	On-site	9/27/2010	Nov-2012	496.87	2.65	494.2	50.72	443.50	—	2.00
MW-180C	MW-180C-90	c00e3e03-4057-431f-b78b-eb79d29b0502	On-site	9/25/2010	Nov-2012	497.05	2.85	494.2	90.42	403.78	—	2.00
MW-181A	MW-181A-15	7053e244-ccfe-4057-a506-7828df70218b	Off-site	10/6/2010	Mar-2013	475.92	-0.57	476.5	15.16	461.33	—	2.00
MW-181B	MW-181B-50	1d082ba1-2360-4893-9032-492b917dbab9	Off-site	10/6/2010	Mar-2013	475.86	-0.50	476.4	50.78	425.58	—	2.00
MW-181C	MW-181C-150	31cedc29-9d51-462a-aff1-95986d865a33	Off-site	10/3/2011	Mar-2013	475.99	-0.41	476.4	150.45	325.95	—	2.00
MW-182A	MW-182A-15	a5ce3813-d458-44e3-b355-abd4d23fea7f	Off-site	10/8/2010	Sept-2013	475.54	-1.26	476.8	15.83	460.97	—	2.00
MW-182B	MW-182B-45	a342983d-d059-4008-bd45-34cda85bb499	Off-site	8/22/2011	Nov-2012	475.40	-0.46	475.9	44.67	431.19	46.0	2.00
MW-183A	MW-183A-15	e5d68eb2-b393-4f15-af05-75786ca4a927	Off-site	10/8/2010	July-2013	478.07	-0.57	478.6	15.88	462.76	—	2.00
MW-183B	MW-183B-60	d252e661-b594-4ae6-90ab-f8e5fa82360f	Off-site	8/29/2011	Nov-2012	478.06	-0.58	478.6	59.74	418.90	59.0	2.00
MW-184	MW-184-45	0cbc893c-b05a-45d2-a842-665464c4c404	Off-site	10/1/2010	Nov-2012	486.64	-0.65	487.3	45.23	442.06	45.0	2.00
MW-185A	MW-185A-15	9e97ae62-a8b1-43d6-8a00-4427bad73915	Off-site	10/12/2010	Mar-2013	478.06	-0.63	478.7	15.57	463.12	—	2.00
MW-185B	MW-185B-50	43642a11-8039-43f5-880e-5f48fd5e6b95	Off-site	10/12/2010	Nov-2012	478.09	-0.41	478.5	51.41	427.09	—	2.00
MW-185C	MW-185C-120	2e90d00a-1f1f-47f0-abfd-62758da35a4e	Off-site	10/2/2011	Nov-2012	478.48	-0.21	478.7	120.99	357.70	121.0	2.00
MW-186A	MW-186A-15	b2087a30-aa24-4f9a-99e4-62668dd7bcbe	On-site	10/19/2010	Sept-2013	495.96	3.25	492.7	15.22	477.49	—	2.00
MW-186B	MW-186B-60	8579ac99-b316-4b4a-b546-77a9e2b51425	On-site	10/16/2010	Sept-2013	495.84	3.13	492.7	60.80	431.91	—	2.00
MW-186C	MW-186C-100	7e1055f3-3687-4b0d-b4f3-0a3e1f8a23d0	On-site	10/15/2010	Sept-2013	495.76	3.13	492.6	100.79	391.84	—	2.00
MW-186D	MW-186D-135	bfda4d89-f544-46af-ae80-d52291ec5926	On-site	12/4/2011	Sept-2013	495.75	3.03	492.7	134.99	357.73	—	2.00
MW-186E	MW-186E-75	653ec055-cba7-47ef-a88d-e431c041b2a5	On-site	4/25/2012	Sept-2013	495.77	3.05	492.7	75.90	416.82	—	2.00
MW-187	MW-187-15	31742dc2-af90-4c87-8b2f-a8dd8fabfc2f	Off-site	10/21/2010	Sept-2013	485.24	2.84	482.4	17.38	465.02	—	2.00
MW-188A	MW-188A-15	5ddda5b9-4293-4bbe-8d06-5a526ab397d3	Off-site	4/28/2012	Nov-2012	461.84	-0.15	462.0	15.33	446.66	—	2.00

Table 3-1
Well Construction Details

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well	New Well Name	LocationNdx	Proximity	Boring Completion Date	Survey Date	Riser Elevation (feet MSL)	Riser Stickup* (feet)	Ground Surface (feet MSL)	Well Depth (feet BGS)	Well Bottom Elevation (feet MSL)	Depth to Top of Permafrost (feet BGS)	Well Diameter (inches)
MW-188B	MW-188B-40	1508d9ed-465d-468e-a259-4359a973ccd2	Off-site	11/24/2010	Nov-2012	461.53	-0.37	461.9	40.90	421.00	45.5	2.00
MW-189A	MW-189A-15	0075df3e-6a72-41ef-ba90-0232d80fd953	Off-site	8/19/2011	July-2013	470.19	-0.67	470.9	16.54	454.32	—	2.00
MW-189B	MW-189B-60	46c3ba4b-71ff-473c-88aa-c18365631d92	Off-site	8/19/2011	Nov-2012	470.25	-0.74	471.0	60.52	410.47	—	2.00
MW-190A	MW-190A-15	74ad20c5-718a-4973-b527-be30857b750e	Off-site	8/23/2011	July-2013	481.87	-0.36	482.2	15.59	466.64	—	2.00
MW-190B	MW-190B-60	51bfae39-4c9e-42db-a9e2-a55efbf01d9e	Off-site	8/23/2011	Nov-2012	481.56	-0.30	481.9	60.71	421.15	—	2.00
MW-190BR-60	MW-190BR-60	62d96ce9-8ff1-41c8-9ff3-4fc9d8810f3f	Off-site	5/21/2013	Aug-2013	481.91	-0.39	482.2	59.87	422.31	—	2.00
MW-190-150	MW-190-150	3f45bf84-d557-4243-8421-643b35e9b0e5	Off-site	4/19/2013	Aug-2013	481.98	-0.30	482.2	150.38	331.80		2.00
MW-191A	MW-191A-15	6dac08f9-6dad-4a62-a22a-a1f38877305b	Off-site	8/24/2011	July-2013	475.64	-0.89	476.5	15.28	461.25	—	2.00
MW-191B	MW-191B-60	804f62a2-513e-437e-b657-16bb498c3370	Off-site	8/24/2011	Nov-2012	475.51	-0.78	476.3	60.29	416.00	—	2.00
MW-192A	MW-192A-15	3841482f-2140-4a33-bb23-4c43b718d176	On-site	8/25/2011	Nov-2012	495.90	2.44	493.5	14.64	478.82	—	2.00
MW-192B	MW-192B-55	3bdff44e-e8f6-47cc-adb6-c0c3d619b8c4	On-site	8/26/2011	Nov-2012	495.47	2.22	493.3	55.51	437.74	—	2.00
MW-193A	MW-193A-15	34ee4657-5706-4dde-9749-f1c11455c8ca	Off-site	8/30/2011	Nov-2012	487.70	-0.43	488.1	15.68	472.45	—	2.00
MW-193B	MW-193B-60	68779b3c-2b08-4919-8b9b-409460f468c0	Off-site	8/30/2011	Nov-2012	487.40	-0.61	488.0	59.88	428.13	61.0	2.00
MW-194A	MW-194A-15	4d0f5a2f-475d-4263-8797-b5c21c213819	Off-site	8/31/2011	July-2013	475.58	-0.72	476.3	15.76	460.54	—	2.00
MW-194B	MW-194B-40	f4955aea-57fd-4d16-8471-19392b1d7051	Off-site	8/31/2011	July-2013	475.58	-0.72	476.3	39.45	436.85	39.0	2.00
MW-195A	MW-195A-15	887ae104-8582-4451-8209-a0b8520c57fe	On-site	10/11/2011	Nov-2012	496.10	2.76	493.3	15.35	477.99	—	2.00
MW-195B	MW-195B-150	c9397f84-fd4e-43b9-8346-b33bb57985d4	On-site	12/5/2011	Nov-2012	496.12	2.66	493.5	149.90	343.56	—	2.00
MW-196	MW-196-15	cbdd5c63-bf3b-475b-91cb-a4a90f449a09	On-site	10/11/2011	Nov-2012	497.37	3.31	494.1	15.20	478.86	—	2.00
MW-197A	MW-197A-65	bcdd521a-7a68-4db1-85af-8742cc98b176	On-site	6/6/2012	Sept-2013	495.27	2.57	492.7	66.06	426.64	—	2.00
MW-197B	MW-197B-150	f6bfaa11-27ff-4d10-9826-803d86858840	On-site	10/16/2011	Sept-2013	495.30	2.57	492.7	149.69	343.04	—	2.00
MW-198	MW-198-150	cd74a54e-c2be-4b85-a0ad-5fe0afc23a57	On-site	12/10/2011	Nov-2012	493.32	-0.28	493.6	149.81	343.79	—	2.00
MW-199	MW-199-150	3136e722-ff90-44ab-b982-974fed428df5	On-site	12/2/2011	Sept-2013	495.90	2.61	493.3	149.83	343.46	—	2.00
MW-300	MW-300-150	b8e6bcad-e6f6-4aa9-be41-fa25bc7d2734	On-site	12/6/2011	Nov-2012	496.00	1.94	494.1	150.30	343.76	—	2.00
MW-301-60	MW-301-60	1309fc47-3c33-474d-9c9a-577acbae8de6	On-site	10/26/2011	Sept-2013	492.61	3.12	489.5	60.85	428.64	—	2.00
MW-301-70	MW-301-70	b0cfe94d-76d3-4744-b315-a39ee4fbccf8	On-site	10/9/2011	Sept-2013	492.65	3.05	489.6	70.75	418.85	71.5	2.00
MW-301-CMT-10	MW-301-CMT-10	45e59375-7d26-43da-805e-c702ad2b0c59	On-site	10/26/2011	Nov-2012	492.88	3.44	489.4	10.00	479.44	—	2.00
MW-301-CMT-20	MW-301-CMT-20	9247d837-6ffc-4dc5-b179-737a02f5475f	On-site	10/26/2011	Nov-2012	492.88	3.44	489.4	20.00	469.44	—	2.00
MW-301-CMT-30	MW-301-CMT-30	15dc715e-3028-45fc-85ab-9707df64c376	On-site	10/26/2011	Nov-2012	492.88	3.44	489.4	30.00	459.44	—	2.00
MW-301-CMT-40	MW-301-CMT-40	b03c66e4-8bb6-4dfa-a4d0-86851956cbc1	On-site	10/26/2011	Nov-2012	492.88	3.44	489.4	40.00	449.44	—	2.00
MW-301-CMT-50	MW-301-CMT-50	24b19377-e3ee-47e9-96d2-c161546244f9	On-site	10/26/2011	Nov-2012	492.88	3.44	489.4	50.00	439.44	—	2.00
MW-302-110	MW-302-110	5d4ba405-cc2a-4338-89ca-740dfc52b3fb	On-site	10/17/2011	Nov-2012	493.65	2.96	490.7	110.18	380.51	110.0	2.00
MW-302-70	MW-302-70	2127dd32-818b-4559-a0fa-6b4d88f76440	On-site	11/5/2011	Nov-2012	493.29	3.02	490.3	70.87	419.40	—	2.00
MW-302-80	MW-302-80	7f284d90-0548-4e9d-b96a-8b28adafbe52	On-site	11/3/2011	Nov-2012	493.49	3.04	490.5	81.45	409.00	—	2.00
MW-302-95	MW-302-95	aac0f671-f5f6-41ff-84d8-5fba21052c32	On-site	10/25/2011	Nov-2012	493.00	2.72	490.3	95.20	395.08	—	2.00
MW-302-CMT-10	MW-302-CMT-10	72042f21-8d91-45b7-aa69-5f22d031dbfd	On-site	10/25/2011	Nov-2012	494.32	3.58	490.7	10.00	480.74	—	2.00
MW-302-CMT-20	MW-302-CMT-20	69ceb9b6-ced9-432c-a175-80db1bb1f36e	On-site	10/25/2011	Nov-2012	494.32	3.58	490.7	20.00	470.74	—	2.00
MW-302-CMT-30	MW-302-CMT-30	e5f8f6d3-92de-4ba9-9a49-56bddea58c53	On-site	10/25/2011	Nov-2012	494.32	3.58	490.7	30.00	460.74	—	2.00
MW-302-CMT-40	MW-302-CMT-40	1a20705e-27f0-4da2-9d3c-47a53796cc5b	On-site	10/25/2011	Nov-2012	494.32	3.58	490.7	40.00	450.74	—	2.00
MW-302-CMT-50	MW-302-CMT-50	21d45ba2-4d7b-491d-bbac-a824d1ff991d	On-site	10/25/2011	Nov-2012	494.32	3.58	490.7	50.00	440.74	—	2.00
MW-303-130	MW-303-130	8ba941a5-e148-4319-9b19-f81ed11ff7fa	On-site	10/18/2011	Nov-2012	495.15	3.16	492.0	130.70	361.29	130.0	2.00
MW-303-70	MW-303-70	7f3741c9-9d92-48f6-8769-9d33b02761da	On-site	11/1/2011	Nov-2012	495.06	2.87	492.2	70.44	421.75	—	2.00
MW-303-80	MW-303-80	d7ff89b9-51f7-492d-abae-dac7daa8425b	On-site	11/2/2011	Nov-2012	495.12	2.92	492.2	80.73	411.47	—	2.00
MW-303-95	MW-303-95	296fd6bd-a783-4b4e-babc-9861f8b6ce53	On-site	4/17/2012	Nov-2012	495.12	3.12	492.0	95.18	396.82	—	2.00
MW-303-CMT-19	MW-303-CMT-19	916f06a0-b984-4f60-882a-5c6f0a3825f6	On-site	10/20/2011	Nov-2012	495.85	3.55	492.3	19.00	473.30	—	2.00
MW-303-CMT-29	MW-303-CMT-29	db5c3a41-aca4-404a-be96-853ec98d0a05	On-site	10/20/2011	Nov-2012	495.85	3.55	492.3	29.00	463.30	—	2.00
MW-303-CMT-39	MW-303-CMT-39	0bb0f695-6d18-4bbd-a0cc-4320f6f2254d	On-site	10/20/2011	Nov-2012	495.85	3.55	492.3	39.00	453.30	—	2.00
MW-303-CMT-49	MW-303-CMT-49	59320960-eddd-4f25-a4cd-2955c2c5885d	On-site	10/20/2011	Nov-2012	495.85	3.55	492.3	49.00	443.30	—	2.00
MW-303-CMT-59	MW-303-CMT-59	ea15de16-22c6-4b3f-a9fc-e1850efb9f6d	On-site	10/20/2011	Nov-2012	495.85	3.55	492.3	59.00	433.30	—	2.00

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Well Construction Details

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well	New Well Name	LocationNdx	Proximity	Boring Completion Date	Survey Date	Riser Elevation (feet MSL)	Riser Stickup* (feet)	Ground Surface (feet MSL)	Well Depth (feet BGS)	Well Bottom Elevation (feet MSL)	Depth to Top of Permafrost (feet BGS)	Well Diameter (inches)
MW-303-CMT-9	MW-303-CMT-9	f553e510-ec65-4ed3-9799-661e3fab173f	On-site	10/20/2011	Nov-2012	495.85	3.55	492.3	9.00	483.30	—	2.00
MW-304-125	MW-304-125	ed20c9f7-47cc-43d3-89d2-d543f79594b7	On-site	10/14/2011	Sept-2013	497.31	3.58	493.7	125.92	367.81	—	2.00
MW-304-15	MW-304-15	60b2d7b6-e484-48de-ab1b-59e65b977bdf	On-site	4/18/2012	Sept-2013	496.97	3.36	493.6	18.17	475.44	—	2.00
MW-304-150	MW-304-150	6355b686-cd1e-424d-864a-ca0cfa171a29	On-site	10/14/2011	Sept-2013	497.16	3.07	494.1	150.65	343.44	—	2.00
MW-304-70	MW-304-70	9cb7ef3c-1124-4d5b-af77-99deed83d16a	On-site	10/20/2011	Nov-2012	496.99	2.75	494.2	70.66	423.58	—	2.00
MW-304-80	MW-304-80	e12389bc-c38d-42a5-8a32-59c8d1b3f661	On-site	10/31/2011	Sept-2013	496.72	2.69	494.0	81.14	412.89	—	2.00
MW-304-96	MW-304-96	8c6ce46b-b92c-4a0a-a7cf-55d59709c34d	On-site	4/18/2012	Nov-2012	496.95	2.86	494.1	95.71	398.38	—	2.00
MW-304-CMT-10	MW-304-CMT-10	10c6425f-9586-4012-87df-3fe6d1b3a7b1	On-site	10/18/2011	Nov-2012	497.63	3.47	494.2	10.00	484.16	—	2.00
MW-304-CMT-20	MW-304-CMT-20	06594c0f-d20a-44c0-9975-7e911a400e42	On-site	10/18/2011	Nov-2012	497.63	3.47	494.2	20.00	474.16	—	2.00
MW-304-CMT-30	MW-304-CMT-30	591f6123-f677-4b01-8c90-85eebbcd9640	On-site	10/18/2011	Nov-2012	497.63	3.47	494.2	30.00	464.16	—	2.00
MW-304-CMT-40	MW-304-CMT-40	31176b97-78e2-449f-b4c9-a030f569a07f	On-site	10/18/2011	Nov-2012	497.63	3.47	494.2	40.00	454.16	—	2.00
MW-304-CMT-50	MW-304-CMT-50	dcad2eeb-1789-4b43-b1bd-723c616c8aba	On-site	10/18/2011	Nov-2012	497.63	3.47	494.2	50.00	444.16	—	2.00
MW-304-CMT-60	MW-304-CMT-60	b0354b9b-de8c-4191-a84d-9c32f6b38868	On-site	10/18/2011	Nov-2012	497.63	3.47	494.2	60.00	434.16	—	2.00
MW-305-100	MW-305-100	191a2bd2-8402-48c7-8cb6-21137bbb8291	On-site	10/8/2011	Nov-2012	495.71	2.74	493.0	99.92	393.05	110.0	2.00
MW-305-70	MW-305-70	99991c64-0234-4042-b07b-42e2cc2d5bca	On-site	10/22/2011	Nov-2012	495.67	2.91	492.8	70.37	422.39	—	2.00
MW-305-80	MW-305-80	f598bd82-ebb5-409f-9ec1-c77ba321b6d7	On-site	10/30/2011	Nov-2012	495.38	2.69	492.7	81.22	411.47	—	2.00
MW-305-CMT-18	MW-305-CMT-18	4fb3d95c-8ad2-4bd9-8e37-61db6ebc6e2e	On-site	10/24/2011	Nov-2012	496.39	3.25	493.1	17.50	475.64	—	2.00
MW-305-CMT-28	MW-305-CMT-28	8236c432-a2cd-4742-ab69-56461724e6c8	On-site	10/24/2011	Nov-2012	496.39	3.25	493.1	27.50	465.64	—	2.00
MW-305-CMT-38	MW-305-CMT-38	3a5529aa-7e30-4025-9770-1a0f58a823b3	On-site	10/24/2011	Nov-2012	496.39	3.25	493.1	37.50	455.64	—	2.00
MW-305-CMT-48	MW-305-CMT-48	97dd08c2-f86c-46af-b12c-906a02b50692	On-site	10/24/2011	Nov-2012	496.39	3.25	493.1	47.50	445.64	—	2.00
MW-305-CMT-58	MW-305-CMT-58	018a5235-21d2-4c61-b416-20fdcbed7ed5	On-site	10/24/2011	Nov-2012	496.39	3.25	493.1	57.50	435.64	—	2.00
MW-305-CMT-8	MW-305-CMT-8	48cb051e-eb13-479e-a53f-63b3636d6d2f	On-site	10/24/2011	Nov-2012	496.39	3.25	493.1	7.50	485.64	—	2.00
MW-306-100	MW-306-100	9eeddcc2-988f-41be-988b-102cf1189eae	On-site	10/13/2011	Nov-2012	495.55	2.46	493.1	100.60	392.49	—	2.00
MW-306-15	MW-306-15	bbcd63ca-6bbc-4916-b167-cb1dab067d17	On-site	4/16/2012	Sept-2013	496.76	3.22	493.5	15.40	478.14	—	2.00
MW-306-150	MW-306-150	e9bd0d60-c9e8-4620-a84d-e6d2175ac89a	On-site	10/7/2011	Sept-2013	496.00	2.89	493.1	150.06	343.05	—	2.00
MW-306-70	MW-306-70	c920d045-510c-44e2-93b0-959bca90d750	On-site	11/6/2011	Nov-2012	496.70	3.39	493.3	70.71	422.60	—	2.00
MW-306-80	MW-306-80	b9bbd97f-e39d-450b-b065-8e6808f08fa7	On-site	11/7/2011	Sept-2013	496.52	3.22	493.3	80.50	412.80	—	2.00
MW-306-CMT-10	MW-306-CMT-10	2e6ac20e-b6ea-4df2-bfc9-308ca328aae2	On-site	10/27/2011	Nov-2012	496.95	3.46	493.5	10.00	483.49	—	2.00
MW-306-CMT-20	MW-306-CMT-20	b219dd40-6e2e-4601-8b74-32b64e1fe761	On-site	10/27/2011	Nov-2012	496.95	3.46	493.5	20.00	473.49	—	2.00
MW-306-CMT-30	MW-306-CMT-30	281c0d3d-9026-43f5-a14d-590fd1dea111	On-site	10/27/2011	Nov-2012	496.95	3.46	493.5	30.00	463.49	—	2.00
MW-306-CMT-40	MW-306-CMT-40	dc309461-2074-49c9-b395-ea5cb8329a05	On-site	10/27/2011	Nov-2012	496.95	3.46	493.5	40.00	453.49	—	2.00
MW-306-CMT-50	MW-306-CMT-50	dea2bf0e-eb82-4065-945c-c464778f7022	On-site	10/27/2011	Nov-2012	496.95	3.46	493.5	50.00	443.49	—	2.00
MW-306-CMT-60	MW-306-CMT-60	733c00e5-c4c4-45fb-bfa7-8f9da2d50b68	On-site	10/27/2011	Nov-2012	496.95	3.46	493.5	60.00	433.49	—	2.00
MW-307	MW-307-150	441c3381-67a7-4762-8deb-f63fb327a678	On-site	12/3/2011	Sept-2013	495.48	2.67	492.8	149.90	342.91	—	2.00
MW-308-15	MW-308-15	0c011cf5-791c-44a6-afcd-e9964827443f	Off-site	4/13/2012	Nov-2012	476.90	3.94	473.0	14.95	458.01	—	2.00
MW-308-30	MW-308-30	c891037a-7eb6-4720-95d2-6eeea2713613	Off-site	4/12/2012	Nov-2012	475.35	3.67	471.7	30.42	441.26	41.0	2.00
MW-309-15	MW-309-15	70313467-cfe0-4f02-a965-980aeb198a51	On-site	4/19/2012	Sept-2013	494.90	2.87	492.0	15.06	476.97	—	2.00
MW-309-150	MW-309-150	85c0579a-38b9-4479-bef3-5dd55a57bdf4	On-site	4/19/2012	Aug-2013	494.80	2.78	492.0	149.75	342.27	—	2.00
MW-309-66	MW-309-66	781887fa-5adc-4c9d-8ec9-0e2d76f6bcd1	On-site	4/23/2012	Sept-2013	495.15	3.14	492.0	65.85	426.16	—	2.00
MW-310-110	MW-310-110	b46ef66a-fdcd-4ee9-aac2-5931c0a920f9	On-site	5/29/2012	Aug-2013	494.28	3.33	491.0	110.42	380.53	—	2.00
MW-310-15	MW-310-15	e18c0cdc-b4a8-4bea-9fae-12f9749e183c	On-site	4/26/2012	Aug-2013	494.26	3.01	491.3	14.72	476.53	—	2.00
MW-310-65	MW-310-65	fa7abb42-23b3-4e08-9c8c-06056aad2c59	On-site	4/20/2012	Nov-2012	494.38	3.00	491.4	65.53	425.85	—	2.00
MW-311-15	MW-311-15	96cf1943-8b19-4ac6-8c3b-bfe333ba1728	Off-site	4/26/2012	Aug-2013	466.78	-0.50	467.3	15.43	451.85	—	2.00
MW-311-46	MW-311-46	c1f358c0-e749-46e4-8100-c67cf94e2e2b	Off-site	4/28/2012	Aug-2013	466.96	-0.14	467.1	45.74	421.36	48.0	2.00
MW-312-15	MW-312-15	a9168da7-1e76-475c-971f-62cc864f15bf	Off-site	4/26/2012	Aug-2013	464.30	-0.28	464.6	15.52	449.06	—	2.00
MW-312-50	MW-312-50	a2203a2c-75d9-4d10-8f11-e3f118423b19	Off-site	5/2/2012	Aug-2013	464.25	-0.39	464.6	50.36	414.28	50.0	2.00
MW-313-15	MW-313-15	697987d2-cfb8-43e5-9e2a-a322b687717d	Off-site	4/30/2012	Nov-2012	465.79	-0.43	466.2	15.18	451.04	—	2.00
MW-313-150	MW-313-150	8d01c1b4-fa8c-4149-a991-0db598130175	Off-site	5/8/2012	Nov-2012	465.88	-0.29	466.2	149.94	316.23	—	2.00

Table 3-1
Well Construction Details

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well	New Well Name	LocationNdx	Proximity	Boring Completion Date	Survey Date	Riser Elevation (feet MSL)	Riser Stickup* (feet)	Ground Surface (feet MSL)	Well Depth (feet BGS)	Well Bottom Elevation (feet MSL)	Depth to Top of Permafrost (feet BGS)	Well Diameter (inches)
MW-314-15	MW-314-15	5b440c33-7fb7-4c58-b5de-7e6f8ec1d251	Off-site	4/30/2012	Nov-2012	476.29	-0.29	476.6	15.56	461.02	—	2.00
MW-315-15	MW-315-15	9dc6b7b5-77ef-485e-ba88-dbe8d31cf0e8	Off-site	5/1/2012	Nov-2012	458.44	-0.74	459.2	15.83	443.35	—	2.00
MW-315-150	MW-315-150	16df1370-4b76-4900-96d6-9582c4714ce4	Off-site	5/2/2012	Nov-2012	458.96	-0.41	459.4	150.63	308.74	—	2.00
MW-316-15	MW-316-15	c6b9be25-8018-464e-ac4c-9382f78d8931	Off-site	5/1/2012	Nov-2012	486.34	-0.29	486.6	15.67	470.96	—	2.00
MW-316-56	MW-316-56	581bbb7e-7429-47cc-aeb0-46400c2adabd	Off-site	5/16/2012	Nov-2012	486.15	-0.48	486.6	56.00	430.63	57.0	2.00
MW-317-15	MW-317-15	21139c52-38cd-48ae-9907-9fb388e87616	Off-site	5/3/2012	Nov-2012	488.86	-0.44	489.3	15.66	473.64	—	2.00
MW-317-71	MW-317-71	18d4b2f7-1e78-43ba-8fb2-ce19ca08d7b3	Off-site	5/21/2012	Nov-2012	488.79	-0.56	489.4	71.23	418.12	—	2.00
MW-318-20	MW-318-20	3d83d8c0-cd5e-43d7-a486-b9aa6be4456b	Off-site	5/3/2012	Sept-2013	493.05	2.98	490.1	20.48	469.59	—	2.00
MW-318-135	MW-318-135	79723bfb-2fe6-4e18-8c9b-fd6d3fc7f20e	Off-site	5/10/2012	Sept-2013	493.10	3.29	489.8	135.29	354.52	—	2.00
MW-319-15	MW-319-15	ecabf49a-cf31-49cf-8176-8aff5d9e8d5b	Off-site	5/4/2012	Nov-2012	456.10	-0.35	456.5	15.28	441.17	—	2.00
MW-319-45	MW-319-45	efab58b1-7d6b-4d41-9c7d-5c30ed547c06	Off-site	5/7/2012	Nov-2012	455.96	-0.69	456.7	45.52	411.13	45.5	2.00
MW-320-130	MW-320-130	30e340e6-c23d-4a92-a98f-f7c6386f9e45	Off-site	5/9/2012	Mar-2013	450.96	-0.53	451.5	131.38	320.11	—	2.00
MW-320-20	MW-320-20	237bb483-53a9-42fd-9e36-cd053f8e7d3c	Off-site	5/4/2012	Mar-2013	450.89	-0.31	451.2	20.15	431.05	—	2.00
MW-321-15	MW-321-15	cbabe175-ebb9-4654-9458-dc55692faabb	On-site	5/5/2012	Nov-2012	495.59	2.74	492.9	15.77	477.08	—	2.00
MW-321-151	MW-321-151	53747ddf-4f2a-432b-b39e-35daed6966cf	On-site	5/26/2012	Nov-2012	495.13	2.20	492.9	150.54	342.39	—	2.00
MW-321-65	MW-321-65	a986308d-ae16-4520-bab4-a6b692edf1fc	On-site	5/5/2012	Nov-2012	495.26	2.44	492.8	66.04	426.78	—	2.00
MW-322-15	MW-322-15	2ace5eba-137c-47db-9ee9-8148e617355d	Off-site	5/8/2012	June-2013	472.14	2.77	469.4	15.73	453.64	—	2.00
MW-322-150	MW-322-150	204f3aa1-271a-4d9c-a645-8c362d712311	Off-site	10/9/2012	June-2013	472.04	2.65	469.4	151.07	318.32	—	2.00
MW-323-15	MW-323-15	1461d9c6-5f85-47fa-88d8-87ee5ad6ec53	Off-site	5/7/2012	Nov-2012	485.27	3.01	482.3	15.55	466.71	—	2.00
MW-323-50	MW-323-50	4aeb9f82-7881-4430-a53e-5c04413639da	Off-site	10/8/2012	Sept-2013	484.76	2.58	482.2	49.93	432.25	55.0	2.00
MW-324-15	MW-324-15	b221462d-f08b-4cbd-b35b-4e9938978f3d	Off-site	5/8/2012	Nov-2012	463.41	-0.37	463.8	15.35	448.43	—	2.00
MW-324-151	MW-324-151	2b6d46e7-1c2a-4af7-acb2-5b338830c8cd	Off-site	5/23/2012	Nov-2012	462.90	-0.70	463.6	150.92	312.68	—	2.00
MW-325-150	MW-325-150	5ea1c21f-747c-4846-83c3-a7c5841e1a63	Off-site	5/14/2012	Mar-2013	486.85	-0.60	487.5	150.54	336.91	—	2.00
MW-325-18	MW-325-18	5250a963-07f5-43ea-b2c3-e7c8a2f5c807	Off-site	5/18/2012	Mar-2013	486.13	-0.81	486.9	18.68	468.26	—	2.00
MW-326-150	MW-326-150	3af2a25d-733d-4ccc-b74a-96d10b24edbe	Off-site	5/15/2012	June-2013	500.48	3.09	497.4	150.51	346.88	—	2.00
MW-326-20	MW-326-20	3c04ce8d-44d1-44ca-be6a-f71fc1292191	Off-site	6/8/2012	June-2013	500.57	3.20	497.4	20.75	476.62	—	2.00
MW-327-15	MW-327-15	d4cfd7e9-b8e6-4d1d-8fd4-4758794db78b	Off-site	5/21/2012	Nov-2012	467.82	-0.25	468.1	15.40	452.67	—	2.00
MW-327-150	MW-327-150	e5d4bed9-ac81-492a-b79d-e0b4edf0f053	Off-site	5/19/2012	Nov-2012	467.61	-0.44	468.1	150.92	317.13	—	2.00
MW-328-15	MW-328-15	e7c54313-53d9-4c57-8445-572f06b029f6	Off-site	5/21/2012	Mar-2013	472.35	-0.63	473.0	15.77	457.21	—	2.00
MW-328-151	MW-328-151	97b7b275-7988-4a4c-8a96-3d5e35bae867	Off-site	5/24/2012	Mar-2013	472.67	-0.52	473.2	150.66	322.53	—	2.00
MW-329-15	MW-329-15	6f49d33c-39e0-47a6-b651-31977836225d	Off-site	4/10/2001	Nov-2012	482.91	2.93	480.0	14.82	465.16	—	2.00
MW-329-66	MW-329-66	38838001-d575-47d0-ab96-ae05e1346198	Off-site	5/22/2012	Nov-2012	479.23	-0.47	479.7	65.67	414.03	67.0	2.00
MW-330-150	MW-330-150	71140f92-8243-421d-9054-da5a0842e30c	On-site	6/2/2012	Nov-2012	499.65	2.40	497.3	150.42	346.83	—	2.00
MW-330-20	MW-330-20	c31c779f-d6c9-4559-b61b-5883c4647541	On-site	6/4/2012	Nov-2012	500.03	2.73	497.3	19.62	477.68	—	2.00
MW-330-65	MW-330-65	0b257fc7-b755-42e1-a1db-b62ec992ed1f	On-site	6/4/2012	Nov-2012	499.83	2.55	497.3	65.39	431.89	—	2.00
MW-331-150	MW-331-150	78935053-88ab-431c-b7b0-3f05a3a67673	On-site	6/5/2012	Nov-2012	495.62	2.67	493.0	150.24	342.71	—	2.00
MW-332-15	MW-332-15	fe6b30ff-bb56-403c-9eaf-f1f53ee9fcba	Off-site	6/8/2012	Aug-2013	481.63	-0.39	482.0	15.67	466.35	—	2.00
MW-332-41	MW-332-41	36d9465a-c222-46e2-9231-7fe2fb0ed4cb	Off-site	4/17/2013	Sept-2013	481.41	-0.42	481.8	41.44	440.38	—	2.00
MW-332-75	MW-332-75	358ffbbf-b720-494e-96c6-9aa2eaff4b70	Off-site	4/22/2013	Sept-2013	481.19	-0.45	481.4	75.56	405.87	—	2.00
MW-332-110	MW-332-110	5ffd59d5-d653-414f-87bc-c50f6cab79e2	Off-site	4/20/2013	Sept-2013	481.10	-0.44	481.6	110.53	371.04	—	2.00
MW-332-150	MW-332-150	f0e33dc9-2d49-4afa-ab1c-8c0d44e5d456	Off-site	6/7/2012	Aug-2013	481.14	-1.30	482.4	150.87	331.57	—	2.00
MW-333-150	MW-333-150	5cfe6e93-b294-4b6c-bc83-66a63690f605	Off-site	6/11/2012	June-2013	497.17	2.69	494.5	150.47	344.01	—	2.00
MW-333-16	MW-333-16	c19cbd08-2ec9-4dcc-a569-c05bf651c1e9	Off-site	6/12/2012	June-2013	497.23	2.81	494.4	16.22	478.20	—	2.00
MW-334-15	MW-334-15	7e6e7b95-8b7d-4af2-a8f5-b74b5a99abb8	On-site	8/21/2012	Sept-2013	495.89	2.43	493.5	15.53	477.93	—	2.00
MW-334-65	MW-334-65	326b5216-c5bc-4bb6-89ad-2ff8fbeb0e56	On-site	8/20/2012	Sept-2013	495.81	2.81	493.0	65.41	427.59	—	2.00
MW-334-85	MW-334-85		On-site	10/7/2013	Nov-2013	496.12	3.04	493.09	85.63		—	2.00
MW-335-41	MW-335-41	70687257-54ee-4e7e-86dd-07be2d04b3ee	Off-site	8/23/2012	Nov-2012	469.34	-1.16	470.5	41.11	429.39	43.0	2.00
MW-336-15	MW-336-15		On-site	10/2/2013	Nov-2013	492.9	-0.71	493.62	15.33		N/A	4.00
MW-336-20	MW-336-20		On-site	9/27/2013	Nov-2013	493.32	-0.33	493.7	20.73	472.92	—	2.00

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North Pole Refinery, North Pole, Alaska
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Well	New Well Name	LocationNdx	Proximity	Boring Completion Date	Survey Date	Riser Elevation (feet MSL)	Riser Stickup* (feet)	Ground Surface Elevation (feet MSL)	Well Depth (feet BGS)	Well Bottom Elevation (feet MSL)	Depth to Top of Permafrost (feet BGS)	Well Diameter (inches)
MW-336-35	MW-336-35		On-site	9/25/2013	Nov-2013	493.27	-0.39	493.6	35.61	457.99	—	2.00
MW-338-15	MW-338-15	83f5e2d6-7f53-49d6-a78e-419a0077f73c	Off-site	4/23/2013	Sept-2013	483.16	-0.50	483.4	15.43	467.95	—	2.00
MW-338-50	MW-338-50	8bc2e644-d7e3-43d7-98b1-8d1abb590ff6	Off-site	4/27/2013	Sept-2013	483.24	-0.56	483.6	49.95	433.60	50.5	2.00
MW-339-15	MW-339-15	af7821a6-71d2-4c4e-b2d6-0c7c314eb9e0	Off-site	5/7/2013	Sept-2013	479.39	-0.50	479.8	15.45	464.32	—	2.00
MW-339-50	MW-339-50	f44f2462-a2ae-46e2-8aed-d187c3f6b5a0	Off-site	5/2/2013	Sept-2013	479.51	-0.70	479.8	50.97	428.83	52.0	2.00
MW-340-18	MW-340-18	54363162-5121-4b2a-86f0-ccff86835bfd	Off-site	5/7/2013	Sept-2013	478.55	-0.34	478.9	17.95	460.99	—	2.00
MW-340-65	MW-340-65	b48f32fa-8839-4ad1-93f0-e4de6c9662fa	Off-site	5/8/2013	Sept-2013	478.74	-0.25	479.4	65.64	413.71	—	2.00
MW-340-150	MW-340-150	30a8ba9f-5ea3-484a-9df7-d784bad04b0a	Off-site	5/3/2013	Sept-2013	479.06	-0.44	479.3	150.73	328.57	—	2.00
MW-341-15	MW-341-15	4da0dbb5-d51e-4f7c-bf0f-e72586f242b6	Off-site	5/15/2013	Sept-2013	480.22	-0.44	480.6	15.66	464.92	—	2.00
MW-341-40	MW-341-40	93fb699e-20b0-4a73-8f09-fcc368b8ec26	Off-site	5/15/2013	Sept-2013	480.02	-0.53	480.5	40.74	439.71	42.5	2.00
MW-342-15	MW-342-15	7c6eb056-0c1d-4f19-a534-1710715b4941	Off-site	5/31/2013	Sept-2013	482.27	-0.64	482.9	15.52	467.37	—	2.00
MW-342-65	MW-342-65	af447328-fc07-4a6d-aa84-7c7cc8c84e4b	Off-site	5/31/2013	Sept-2013	482.47	-0.48	483.0	65.20	417.81	65.5	2.00
MW-343-15	MW-343-15	0dce5f0b-2713-4465-84b5-4bd416794b3e	Off-site	6/28/2013	Sept-2013	484.15	2.40	481.4	14.59	466.85	—	2.00
MW-343-50	MW-343-50	ec0d82f6-c835-4520-ac07-9796b7cf7acf	Off-site	6/19/2013	Sept-2013	484.12	2.82	481.7	50.79	430.93	52.0	2.00
MW-344-15	MW-344-15	b8afe1eb-237c-419f-ab27-d1f78a5091bc	On-site	7/26/2013	Sept-2013	493.51	3.64	490.7	15.57	475.10	—	2.00
MW-344-55	MW-344-55		On-site	10/10/2013	Nov-2013	493.93	2.90	490.9	56.63		—	2.00
MW-344-75	MW-344-75		On-site	10/9/2013	Nov-2013	493.35	2.64	490.71	75.65		—	2.00
MW-345-15	MW-345-15	2eaa8ce0-a19e-40bd-b6f3-f5451d3f20eb	On-site	7/26/2013	Sept-2013	495.48	3.34	492.7	15.67	477.03	—	2.00
MW-345-55	MW-345-55		On-site	10/10/2013	Nov-2013	495.99	3.15	492.75	55.43		—	2.00
MW-345-75	MW-345-75		On-site	10/11/2013	Nov-2013	495.62	2.78	492.75	75.56		—	2.00
MW-346-15	MW-346-15	d89d51c2-534b-4e62-8f48-35cc71c61d71	Off-site	7/31/2013	Sept-2013	473.12	-0.22	473.2	15.48	457.74	—	2.00
MW-346-150	MW-346-150	50e5a829-87ac-4b11-8507-45c7bdc6d196	Off-site	7/30/2013	Sept-2013	472.69	-0.38	473.2	149.28	323.92	—	2.00
MW-346-65	MW-346-65	a17e37cb-653f-4bd5-bd83-57f248c44cd0	Off-site	8/1/2013	Sept-2013	472.71	-0.37	473.1	64.71	408.39	—	2.00
MW-347-150	MW-347-150	bd799307-5940-4189-815a-a35add43475c	Off-site	8/5/2013	Sept-2013	482.58	-0.43	483.1	151.52	331.56	—	2.00
MW-347-20	MW-347-20	fa56f426-4d31-4c78-a3f5-2387ee43331b	Off-site	9/3/2013	Sept-2013	482.93	-0.30	483.5	20.40	463.10	—	2.00
MW-347-65	MW-347-65	3961ea26-e68e-4d5d-bace-1a2f678c9bea	Off-site	9/3/2013	Sept-2013	481.79	-0.30	483.1	65.20	417.93	—	2.00
MW-348-15	MW-348-15	efe09e39-3d0b-451e-b8e3-b7914f25c630	On-site	8/8/2013	Nov-2013	493.74	-0.45	494.2	15.46	478.72	—	2.00
MW-348-65	MW-348-65	487f21d8-9c5c-42b7-aa6b-6ebe9197696c	On-site	8/7/2013	Nov-2013	493.89	-0.42	494.3	64.32	429.98	—	2.00
MW-349-15	MW-349-15	3f0957b8-c363-404a-b767-9be2b56c3bc0	Off-site	8/12/2013	Aug-2013	484.58	-0.33	484.9	15.04	469.88	—	2.00
MW-349-45	MW-349-45	80fdcbcc-164a-4636-9f34-4e1561b8c228	Off-site	8/12/2013	Aug-2013	484.46	-0.42	484.9	45.50	439.35	46.5	2.00
MW-350-15	MW-350-15	1AD40915-8EA1-40BC-9161-2D091B9DD96C	Off-site	8/18/2013	Sept-2013	483.64	-0.77	484.4	16.04	468.34	—	2.00
MW-350-50	MW-350-50	9b4e1604-60af-4ac5-9882-6e40d78b88e6	Off-site	8/18/2013	Sept-2013	483.98	-0.32	484.2	47.06	437.18	50.0	2.00
MW-351-150	MW-351-150		On-site	10/14/2013	Nov-2013	493.76	3.04	490.62	150.83		—	2.00
MW-351-15	MW-351-15		On-site	10/17/2013	Nov-2013	493.42	3.10	490.47	15.48		—	2.00
MW-351-55	MW-351-55		On-site	10/15/2013	Nov-2013	493.57	3.13	490.35	55.68		—	2.00
MW-351-75	MW-351-75		On-site	10/16/2013	Nov-2013	493.44	3.13	490.34	76.39		—	2.00
MW-352-15	MW-352-15	148af05b-44a8-4644-89d5-a35d6606d7b5	Off-site	9/1/2013	Sept-2013	474.76	-0.40	475.1	15.59	459.51	—	2.00
MW-352-40	MW-352-40	2353e899-fe52-4013-9ec7-b6eb3afc2356	Off-site	9/1/2013	Sept-2013	474.89	-0.68	475.5	38.18	437.27	42.5	2.00
MW-353-100	MW-353-100	9d20daa2-b4b5-4aea-81e5-a53852c10dde	Off-site	9/5/2013	Sept-2013	480.58	-0.43	481.1	100.61	380.48	110	2.00
MW-353-15	MW-353-15	6d15b028-469b-41a2-8e5e-b9b57bf96620	Off-site	9/6/2013	Sept-2013	480.16	-0.53	480.7	15.50	465.15	—	2.00
MW-353-65	MW-353-65	ef952f85-0df2-4b43-a581-ac53f0f5348d	Off-site	9/6/2013	Sept-2013	480.40	-0.42	480.9	65.50	415.41	—	2.00
MW-354-15	MW-354-15		On-site	9/18/2013		#N/A	2.78		16.09		—	2.00
MW-354-35	MW-354-35		On-site	9/19/2013		#N/A	2.87		34.84		—	2.00
MW-354-60	MW-354-60		On-site	9/16/2013		#N/A	3.51		60.02		—	2.00
MW-355-15	MW-355-15		On-site	9/25/2013		#N/A	2.59		16.05		—	2.00
MW-355-55	MW-355-55		On-site	9/24/2013		#N/A	2.58		55.78		—	2.00
MW-356-15	MW-356-15		Off-site	10/17/2013	Nov-2013	478.67	-0.72	479.4	18.39		—	2.00
MW-356-65	MW-356-65		Off-site	10/17/2013	Nov-2013	478.75	-0.46	479.28	65.77		—	2.00
MW-356-90	MW-356-90		Off-site	10/16/2013	Nov-2013	478.74	-0.43	479.49	88.73		90.0	2.00
MW-357-15	MW-357-15		Off-site	10/21/2013	Nov-2013	487.73	2.80	484.99	15.59		—	2.00

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North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well	New Well Name	LocationNdx	Proximity	Boring Completion Date	Survey Date	Riser Elevation (feet MSL)	Riser Stickup* (feet)	Ground Surface Elevation (feet MSL)	Well Depth (feet BGS)	Well Bottom Elevation (feet MSL)	Depth to Top of Permafrost (feet BGS)	Well Diameter (inches)
MW-357-150	MW-357-150		Off-site	10/18/2013	Nov-2013	488.01	3.09	484.92	150.46		—	2.00
MW-357-65	MW-357-65		Off-site	10/21/2013	Nov-2013	487.9	2.87	485.05	66.00		—	2.00
MW-358-150	MW-358-150		On-site	10/30/2013		#N/A	3.11		150.57		—	2.00
MW-358-20	MW-358-20		On-site	11/2/2013		#N/A	3.15		20.72		—	2.00
MW-358-40	MW-358-40		On-site	11/2/2013		#N/A	2.98		40.25		—	2.00
MW-358-60	MW-358-60		On-site	10/31/2013		#N/A	2.96		60.69		—	2.00
MW-359-15	MW-359-15		On-site	11/5/2013		#N/A	2.69		15.51		—	2.00
MW-359-35	MW-359-35		On-site	11/18/2013		#N/A	2.69		35.06		—	2.00
MW-359-60	MW-359-60		On-site	11/1/2013		#N/A	2.85		60.52		—	2.00
MW-359-80	MW-359-80		On-site	11/11/2013		#N/A	2.65		80.58		—	2.00
MW-359-150	MW-359-150		On-site	10/31/2013		#N/A	2.90		150.31		—	2.00
MW-359-60	MW-359-60		On-site	11/1/2013		#N/A	2.85		60.52		—	2.00
MW-360-15	MW-360-15		On-site	11/6/2013		#N/A	2.99		15.41		—	2.00
MW-360-150	MW-360-150		On-site	11/4/2013		#N/A	2.73		150.01		—	2.00
MW-360-35	MW-360-35		On-site	11/6/2013		#N/A	2.98		35.76		—	2.00
MW-360-50	MW-360-50		On-site	11/5/2013		#N/A	2.71		50.60		—	2.00
MW-360-80	MW-360-80		On-site	11/12/2013		#N/A	2.89		80.23		—	2.00
MW-361-15	MW-361-15		On-site	11/5/2013		#N/A	2.73		15.29		—	2.00
MW-362-15	MW-362-15		On-site	11/16/2013		#N/A	3.46		15.19		—	2.00
MW-362-25	MW-362-25		On-site	11/18/2013		#N/A	3.48		25.06		—	2.00
MW-362-35	MW-362-35		On-site	11/17/2013		#N/A	3.21		35.57		—	2.00
MW-362-50	MW-362-50		On-site	11/17/2013		#N/A	3.02		49.92		—	2.00
MW-362-80	MW-362-80		On-site	11/16/2013		#N/A	3.02		80.31		—	2.00
MW-362-150	MW-362-150		On-site	11/7/2013		#N/A	3.00		150.65		—	2.00
MW-363-15	MW-363-15		On-site	11/9/2013		#N/A	3.16		15.69		—	2.00
MW-364-15	MW-364-15		On-site	11/25/2013		#N/A	3.68		15.54		N/A	2
MW-364-30	MW-364-30		On-site	11/25/2013		#N/A	3.42		30.29		N/A	2
MW-364-65	MW-364-65		On-site	11/12/2013		#N/A	3.10		65.79		N/A	2
MW-364-90	MW-364-90		On-site	11/24/2013		#N/A	3.30		90.29		N/A	2
MW-364-150	MW-364-150		On-site	11/11/2013		#N/A	3.17		150.81		N/A	2
MW-365-15	MW-365-15		On-site	Monument Installation Pending							N/A	2
MW-366-15	MW-366-15		On-site	Monument Installation Pending							N/A	2
MW-367-15	MW-367-15		On-site	11/22/2013			2.91		16.17		N/A	2
MW-368-15	MW-368-15		On-site	11/19/2013			2.75		15.78		—	2.00
MW-369-15	MW-369-15		On-site	Installation Pending							—	2.00
MW-369-55	MW-369-55		On-site	Installation Pending							—	2.00
MW-369-75	MW-369-75		On-site	Installation Pending							—	2.00
MW-370-15	MW-370-15		On-site	Installation Pending							—	2.00
MW-370-55	MW-370-55		On-site	Installation Pending							—	2.00
MW-370-75	MW-370-75		On-site	12/6/2013		#N/A	3.00		75.8		N/A	2.00
MW-371-15	MW-371-15		On-site	Installation Pending							—	2.00
MW-371-55	MW-371-55		On-site	Installation Pending							—	2.00
MW-371-75	MW-371-75		On-site	Installation Pending							—	2.00
MW-371-PF	MW-371-PF		On-site	Installation Pending							—	2.00
PW_ID 1230	PW-1230	16C859EA-43D5-43AD-8B5B-3847E2256ECD	Off-site	10/6/1982	Aug-2013	486.05	1.18	484.9	231.00	253.87	33.0	6.00
O-1	O-1	aebc1713-e287-4bcf-b881-526bf1d2b531	On-site	9/23/2010	Nov-2012	497.14	2.60	494.5	15.09	479.45	—	2.00
O-10	O-10	61ef2a2f-f41e-4d4f-a188-b4ad2705c1f7	On-site	9/16/2011	Nov-2012	496.36	2.76	493.6	16.37	477.23	—	4.00
O-11	O-11	504a120b-2810-4b4e-8f91-16d36ad8160b	On-site	9/20/2011	Aug-2013	497.90	3.20	494.7	16.40	478.30	—	2.00
O-12	O-12	61b818f0-f90f-4f1a-b89e-9b17c7a93117	On-site	9/21/2011	Sept-2013	496.28	3.66	492.6	16.99	475.63	—	2.00
O-12-65	O-12-65	e81c02dd-3ee1-4492-b0f6-5c04851cf6aa	On-site	7/13/2013	Sept-2013	495.79	2.89	493.1	65.68	427.38	—	2.00
O-13	O-13	3c094e6e-32f7-49e5-afce-adfc42212bd7	On-site	9/21/2011	Aug-2013	495.38	3.47	491.9	15.88	476.03	—	2.00
O-14	O-14	0b7c92d9-e29b-4737-bc28-f85e814ce772	On-site	10/1/2011	Nov-2012	494.90	-0.36	495.3	15.30	479.96	—	2.00
O-15	O-15	c0a9a3fe-8ee9-43e2-8fb1-8c0636d64ff1	On-site	10/6/2011	Nov-2012	498.70	3.15	495.6	15.37	480.18	—	2.00
O-16	O-16	02e3224f-e1d1-4254-b9ff-b910468e7acc	On-site	10/7/2011	Nov-2012	493.09	-0.50	493.6	14.60	478.99	—	2.00
O-17	O-17	64970964-3127-492e-8a24-609ea636f499	On-site	10/13/2011	Nov-2012	493.26	-0.34	493.6	15.04	478.56	—	2.00
O-18	O-18	a502306d-93a6-4716-92fe-2dc8d59e1865	On-site	10/12/2011	Nov-2012	492.70	-0.39	493.1	15.32	477.77	—	2.00
O-19	O-19	877eaf31-e1ac-4f94-8c38-731091093a64	On-site	10/15/2011	Sept-2013	496.50	3.23	493.3	15.34	477.93	—	2.00
O-2	O-2	dc344077-df6a-4d0b-8838-bab426be6727	On-site	9/23/2010	Sept-2013	496.89	3.17	493.7	15.03	478.69	—	2.00
O-19-55	O-19-55		On-site	11/4/2013		#N/A	2.92		54.41		—	2.00
O-19-90	O-19-90		On-site	10/30/2013		#N/A	2.79		90.72		—	2.00
O-20	O-20	92d746d1-25c5-4986-b55d-12a465a6bdc1	On-site	10/13/2011	Nov-2012	497.41	3.12	494.3	15.84	478.45	—	2.00

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Well	New Well Name	LocationNdx	Proximity	Boring Completion Date	Survey Date	Riser Elevation (feet MSL)	Riser Stickup* (feet)	Ground Surface Elevation (feet MSL)	Well Depth (feet BGS)	Well Bottom Elevation (feet MSL)	Depth to Top of Permafrost (feet BGS)	Well Diameter (inches)
O-21	O-21	b6efd363-a9c5-466f-95db-7eff6ba9f740	On-site	10/14/2011	Nov-2012	493.12	-0.46	493.6	15.69	477.89	—	2.00
O-22	O-22	09cfce39-09a5-4216-8de9-211a0e06d146	On-site	11/14/2011	Nov-2012	496.76	1.92	494.8	18.59	476.25	—	2.00
O-23	O-23	06321e7f-5604-4dd0-8036-3c3e8d8be652	On-site	12/5/2011	Nov-2012	495.83	2.37	493.5	16.32	477.14	—	2.00
O-24	O-24	321d4d14-3393-4ec4-92f1-c7a3b0e3c5df	On-site	9/16/2011	Sept-2013	496.89	2.54	494.4	15.24	479.11	—	2.00
O-24-65	O-24-65	4dc00879-b7b5-4c66-8318-2227e69be4d8	On-site	8/21/2013	Nov-2013	497.00	2.56	494.4	65.35	429.01	—	2.00
O-25	O-25	b59cf0bc-0164-40cc-9810-5df06491c80c	On-site	11/10/2011	Nov-2012	497.75	2.59	495.2	16.41	478.75	—	2.00
O-5-65	O-5-65	2fe82ffc-5986-446c-b856-ba3202b8afeb	On-site	7/11/2013	Sept-2013	495.66	2.61	493.0	64.70	428.25	—	2.00
O-26	O-26	53ce3f5c-d20a-4037-8151-e0219f945541	On-site	11/9/2011	Nov-2012	496.82	2.89	493.9	14.96	478.97	—	2.00
O-26-65	O-26-65	83962db0-e6b6-48f3-97fe-1803451cb554	On-site	8/22/2013	Nov-2013	496.58	2.79	493.8	65.95	427.89	—	2.00
O-27	O-27	d8542910-9d33-4be6-97ef-633f281883af	On-site	11/10/2011	Nov-2012	496.86	1.86	495.0	17.37	477.63	—	2.00
O-27-65	O-27-65		On-site	11/26/2013			2.55		66.18		—	2.00
O-27-150	O-27-150		On-site	11/24/2013			2.64		150.28		N/A	2.00
O-28	O-28	599c5ffb-bd3c-412e-aa5c-9f796a9304b0	On-site	11/14/2011	Nov-2012	494.65	2.16	492.5	14.84	477.65	—	2.00
O-29	O-29	409679b2-004a-4999-900b-874ad1242431	On-site	11/12/2011	Nov-2012	498.61	2.37	496.2	18.16	478.08	—	2.00
O-30	O-30	39dfa892-9aee-4505-9c6b-dbfe8aeddc0b	On-site	8/14/2012	Nov-2012	497.97	2.97	495.0	15.82	479.18	—	2.00
O-3	O-3	80846ceb-37be-4f30-ae0e-c175b577c7f6	On-site	9/23/2010	Sept-2013	497.83	3.35	494.5	14.57	479.91	—	2.00
O-4	O-4	4aa65813-5850-48fd-a96b-6be7e39ef9fe	On-site	9/16/2010	Sept-2013	496.53	2.61	493.9	15.11	478.81	—	2.00
O-5	O-5	ff178d54-dc16-4ac3-a8f7-349c1ba9cddb	On-site	9/13/2011	Sept-2013	496.19	2.89	493.3	15.08	478.22	—	2.00
O-6	O-6	30fed606-c99b-441d-a004-62b0a03f15fd	On-site	9/14/2011	Sept-2013	495.02	2.78	492.2	15.58	476.66	—	2.00
O-7	O-7	ee2ca6ff-9b9a-41b8-8abf-b8d383b84ed4	On-site	9/14/2011	Nov-2012	496.01	2.52	493.5	15.33	478.16	—	2.00
O-8	O-8	bba1b9c3-500d-4981-bb81-c9b62888fc14	On-site	9/15/2011	Nov-2012	496.72	2.74	494.0	15.86	478.12	—	2.00
O-9	O-9	11cfca51-adf6-4d73-ad68-20397615284d	On-site	9/15/2011	Nov-2012	496.95	3.11	493.8	15.14	478.70	—	2.00
O-31	O-31		On-site	9/3/2013	Nov-2013	496.11	3.67	492.2	15		N/A	4.00
O-32	O-32		On-site	9/4/2013	Nov-2013	496.36	3.49	492.8	16		N/A	4.00
O-33	O-33		On-site	9/5/2013	Nov-2013	496.53	3.43	493.1	16		N/A	4.00
O-34	O-34		On-site	9/18/2013	Nov-2013	496.31	3	493.4	16		N/A	4.00
O-35	O-35		On-site	9/20/2013	Nov-2013	496.88	3	493.8	15		N/A	4.00
O-36	O-36		On-site	9/21/2013	Nov-2013	496.49	3	493.7	16		N/A	4.00
O-37	O-37		On-site	9/17/2013	Nov-2013	496.42	3	493.0	16		N/A	4.00
O-38	O-38		On-site	9/20/2013	Nov-2013	496.60	3	493.5	15		N/A	4.00
R-14	R-14	caa9817e-4f2b-4233-b4f4-a8377760b988	On-site	6/10/1986	Nov-2012	493.99	1.43	492.6	6.06	486.50	—	20.00
R-14A	R-14A	7fdd565a-0193-4f47-8433-34e5c2660bc9	On-site	6/10/1987	Sept-2013	494.13	1.12	493.0	10.73	482.28	—	4.00
R-18	R-18	c2f799b7-d014-4994-81f2-9e2533253cf2	On-site	6/10/1987	Sept-2013	499.83	3.53	496.3	32.77	463.53	—	10.00
R-20R	R-20R	85499ab5-dd2d-4277-abd8-87b92c578476	On-site	2/20/2011	Nov-2012	498.74	3.80	494.9	19.70	475.24	—	6.00
R-21	R-21	9f137b38-ba79-4ae5-bb8d-46e9a417e04b	On-site	10/15/2011	Aug-2013	495.54	2.84	492.7	24.17	468.53	—	12.00
R-22	R-22	8c305764-c507-42e8-bacb-a0b03c47ad5c	On-site	10/15/1987	Sept-2013	495.59	2.71	492.9	24.65	468.23	—	12.00
R-3	R-3	83c3263b-4011-4de1-b368-0d8e2113f940	On-site	11/15/1987	Nov-2012	494.08	0.54	493.5	6.92	486.62	—	38.00
R-32	R-32	e15ef341-b862-4f88-b3ce-c26e4547206f	On-site	11/15/1987	Nov-2012	494.33	0.58	493.8	10.97	482.78	—	24.00
R-32R	R-32R		On-site	9/17/2013	Nov-2013	496.55	3	493.4	16		N/A	4.00
R-33	R-33	6b29bfc2-5666-4070-b630-7d5e23082b03	On-site	8/15/1988	Nov-2012	495.82	2.62	493.2	24.60	468.60	—	12.00
R-34	R-34	5d95529c-6f50-42fc-83aa-abafcc77ca7a	On-site	8/15/1988	Nov-2012	495.20	1.95	493.3	20.83	472.42	—	12.00
R-35R	R-35R	49df7ef6-c636-4e9b-8822-a2ffbc663e55	On-site	2/16/2011	Aug-2013	494.71	1.84	492.9	39.00	453.87	—	8.00
R-38	R-38	c9b76453-0ce2-4dbb-9e15-f506be5509ba	On-site	8/15/1988	Nov-2012	498.64	2.72	495.9	9.80	486.12	—	24.00
R-39	R-39	cbbd012f-f628-480e-9855-e645d7515df5	On-site	8/15/1988	Sept-2013	495.06	1.72	493.3	25.50	467.84	—	10.00
R-4	R-4	1ecb28c8-af37-4d8f-b205-ef27277b77c5	On-site	11/15/1987	Nov-2012	494.92	0.82	494.1	8.56	485.54	—	50.00
R-40	R-40	680f2c9e-b0d5-4531-b94c-55be0ab04461	On-site	6/15/1989	Sept-2013	494.47	1.77	492.7	25.17	467.53	—	10.00
R-42	R-42	cf93c75f-3b0e-4513-94eb-64cd1f4583d0	On-site	5/15/2011	Aug-2013	493.29	1.49	491.8	35.00	456.80	—	8.00
R-43	R-43	3589d73a-5361-4638-9732-1d61ac44f852	On-site	11/28/2012	Aug-2013	495.45	2.17	493.3	40.98	452.30	—	12.00
R-44	R-44	1549b1bc-16d2-4b4f-ac7d-8a7515537669	On-site	3/2/2013	Aug-2013	496.25	1.77	494.5	40.78	453.70	—	12.00
R-45	R-45	46bdb750-0705-48d6-bbaa-163ab1c19957	On-site	3/8/2013	Aug-2013	495.97	2.91	493.1	32.25	460.81	—	12.00

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R-46	R-46	f89da44d-de91-4456-8d18-074d8154eddc	On-site	3/15/2013	Aug-2013	496.10	1.92	494.2	30.88	463.30	—	12.00
R-5	R-5	5cc0c825-65df-4fa2-b964-b3cdebe693d2	On-site	6/15/1986	Nov-2012	495.33	1.83	493.5	7.23	486.27	—	38.00
S-21	S-21	825a56e5-b2e1-41ba-84da-88a3ce17f214	On-site	5/15/1987	Nov-2012	497.19	2.84	494.4	13.40	480.95	—	2.00
S-39	S-39	9c371847-27b4-4566-af21-ceb94c6f2dbe	On-site	12/15/1989	Nov-2012	494.07	1.02	493.1	13.00	480.05	—	2.00
S-41R	S-41R		On-site	10/4/2013	Nov-2013	496.68	3.23	493.37	14.84		—	2.00
S-43	S-43	7b7657c1-4653-4ac4-bd53-e9dc1413f2ac	On-site	6/15/1991	Sept-2013	496.29	2.21	494.1	13.00	481.08	—	4.00
S-44	S-44	94f07584-9b9b-42bd-9052-9be15e5b91b2	On-site	6/15/1991	Sept-2013	495.03	2.47	492.6	13.00	479.56	—	4.00
S-50	S-50	4120e3c2-9ed0-4501-95d4-c4a45261a375	On-site	7/15/1997	Sept-2013	496.70	2.77	493.9	15.00	478.93	—	4.00
S-51	S-51	a9131fdb-af15-4090-a9d6-096dfc65add8	On-site	6/15/1997	Sept-2013	495.92	2.94	493.0	15.00	477.98	—	2.00
S-54	S-54	61f52795-244b-46e1-9d93-dbb04c1bbd0b	On-site	7/15/1998	Nov-2012	497.01	3.03	494.0	15.00	478.98	—	2.00
S-9	S-9	a5d71bd8-ae65-4c55-9120-221e8e2ad0f7	On-site	8/15/2001	Nov-2012	495.12	2.89	492.2	19.80	472.43	—	2.00

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	Well Screen								Filter Pack		WATER TABLE			ALASKA STATE PLANE NAD83, ZONE 3	
Well	Depth to Top (feet BGS)	Top Elevation (feet MSL)	Depth to Bottom (feet BGS)	Bottom Elevation (feet MSL)	Length (feet)	Screen Slot Size (inches)	Material	Riser Material	Depth to Top (feet BGS)	Depth to Bottom (feet BGS)	Approx Depth (ft BGS)	In Screen	Feet above top of Screen	NORTHING	EASTING
MW-101	56.00	435.14	61.00	430.14	5.00	0.02	ss	ss?	?	?	8.0	N	48.0	3927588.78	1428199.67
MW-101A	17.80	473.21	22.80	468.21	5.00	0.02	ss	ss?	?	?	8.0	N	9.8	3927590.29	1428209.63
MW-102	61.50	431.06	71.50	421.06	10.00	0.01	PVC	PVC?	?	?	9.0	N	52.5	3927955.12	1429113.91
MW-104	63.00	430.03	67.00	426.03	4.00	0.02	PVC	PVC?	?	?	7.0	N	56.0	3927958.82	1429747.75
MW-105	58.00	437.20	63.00	432.20	5.00	0.02	ss	ss?	?	?	8.0	N	50.0	3924919.0	1430402.38
MW-105A	18.00	477.63	23.00	472.63	5.00	0.02	ss	ss?	?	?	8.0	N	10.0	3924910.02	1430404.24
MW-106	18.50	479.27	23.00	474.77	4.50	0.02	PVC	PVC?	?	?	12.4	N	6.1	3926112.10	1428065.05
MW-109	9.50	485.34	14.00	480.84	4.50	0.02	PVC	PVC?	?	?	4.5	N	5.0	3925855.20	1428674.99
MW-110	13.50	479.97	18.00	475.47	4.50	0.02	PVC	PVC?	?	?	5.0	N	8.5	3925975.36	1428873.06
MW-110-65	60.78		65.34		4.56	0.01	PVC	PVC	Natural pack		6.6	N	54.23	3925984.07	1428864.82
MW-113	11.50	479.89	16.00	475.39	4.50	0.02	PVC	PVC?	?	?	8.3	N	3.2	3926957.71	1428777.98
MW-115	12.50	480.79	17.00	476.29	4.50	0.02	ss	ss?	?	?	9.0	N	3.5	3925758.76	1429540.81
MW-116	12.00	481.26	17.00	476.26	5.00	0.02	ss	ss?	?	?	9.0	N	3.0	3925670.10	1429332.64
MW-118	38.50	454.14	43.00	449.64	4.50	0.02	ss	PVC	?	?	7.0	N	31.5	3927467.01	1429638.43
MW-124	20.00	474.03	24.50	469.53	4.50	0.02	PVC	PVC?	?	?	8.0	N	12.0	3927015.09	1429816.83
MW-125	19.50	473.53	24.00	469.03	4.50	0.02	PVC	PVC	?	?	8.0	N	11.5	3927032.49	1429569.75
MW-126	20.00	471.81	24.50	467.31	4.50	0.02	PVC	PVC	?	?	7.0	N	13.0	3927426.37	1429419.17
MW-127	20.00	472.85	24.50	468.35	4.50	0.02	PVC	PVC	?	?	8.5	N	11.5	3927476.29	1429065.47
MW-129	37.00	455.93	41.50	451.43	4.50	0.02	PVC	PVC	?	?	8.2	N	28.8	3927205.45	1429720.22
MW-130	19.00	474.83	23.00	470.83	4.00	0.02	PVC	PVC	?	?	9.0	N	10.0	3926825.66	1429354.64
MW-131	20.00	473.75	24.50	469.25	4.50	0.02	PVC	PVC	?	?	9.0	N	11.0	3927936.24	1429024.82
MW-132	17.50	479.22	22.00	474.72	4.50	0.02	PVC	PVC	?	?	9.0	N	8.5	3926600.34	1429997.01
MW-133	17.50	478.25	22.00	473.75	4.50	0.02	PVC	PVC	?	?	9.0	N	8.5	3926597.42	1430160.18
MW-134	17.00	478.20	21.50	473.70	4.50	0.02	PVC	PVC	?	?	8.6	N	8.4	3926000.91	1430170.26
MW-135	10.60	482.59	19.50	473.69	8.90	0.02	PVC	PVC	?	?	9.0	N	1.6	3927024.53	1429730.91
MW-136	10.10	483.34	19.10	474.34	9.00	0.02	PVC	PVC	?	?	9.0	N	1.1	3927024.41	1429778.02
MW-137	10.40	483.84	19.30	474.94	8.90	0.02	PVC	PVC	?	?	9.0	N	1.4	3927083.81	1429737.46
MW-138	3.90	489.30	18.10	475.10	14.20	0.02	PVC	PVC	?	?	9.0	Y	-5.1	3925738.32	1429686.77
MW-139	5.70	489.59	25.00	470.29	19.30	0.02	PVC	PVC	?	?	9.0	Y	-3.3	3927427.97	1428848.56
MW-140	4.20	487.87	23.50	468.57	19.30	0.02	PVC	PVC	?	?	8.0	Y	-3.8	3927683.10	1429244.57
MW-141	7.90	482.31	22.40	467.81	14.50	0.02	PVC	PVC	?	?	5.4	N	2.5	3927598.03	1427540.67
MW-142	5.40	487.60	19.40	473.60	14.00	0.02	PVC	PVC	?	?	9.1	Y	-3.7	3927602.87	1428813.48
MW-143	4.70	487.31	19.50	472.51	14.80	0.02	PVC	PVC	?	?	7.5	Y	-2.8	3927688.65	1428487.50
MW-144A	5.70	486.70	24.70	467.70	19.00	0.02	PVC	PVC	?	?	6.8	Y	-1.1	3927485.68	1429623.04
MW-144BR	85.44	406.66	89.91	402.19	4.47	0.01	PVC	PVC	80.0	92.0	6.5	N	78.9	3927483.2	1429632.06
MW-145	4.70	488.15	19.00	473.85	14.30	0.02	PVC	PVC	?	?	8.0	Y	-3.3	3927212.61	1429712.57
MW-146A	6.00	486.57	16.00	476.57	10.00	0.02	PVC	PVC	4.5	16.0	7.0	Y	-1.0	3927201.05	1427049.42
MW-146B	22.00	470.59	27.00	465.59	5.00	0.02	PVC	PVC	16.0	27.0	7.0	N	15.0	3927193.28	1427048.17
MW-147A	3.00	486.67	13.00	476.67	10.00	0.02	PVC	PVC	2.4	13.0	5.5	Y	-2.5	3927723.21	1427288.46
MW-147B	20.50	469.19	25.50	464.19	5.00	0.02	PVC	PVC	17.5	25.0	5.5	N	15.0	3927729.22	1427290.37
MW-148A	5.00	485.90	15.00	475.90	10.00	0.02	PVC	PVC	4.0	15.0	6.9	Y	-1.9	3928675.03	1428153.49
MW-148B	22.00	468.26	27.00	463.26	5.00	0.02	PVC	PVC	17.0	27.0	6.9	N	15.1	3928677.21	1428158.65
MW-148C	50.72	439.87	55.15	435.44	4.43	0.01	PVC	PVC	45.0	56.0	9	N	41.7	3928670.73	1428140.18
MW-148D	145.92	344.43	150.36	339.99	4.44	0.01	PVC	PVC	140.0	152.0	9.0	N	136.9	3928673.10	1428146.93
MW-148-100	95.38		99.93		4.55	0.01	PVC	PVC	92	100.40	7.3	N	88.08	3928677.4	1428142.0
MW-148-80	75.50		80.00		4.50	0.01	PVC	PVC	69	80	7.5	N	68.00	3928674.9	1428135.4

Table 3-1
Well Construction Details

Offsite Site Characterization Report - 2013 Addendum
North pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

	Well Screen								Filter Pack		WATER TABLE			ALASKA STATE PLANE NAD83, ZONE 3	
Well	Depth to Top (feet BGS)	Top Elevation (feet MSL)	Depth to Bottom (feet BGS)	Bottom Elevation (feet MSL)	Length (feet)	Screen Slot Size (inches)	Material	Riser Material	Depth to Top (feet BGS)	Depth to Bottom (feet BGS)	Approx Depth (ft BGS)	In Screen	Feet above top of Screen	NORTHING	EASTING
MW-149A	4.00	486.91	14.00	476.91	10.00	0.02	PVC	PVC	3.0	14.0	7.2	Y	-3.2	3928676.81	1428953.13
MW-149B	14.00	477.06	19.00	472.06	5.00	0.02	PVC	PVC	12.5	19.0	7.2	N	6.8	3928677.69	1428959.56
MW-150A	6.70	480.87	11.10	476.47	4.40	0.01	PVC	PVC	5.5	17.0	8.0	Y	-1.3	3930163.44	1426522.55
MW-150B	20.60	466.92	24.50	463.02	3.90	0.01	PVC	PVC	18.0	26.5	8.0	N	12.6	3930162.06	1426527.97
MW-150C	55.43	431.54	60.08	426.89	4.65	0.01	PVC	PVC	Natural pack		8.0	N	47.4	3930159.85	1426535.91
MW-151A	10.00	477.50	15.00	472.50	5.00	0.01	PVC	PVC	4.0	17.0	8.0	N	2.0	3930152.81	1427042.16
MW-151B	18.50	469.12	23.10	464.52	4.60	0.01	PVC	PVC	17.0	26.5	8.0	N	10.5	3930154.30	1427034.87
MW-151C	52.55	435.02	57.15	430.42	4.60	0.01	PVC	PVC	50.0	63.3	8.0	N	44.6	3930151.93	1427038.65
MW-152A	10.60	478.03	15.00	473.63	4.40	0.01	PVC	PVC	8.0	17.0	8.0	N	2.6	3930112.63	1427987.59
MW-152B	19.90	468.58	24.40	464.08	4.50	0.01	PVC	PVC	19.0	27.0	8.0	N	11.9	3930112.89	1427983.05
MW-152C	60.13	428.57	64.57	424.13	4.44	0.01	PVC	PVC	55.0	65.5	11.3	N	48.8	3930113.17	1427992.07
MW-153A	10.60	479.91	14.50	476.01	3.90	0.01	PVC	PVC	8.5	17.0	8.0	N	2.6	3928749.86	1427720.55
MW-153B	51.60	438.68	56.10	434.18	4.50	0.01	PVC	PVC	45.0	59.0	9.0	N	42.6	3928741.21	1427721.08
MW-154A	71.00	424.48	75.00	420.48	4.00	0.01	PVC	PVC	68.0	76.5	12.5	N	58.5	3927391.51	1428835.89
MW-154B	90.15	404.91	94.75	400.31	4.60	0.01	PVC	PVC	80.0	103.5	7.0	N	83.2	3927410.23	1428845.45
MW-155A	5.35	483.24	15.08	473.51	9.73	0.01	PVC	PVC	3.5	15.5	7.5	Y	-2.2	3930320.08	1425509.58
MW-155B	60.78	427.92	65.20	423.50	4.42	0.02	PVC	PVC	45.0	70.0	9	N	51.8	3930314.75	1425510.07
MW-156A	5.35	480.78	15.09	471.04	9.74	0.01	PVC	PVC	3.5	15.5	7.0	Y	-1.7	3931955.04	1425536.52
MW-156B	45.20	441.29	50.00	436.49	4.80	0.01	PVC	PVC	35.0	51.5	8.0	N	37.2	3931949.92	1425537.02
MW-157A	5.36	479.91	15.09	470.18	9.73	0.01	PVC	PVC	3.5	15.5	7.0	Y	-1.6	3932561.84	1426870.93
MW-157B	25.71	459.55	30.14	455.12	4.43	0.01	PVC	PVC	20.0	31.0	10.3	N	15.4	3932567.15	1426874.11
MW-158A	5.50	482.61	15.20	472.91	9.70	0.02	PVC	PVC	3.0	16.5	8.5	Y	-3.0	3931120.65	1426869.14
MW-158B	55.62	432.33	60.14	427.81	4.52	0.02	PVC	PVC	43.0	67.0	10.0	N	45.6	3931119.26	1426874.85
MW-159A	5.50	483.39	15.20	473.69	9.70	0.02	PVC	PVC	3.0	16.5	8.0	Y	-2.5	3931101.34	1427690.57
MW-159B	41.16	447.83	45.60	443.39	4.44	0.01	PVC	PVC	35.0	46.5	8.0	N	33.2	3931101.12	1427679.28
MW-159C	67.13	421.95	71.84	417.24	4.71	0.01	PVC	PVC	60.0	72.5	8.0	N	59.1	3931100.83	1427684.86
MW-160AR-15	4.91	481.04	14.77	471.18	9.86	0.01	PVC	PVC	3.0	15.27	7.0	Y	-2.1	3932566.91	1427454.76
MW-160B	85.58	400.22	90.18	395.62	4.60	0.01	PVC	PVC	80.0	91.5	8.0	N	77.6	3932566.90	1427459.68
MW-161A	5.50	474.68	15.20	464.98	9.70	0.02	PVC	PVC	3.8	16.5	8.0	Y	-2.5	3935554.06	1421680.78
MW-161B	46.02	433.92	50.44	429.50	4.42	0.02	PVC	PVC	35.0	51.5	6.5	N	39.5	3935553.83	1421678.29
MW-161-30	25.18	454.65	29.73	450.10	4.55	0.01	PVC	PVC	Natural pack		8.0	N	17.2	3935553.69	1421673.97
MW-162A	5.50	478.99	15.20	469.29	9.70	0.02	PVC	PVC	3.8	16.5	7.5	Y	-2.0	3934831.10	1425571.90
MW-162B	60.18	424.24	64.73	419.69	4.55	0.01	PVC	PVC	50.0	66.5	7.5	Y	52.7	3934825.07	1425574.08
MW-163A	5.50	480.30	15.20	470.60	9.70	0.02	PVC	PVC	3.6	16.5	9.0	Y	-3.5	3935430.75	1426901.11
MW-163B	34.53	451.20	38.96	446.77	4.43	0.02	PVC	PVC	30.0	41.5	9.5	N	25.0	3935430.72	1426906.78
MW-164A	5.50	475.18	15.20	465.48	9.70	0.02	PVC	PVC	3.8	16.5	9.0	Y	-3.5	3938026.16	1425651.07
MW-164B	45.62	434.56	50.06	430.12	4.44	0.02	PVC	PVC	35.0	51.5	9.0	N	36.6	3938027.01	1425654.08
MW-164C	57.34	423.00	61.99	418.35	4.65	0.01	PVC	PVC	52.0	63.5	8.0	N	49.3	3938023.06	1425652.19
MW-165A	5.19	470.06	14.90	460.35	9.71	0.01	PVC	PVC	4.0	15.5	7.5	Y	-2.3	3938692.18	1416849.70
MW-165B	45.87	429.39	50.35	424.91	4.48	0.02	PVC	PVC	35.0	51.5	8.0	N	37.9	3938690.33	1416854.17
MW-166A	5.44	467.26	15.15	457.55	9.71	0.01	PVC	PVC	4.0	16.0	7.5	Y	-2.1	3940972.27	1419512.27
MW-166B	27.15	445.12	31.35	440.92	4.20	0.01	PVC	PVC	21.0	33.5	7.0	N	20.2	3940967.37	1419509.53
MW-167A	5.65	470.37	15.35	460.67	9.70	0.01	PVC	PVC	4.0	16.0	9.0	Y	-3.4	3942809.92	1423092.52
MW-167B	28.17	447.92	33.15	442.94	4.98	0.01	PVC	PVC	25.0	34.0	6.5	N	21.7	3942813.73	1423092.51
MW-168A	5.36	473.30	15.06	463.60	9.70	0.01	PVC	PVC	4.0	16.0	9.0	Y	-3.6	3941284.64	1425723.88
MW-168B	46.29	432.33	51.00	427.62	4.71	0.01	PVC	PVC	40.0	52.0	10.9	N	35.4	3941289.40	1425724.13
MW-169A	5.27	477.91	15.06	468.12	9.79	0.01	PVC	PVC	4.0	15.5	8.0	Y	-2.7	3931955.69	1423035.08

Table 3-1
Well Construction Details

Offsite Site Characterization Report - 2013 Addendum
North pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

	Well Screen								Filter Pack		WATER TABLE			ALASKA STATE PLANE NAD83, ZONE 3	
Well	Top (feet BGS)	Elevation (feet MSL)	Bottom (feet BGS)	Elevation (feet MSL)	Length (feet)	Slot Size (inches)	Material	Riser Material	Depth to Top (feet BGS)	Bottom (feet BGS)	Depth (ft BGS)	In Screen	Feet above top of	NORTHING	EASTING
MW-169B	44.09	438.81	48.72	434.18	4.63	0.02	PVC	PVC	35.0	51.5	10.0	N	34.1	3931960.39	1423037.49
MW-169C	54.82	428.17	59.47	423.52	4.65	0.02	PVC	PVC	50.0	60.0	8.0	N	46.8	3931966.50	1423042.84
MW-170A	4.60	486.51	14.40	476.71	9.80	0.01	PVC	PVC	4.6	16.0	8.0	Y	-3.4	3930005.65	1429184.98
MW-170B	69.70	421.31	74.06	416.95	4.36	0.01	PVC	PVC	65.0	75.6	8.0	N	61.7	3930000.43	1429187.53
MW-170C	125.90	365.40	130.20	361.10	4.30	0.01	PVC	PVC	120.0	135.0	8.0	N	117.9	3929995.96	1429188.84
MW-170D	45.52	445.44	50.14	440.82	4.62	0.02	PVC	PVC	35.0	51.5	8.0	N	37.5	3929991.96	1429189.27
MW-171A	4.96	480.63	14.77	470.82	9.81	0.01	PVC	PVC	4.0	16.0	9.0	Y	-4.0	3935401.97	1428945.84
MW-171B	35.26	449.97	39.70	445.53	4.44	0.01	PVC	PVC	30.0	44.5	10.0	N	25.3	3935402.47	1428941.37
MW-172A	5.33	470.49	15.04	460.78	9.71	0.01	PVC	PVC	3.5	16.0	8.0	Y	-2.7	3942632.06	1427431.58
MW-172B	145.35	330.74	149.78	326.31	4.43	0.01	PVC	PVC	135.0	151.5	8.0	N	137.4	3942631.33	1427425.63
MW-173A	4.54	488.44	14.24	478.74	9.70	0.01	PVC	PVC	4.0	16.0	8.0	Y	-3.5	3927534.58	1430223.98
MW-173B	145.80	347.27	150.20	342.87	4.40	0.01	PVC	PVC	135.0	151.5	8.0	N	137.8	3927527.38	1430222.41
MW-174A	44.96	446.38	49.68	441.66	4.72	0.02	PVC	PVC	30.0	51.5	7.5	N	37.5	3926454.50	1428665.44
MW-174B	85.16	406.26	89.88	401.54	4.72	0.02	PVC	PVC	70.0	91.5	7.5	N	77.7	3926461.30	1428664.22
MW-174-15	3.22	488.11	13.02	478.31	9.80	0.01	PVC	PVC	3.2	13.6	8.5	Y	-5.3	3926469.65	1428666.66
MW-175	85.81	407.97	90.30	403.48	4.49	0.02	PVC	PVC	75.0	91.5	8.0	N	77.8	3926774.40	1429593.36
MW-176A	4.67	489.15	14.42	479.40	9.75	0.02	PVC	PVC	4.0	16.5	9.5	Y	-4.8	3926055.80	1429416.30
MW-176B	45.56	448.16	50.06	443.66	4.50	0.02	PVC	PVC	35.0	51.5	9.5	N	36.1	3926056.30	1429412.03
MW-176C	85.43	408.28	89.93	403.78	4.50	0.02	PVC	PVC	75.0	91.5	9.5	N	75.9	3926056.80	1429407.76
MW-177	84.71	410.20	89.19	405.72	4.48	0.02	PVC	PVC	70.0	91.5	7.5	N	77.2	3925072.46	1430037.88
MW-178A	5.90	488.26	15.64	478.52	9.74	0.02	PVC	PVC	3.0	16.5	7.0	Y	-1.1	3926117.29	1429586.63
MW-178B	46.01	447.90	50.73	443.18	4.72	0.02	PVC	PVC	40.0	51.5	7.5	N	38.5	3926117.08	1429579.97
MW-178C	85.16	409.08	89.93	404.31	4.77	0.02	PVC	PVC	75.0	91.5	7.5	N	77.7	3926117.30	1429573.58
MW-179A	5.56	488.35	15.20	478.71	9.64	0.02	PVC	PVC	5.0	16.5	8.0	Y	-2.4	3926050.54	1429676.64
MW-179B	45.80	448.27	50.29	443.78	4.49	0.02	PVC	PVC	40.0	51.5	8.0	N	37.8	3926047.16	1429680.75
MW-179C	85.41	409.00	89.90	404.51	4.49	0.02	PVC	PVC	75.0	91.5	8.5	N	76.9	3926045.58	1429674.43
MW-179D	128.95	365.03	133.65	360.33	4.70	0.02	PVC	PVC	115.0	140.5	8.0	N	121.0	3926048.88	1429668.63
MW-180A	5.25	489.08	14.97	479.36	9.72	0.02	PVC	PVC	3.0	16.5	7.5	Y	-2.3	3925874.85	1429928.62
MW-180B	45.71	448.51	50.19	444.03	4.48	0.02	PVC	PVC	35.0	51.5	7.5	N	38.2	3925879.52	1429922.58
MW-180C	85.33	408.87	89.87	404.33	4.54	0.02	PVC	PVC	75.0	91.5	7.5	N	77.8	3925873.80	1429924.19
MW-181A	5.05	471.44	14.75	461.74	9.70	0.02	PVC	PVC	4.0	16.5	10.0	Y	-5.0	3944095.46	1425755.04
MW-181B	45.77	430.59	50.30	426.06	4.53	0.02	PVC	PVC	35.0	51.5	10.0	N	35.8	3944099.95	1425752.10
MW-181C	145.43	330.97	149.86	326.54	4.43	0.01	PVC	PVC	140.0	150.5	10.3	N	135.1	3944089.21	1425759.17
MW-182A	5.70	471.10	15.42	461.38	9.72	0.02	PVC	PVC	4.0	16.5	7.0	Y	-1.3	3941132.12	1423038.13
MW-182B	39.57	436.29	44.27	431.59	4.70	0.02	PVC	PVC	30.0	50.5	7.0	N	32.6	3941136.42	1423037.29
MW-183A	5.77	472.87	15.47	463.17	9.70	0.02	PVC	PVC	4.0	16.5	7.0	Y	-1.2	3937529.71	1420159.70
MW-183B	54.64	424.00	59.34	419.30	4.70	0.02	PVC	PVC	45.0	60.0	7.0	N	47.6	3937532.14	1420157.14
MW-184	40.12	447.17	44.75	442.54	4.63	0.02	PVC	PVC	30.0	45.5	7.0	N	33.1	3932560.61	1428756.36
MW-185A	5.48	473.21	15.10	463.59	9.62	0.02	PVC	PVC	4.0	16.5	7.0	Y	-1.5	3940802.50	1428251.19
MW-185B	46.30	432.20	50.93	427.57	4.63	0.02	PVC	PVC	35.0	51.5	7.0	N	39.3	3940797.61	1428251.05
MW-185C	115.96	362.73	120.40	358.29	4.44	0.01	PVC	PVC	110.0	121.0	9.5	N	106.5	3940806.68	1428250.19
MW-186A	5.11	487.60	14.79	477.92	9.68	0.02	PVC	PVC	4.0	16.5	7.0	Y	-1.9	3927025.87	1429092.83
MW-186B	50.69	442.02	60.37	432.34	9.68	0.02	PVC	PVC	40.0	61.5	7.0	N	43.7	3927021.15	1429092.67
MW-186C	90.69	401.94	100.32	392.31	9.63	0.02	PVC	PVC	80.0	101.5	7.0	N	83.7	3927017.05	1429092.45
MW-186D	129.83	362.89	134.62	358.10	4.79	0.01	PVC	PVC	124.0	136.5	7.0	N	122.8	3927010.35	1429093.23
MW-186E	70.76	421.96	75.42	417.30	4.66	0.01	PVC	PVC	Natural pack		7.0	N	63.8	3927030.39	1429093.30
MW-187	7.28	475.12	16.91	465.49	9.63	0.02	PVC	PVC	4.0	16.5	10.5	Y	-3.2	3934464.24	1420335.62
MW-188A	5.20	456.79	14.98	447.01	9.78	0.01	PVC	PVC	3.0	15.3	10.0	Y	-4.8	3951510.80	1410365.41

Table 3-1
Well Construction Details

Offsite Site Characterization Report - 2013 Addendum
North pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

	Well Screen								Filter Pack		WATER TABLE			ALASKA STATE PLANE	
	Top	Elevation	Bottom	Elevation	Length	Slot Size		Riser	Depth to Top	Bottom	Depth		Feet above	NAD83, ZONE 3	
Well	(feet BGS)	(feet MSL)	(feet BGS)	(feet MSL)	(feet)	(inches)	Material	Material	(feet BGS)	(feet BGS)	(ft BGS)	In Screen	top of	NORTHING	EASTING
MW-188B	35.40	426.50	40.40	421.50	5.00	0.02	PVC	PVC	35.5	42.5	4.5	N	30.9	3951521.8	1410365.52
MW-189A	6.49	464.37	16.16	454.70	9.67	0.01	PVC	PVC	4.0	17.5	7.0	Y	-0.5	3945399.36	1424696.44
MW-189B	55.42	415.57	60.07	410.92	4.65	0.01	PVC	PVC	45.0	61.5	7.0	N	48.4	3945396.24	1424692.19
MW-190A	5.49	476.74	15.20	467.03	9.71	0.01	PVC	PVC	4.0	16.0	7.0	Y	-1.5	3938370.06	1429592.42
MW-190B	55.62	426.24	60.28	421.58	4.66	0.01	PVC	PVC	45.0	61.5	7.0	N	48.6	3938370.16	1429596.16
MW-190BR-60	54.85	427.33	59.41	422.77	4.56	0.01	PVC	PVC	Natural pack		7.0	N	47.9	3938372.96	1429596.46
MW-190-150	145.35	336.83	149.91	332.27	4.56	0.01	PVC	PVC	Natural pack		7.0	N	138.4	3938379.86	1429596.16
MW-191A	5.18	471.35	14.90	461.63	9.72	0.01	PVC	PVC	4.0	16.0	8.0	Y	-2.8	3937781.57	1417713.87
MW-191B	55.22	421.07	59.84	416.45	4.62	0.01	PVC	PVC	45.0	61.5	8.0	N	47.2	3937777.89	1417714.18
MW-192A	4.54	488.92	14.24	479.22	9.70	0.02	PVC	PVC	5.0	15.0	4.5	Y	0.0	3924992.22	1428889.36
MW-192B	50.41	442.84	55.11	438.14	4.70	0.02	PVC	PVC	54.0	60.0	4.0	N	46.4	3924992.57	1428887.11
MW-193A	5.00	483.13	15.50	472.63	10.50	0.02	PVC	PVC	5.0	15.5	6.8	Y	-1.8	3930483.21	1424590.71
MW-193B	54.72	433.29	59.41	428.60	4.69	0.02	PVC	PVC	45.0	60.0	6.5	N	48.2	3930481.25	1424593.75
MW-194A	6.00	470.30	15.36	460.94	9.36	0.02	PVC	PVC	4.0	15.0	6.5	Y	-0.5	3939634.55	1418923.90
MW-194B	34.38	441.92	38.96	437.34	4.58	0.02	PVC	PVC	24.0	40.0	6.5	N	27.9	3939630.80	1418924.87
MW-195A	5.15	488.19	14.95	478.39	9.80	0.01	PVC	PVC	4.0	16.0	8.0	Y	-2.9	3926110.91	1428572.63
MW-195B	144.80	348.66	149.50	343.96	4.70	0.01	PVC	PVC	130.0	149.9	8.0	N	136.8	3926110.92	1428566.32
MW-196	5.01	489.05	14.73	479.33	9.72	0.01	PVC	PVC	4.0	16.5	7.5	Y	-2.5	3925033.44	1429646.49
MW-197A	61.09	431.61	65.74	426.96	4.65	0.01	PVC	PVC	Natural pack		7.0	N	54.1	3926959.84	1429490.28
MW-197B	144.61	348.12	149.08	343.65	4.47	0.01	PVC	PVC	135.0	152.0	9.0	N	135.6	3926950.83	1429491.74
MW-198	144.73	348.87	149.38	344.22	4.65	0.01	PVC	PVC	135.0	150.0	8.0	N	136.7	3925820.02	1429027.70
MW-199	144.65	348.64	149.44	343.85	4.79	0.01	PVC	PVC	140.0	151.5	9.0	N	135.7	3926959.18	1428830.82
MW-300	145.00	349.06	149.70	344.36	4.65	0.01	PVC	PVC	130.0	150.3	9.0	N	136.0	3926139.62	1429895.14
MW-301-60	55.61	433.88	60.26	429.23	4.65	0.01	PVC	PVC	50.0	62.0	5.0	N	50.6	3927435.06	1427867.56
MW-301-70	65.70	423.90	70.14	419.46	4.44	0.01	PVC	PVC	60.0	70.0	5.0	N	60.7	3927422.66	1427894.40
MW-301-CMT-10	9.87	479.57	10.13	479.31	0.25	CMT	PVC	PVC	8.0	12.0	5.0	N	4.9	3927444.5	1427850.40
MW-301-CMT-20	19.87	469.57	20.13	469.31	0.25	CMT	PVC	PVC	18.0	22.0	5.0	N	14.9	3927444.5	1427850.40
MW-301-CMT-30	29.87	459.57	30.13	459.31	0.25	CMT	PVC	PVC	28.0	32.0	5.0	N	24.9	3927444.5	1427850.40
MW-301-CMT-40	39.87	449.57	40.13	449.31	0.25	CMT	PVC	PVC	38.0	42.0	5.0	N	34.9	3927444.5	1427850.40
MW-301-CMT-50	49.87	439.57	50.13	439.31	0.25	CMT	PVC	PVC	48.0	52.0	5.0	N	44.9	3927444.5	1427850.40
MW-302-110	105.11	385.58	109.58	381.11	4.47	0.01	PVC	PVC	95.0	110.5	9.0	N	96.1	3927616.89	1428196.81
MW-302-70	65.75	424.52	70.40	419.87	4.65	0.01	PVC	PVC	60.0	71.0	9.0	N	56.8	3927612.39	1428219.37
MW-302-80	76.33	414.12	80.98	409.47	4.65	0.01	PVC	PVC	70.0	81.5	9.0	N	67.3	3927614.39	1428208.27
MW-302-95	90.15	400.13	94.81	395.47	4.66	0.01	PVC	PVC	Natural pack		9.0	N	81.2	3927608.27	1428231.29
MW-302-CMT-10	9.87	480.87	10.13	480.61	0.25	CMT	PVC	PVC	8.0	12.0	5.0	N	4.9	3927605.7	1428194.16
MW-302-CMT-20	19.87	470.87	20.13	470.61	0.25	CMT	PVC	PVC	18.0	22.0	5.0	N	14.9	3927605.7	1428194.16
MW-302-CMT-30	29.87	460.87	30.13	460.61	0.25	CMT	PVC	PVC	28.0	32.0	5.0	N	24.9	3927605.7	1428194.16
MW-302-CMT-40	39.87	450.87	40.13	450.61	0.25	CMT	PVC	PVC	38.0	41.5	5.0	N	34.9	3927605.7	1428194.16
MW-302-CMT-50	49.87	440.87	50.13	440.61	0.25	CMT	PVC	PVC	47.0	50.5	5.0	N	44.9	3927605.7	1428194.16
MW-303-130	125.60	366.39	130.23	361.76	4.63	0.01	PVC	PVC	115.0	131.0	9.0	N	116.6	3927682.57	1428479.64
MW-303-70	65.24	426.95	70.04	422.15	4.80	0.01	PVC	PVC	60.0	70.5	9.0	N	56.2	3927668.05	1428484.37
MW-303-80	75.54	416.66	80.33	411.87	4.79	0.01	PVC	PVC	70.0	81.0	9.0	N	66.5	3927660.37	1428485.11
MW-303-95	90.13	401.87	94.78	397.22	4.65	0.01	PVC	PVC	Natural pack		9.0	N	81.1	3927651.67	1428487.31
MW-303-CMT-19	18.87	473.43	19.13	473.17	0.25	CMT	PVC	PVC	17.0	21.0	4.0	N	14.9	3927676.0	1428481.84
MW-303-CMT-29	28.87	463.43	29.13	463.17	0.25	CMT	PVC	PVC	27.0	31.0	4.0	N	24.9	3927676.0	1428481.84
MW-303-CMT-39	38.87	453.43	39.13	453.17	0.25	CMT	PVC	PVC	37.0	41.0	4.0	N	34.9	3927676.0	1428481.84
MW-303-CMT-49	48.87	443.43	49.13	443.17	0.25	CMT	PVC	PVC	47.0	51.0	4.0	N	44.9	3927676.0	1428481.84
MW-303-CMT-59	58.87	433.43	59.13	433.17	0.25	CMT	PVC	PVC	57.0	59.5	4.0	N	54.9	3927676.0	1428481.84

Table 3-1
Well Construction Details

Offsite Site Characterization Report - 2013 Addendum
North pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

	Well Screen								Filter Pack		WATER TABLE			ALASKA STATE PLANE NAD83, ZONE 3	
Well	Top (feet BGS)	Elevation (feet MSL)	Bottom (feet BGS)	Elevation (feet MSL)	Length (feet)	Slot Size (inches)	Material	Riser Material	Depth to Top (feet BGS)	Bottom (feet BGS)	Depth (ft BGS)	In Screen	Feet above top of	NORTHING	EASTING
MW-303-CMT-9	8.87	483.43	9.13	483.17	0.25	CMT	PVC	PVC	7.0	11.0	4.0	N	4.9	3927676.0	1428481.84
MW-304-125	120.89	372.84	125.32	368.41	4.43	0.01	PVC	PVC	115.0	126.0	10.5	N	110.4	3927730.33	1428833.79
MW-304-15	8.02	485.59	17.83	475.78	9.81	0.01	PVC	PVC	3.4	18.7	10.5	Y	-2.5	3927723.82	1428828.03
MW-304-150	145.53	348.56	150.18	343.91	4.65	0.01	PVC	PVC	135.0	150.0	10.5	N	135.1	3927769.24	1428870.53
MW-304-70	65.54	428.70	70.20	424.04	4.66	0.01	PVC	PVC	58.0	71.0	10.5	N	55.1	3927751.83	1428854.08
MW-304-80	76.02	418.01	80.67	413.36	4.65	0.01	PVC	PVC	71.5	81.5	10.5	N	65.6	3927740.60	1428843.75
MW-304-96	90.57	403.52	95.22	398.87	4.65	0.01	PVC	PVC	Natural pack		10.5	N	80.1	3927746.17	1428848.56
MW-304-CMT-10	9.87	484.29	10.13	484.03	0.25	CMT	PVC	PVC	8.0	12.0	9.5	N	0.4	3927758.3	1428860.58
MW-304-CMT-20	19.87	474.29	20.13	474.03	0.25	CMT	PVC	PVC	18.0	22.0	9.5	N	10.4	3927758.3	1428860.58
MW-304-CMT-30	29.87	464.29	30.13	464.03	0.25	CMT	PVC	PVC	28.0	32.0	9.5	N	20.4	3927758.3	1428860.58
MW-304-CMT-40	39.87	454.29	40.13	454.03	0.25	CMT	PVC	PVC	36.0	41.5	9.5	N	30.4	3927758.3	1428860.58
MW-304-CMT-50	49.87	444.29	50.13	444.03	0.25	CMT	PVC	PVC	48.0	52.0	9.5	N	40.4	3927758.3	1428860.58
MW-304-CMT-60	59.87	434.29	60.13	434.03	0.25	CMT	PVC	PVC	58.0	61.0	9.5	N	50.4	3927758.3	1428860.58
MW-305-100	94.88	398.09	99.32	393.65	4.44	0.01	PVC	PVC	85.0	100.0	10.0	N	84.9	3927946.36	1429034.54
MW-305-70	65.00	427.76	69.90	422.86	4.90	0.01	PVC	PVC	2.5	72.0	10.0	N	55.0	3927953.08	1429040.73
MW-305-80	76.10	416.59	80.75	411.94	4.65	0.01	PVC	PVC	70.0	81.5	10.0	N	66.1	3927959.70	1429046.56
MW-305-CMT-18	17.37	475.77	17.63	475.51	0.25	CMT	PVC	PVC	15.0	19.5	4.0	N	13.4	3927940.7	1429048.97
MW-305-CMT-28	27.37	465.77	27.63	465.51	0.25	CMT	PVC	PVC	25.0	29.5	4.0	N	23.4	3927940.7	1429048.97
MW-305-CMT-38	37.37	455.77	37.63	455.51	0.25	CMT	PVC	PVC	34.5	39.5	4.0	N	33.4	3927940.7	1429048.97
MW-305-CMT-48	47.37	445.77	47.63	445.51	0.25	CMT	PVC	PVC	44.5	49.5	4.0	N	43.4	3927940.7	1429048.97
MW-305-CMT-58	57.37	435.77	57.63	435.51	0.25	CMT	PVC	PVC	54.8	57.5	4.0	N	53.4	3927940.7	1429048.97
MW-305-CMT-8	7.37	485.77	7.63	485.51	0.25	CMT	PVC	PVC	5.5	9.5	4.0	N	3.4	3927940.7	1429048.97
MW-306-100	95.40	397.69	100.16	392.93	4.76	0.01	PVC	PVC	90.0	101.0	9.0	N	86.4	3928121.97	1429302.41
MW-306-15	5.20	488.34	15.01	478.53	9.81	0.01	PVC	PVC	3.2	15.4	11.0	Y	-5.8	3928103.64	1429299.52
MW-306-150	144.86	348.25	149.63	343.48	4.77	0.01	PVC	PVC	133.0	150.5	9.0	N	135.9	3928118.47	1429293.75
MW-306-70	65.51	427.80	70.31	423.00	4.80	0.01	PVC	PVC	60.0	71.0	9.0	N	56.5	3928115.77	1429309.12
MW-306-80	75.31	417.99	80.10	413.20	4.79	0.01	PVC	PVC	70.0	81.0	9.0	N	66.3	3928108.87	1429292.74
MW-306-CMT-10	9.87	483.62	10.13	483.36	0.25	CMT	PVC	PVC	8.3	12.0	5.0	N	4.9	3928108.3	1429306.73
MW-306-CMT-20	19.87	473.62	20.13	473.36	0.25	CMT	PVC	PVC	17.3	22.0	5.0	N	14.9	3928108.3	1429306.73
MW-306-CMT-30	29.87	463.62	30.13	463.36	0.25	CMT	PVC	PVC	27.7	32.0	5.0	N	24.9	3928108.3	1429306.73
MW-306-CMT-40	39.87	453.62	40.13	453.36	0.25	CMT	PVC	PVC	37.3	41.5	5.0	N	34.9	3928108.3	1429306.73
MW-306-CMT-50	49.87	443.62	50.13	443.36	0.25	CMT	PVC	PVC	47.8	52.0	5.0	N	44.9	3928108.3	1429306.73
MW-306-CMT-60	59.87	433.62	60.13	433.36	0.25	CMT	PVC	PVC	57.7	62.0	5.0	N	54.9	3928108.3	1429306.73
MW-307	144.76	348.05	149.56	343.25	4.80	0.01	PVC	PVC	140.0	151.5	9.0	N	135.8	3926951.83	1429734.66
MW-308-15	4.91	468.05	14.36	458.60	9.45	0.01	PVC	PVC	3.5	15.0	9.0	Y	-4.1	3943105.50	1420578.30
MW-308-30	25.21	446.47	30.02	441.66	4.81	0.01	PVC	PVC	Natural pack		10.0	N	15.2	3943026.01	1420453.62
MW-309-15	4.92	487.11	14.72	477.31	9.80	0.01	PVC	PVC	3.2	15.0	7.0	Y	-2.1	3927042.65	1428539.04
MW-309-150	144.61	347.41	149.27	342.75	4.66	0.01	PVC	PVC	Natural pack		7.0	N	137.6	3927043.93	1428525.49
MW-309-66	59.43	432.58	64.10	427.91	4.67	0.01	PVC	PVC	Natural pack		7.0	N	52.4	3927043.2	1428532.39
MW-310-110	105.28	385.67	109.94	381.01	4.66	0.01	PVC	PVC	Natural pack		6.0	N	99.3	3926802.76	1428044.57
MW-310-15	4.58	486.67	14.38	476.87	9.80	0.01	PVC	PVC	3.2	14.7	6.0	Y	-1.4	3926810.88	1428028.92
MW-310-65	60.47	430.91	65.13	426.25	4.66	0.01	PVC	PVC	Natural pack		6.0	N	54.5	3926805.71	1428036.73
MW-311-15	5.24	462.04	15.04	452.24	9.80	0.01	PVC	PVC	3.2	15.4	4.5	N	0.7	3946536.13	1415602.20
MW-311-46	40.60	426.50	45.26	421.84	4.66	0.01	PVC	PVC	Natural pack		4.5	N	36.1	3946534.99	1415612.86
MW-312-15	5.34	459.24	15.13	449.45	9.79	0.01	PVC	PVC	2.7	15.5	5.7	Y	-0.4	3951394.25	1415642.38
MW-312-50	44.90	419.74	49.56	415.08	4.66	0.01	PVC	PVC	Natural pack		7.0	N	37.9	3951399.72	1415642.19
MW-313-15	4.99	461.23	14.79	451.43	9.80	0.01	PVC	PVC	3.0	15.2	9.5	Y	-4.5	3951374.78	1423235.06
MW-313-150	144.69	321.48	149.34	316.83	4.65	0.01	PVC	PVC	Natural pack		9.5	N	135.2	3951370.40	1423237.65

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North pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

	Well Screen								Filter Pack		WATER TABLE			ALASKA STATE PLANE	
	Top	Elevation	Bottom	Elevation	Length	Slot Size		Riser	Depth to Top	Bottom	Depth		Feet above	NAD83, ZONE 3	
Well	(feet BGS)	(feet MSL)	(feet BGS)	(feet MSL)	(feet)	(inches)	Material	Material	(feet BGS)	(feet BGS)	(ft BGS)	In Screen	top of	NORTHING	EASTING
MW-314-15	5.38	471.20	15.16	461.42	9.78	0.01	PVC	PVC	3.0	15.6	7.0	Y	-1.6	3943869.90	1427115.02
MW-315-15	5.70	453.48	15.49	443.69	9.79	0.01	PVC	PVC	3.0	15.8	7.0	Y	-1.3	3949804.15	1403467.06
MW-315-150	145.58	313.79	150.23	309.14	4.65	0.01	PVC	PVC	Natural pack		7.0	N	138.6	3949809.75	1403467.06
MW-316-15	5.46	481.17	15.26	471.37	9.80	0.01	PVC	PVC	3.0	15.0	7.0	Y	-1.5	3932950.20	1428372.65
MW-316-56	50.95	435.68	55.59	431.04	4.64	0.01	PVC	PVC	Natural pack		7.0	N	44.0	3932950.03	1428377.41
MW-317-15	5.46	483.84	15.25	474.05	9.79	0.01	PVC	PVC	3.0	15.7	9.0	Y	-3.5	3930184.86	1428701.63
MW-317-71	66.10	423.25	70.73	418.62	4.63	0.01	PVC	PVC	Natural pack		9.0	N	57.1	3930185.90	1428666.62
MW-318-20	10.29	479.78	20.08	469.99	9.79	0.01	PVC	PVC	8.0	20.5	10.0	Y	0.3	3928866.23	1424726.43
MW-318-135	130.15	359.66	134.80	355.01	4.65	0.01	PVC	PVC	Natural pack		7.0	N	123.2	3928883.99	1424703.15
MW-319-15	5.08	451.37	14.89	441.56	9.81	0.01	PVC	PVC	3.0	15.3	7.0	Y	-1.9	3953109.18	1404197.93
MW-319-45	40.44	416.21	45.10	411.55	4.66	0.01	PVC	PVC	Natural pack		7.0	N	33.4	3953109.18	1404192.73
MW-320-130	126.32	325.17	130.97	320.52	4.65	0.01	PVC	PVC	Natural pack		10.0	N	116.3	3963539.90	1402678.14
MW-320-20	9.96	441.24	19.76	431.44	9.80	0.01	PVC	PVC	7.9	20.2	10.2	Y	-0.2	3963542.54	1402682.33
MW-321-15	5.62	487.23	15.41	477.44	9.79	0.01	PVC	PVC	3.9	15.8	7.0	Y	-1.4	3926256.76	1428855.78
MW-321-151	145.41	347.52	150.06	342.87	4.65	0.01	PVC	PVC	Natural pack		7.0	N	138.4	3926273.73	1428856.06
MW-321-65	60.89	431.93	65.55	427.27	4.66	0.01	PVC	PVC	Natural pack		7.0	N	53.9	3926265.14	1428856.30
MW-322-15	5.55	463.82	15.34	454.03	9.79	0.01	PVC	PVC	3.0	15.7	7.0	Y	-1.5	3940670.73	1410082.02
MW-322-150	145.94	323.45	150.59	318.80	4.65	0.01	PVC	PVC	Natural pack		7.0	N	138.9	3940646.94	1410074.03
MW-323-15	5.42	476.84	15.21	467.05	9.79	0.01	PVC	PVC	3.0	15.6	7.0	Y	-1.6	3931840.58	1422094.72
MW-323-50	44.90	437.28	49.46	432.72	4.56	0.01	PVC	PVC	Natural pack		7.0	N	37.9	3931846.38	1422088.29
MW-324-15	5.17	458.61	14.96	448.82	9.79	0.01	PVC	PVC	3.0	15.4	7.0	Y	-1.8	3945444.19	1404965.19
MW-324-151	145.78	317.82	150.44	313.16	4.66	0.01	PVC	PVC	Natural pack		7.0	N	138.8	3945446.0	1404958.62
MW-325-150	145.48	341.97	150.13	337.32	4.65	0.01	PVC	PVC	Natural pack		12.0	N	133.5	3937085.15	1430633.64
MW-325-18	8.53	478.41	18.33	468.61	9.80	0.01	PVC	PVC	6.5	18.7	12.0	Y	-3.5	3937079.28	1430639.29
MW-326-150	145.45	351.94	150.10	347.29	4.65	0.01	PVC	PVC	Natural pack		7.0	N	138.5	3921145.09	1430276.63
MW-326-20	10.61	486.76	20.40	476.97	9.79	0.01	PVC	PVC	7.0	20.8	7.0	N	3.6	3921150.73	1430277.63
MW-327-15	5.21	462.86	15.01	453.06	9.80	0.01	PVC	PVC	2.8	15.4	7.0	Y	-1.8	3951301.83	1420336.90
MW-327-150	145.79	322.26	150.44	317.61	4.65	0.01	PVC	PVC	Natural pack		7.0	N	138.8	3951297.90	1420342.92
MW-328-15	5.83	467.15	15.33	457.65	9.50	0.01	PVC	PVC	2.8	15.8	8.5	Y	-2.7	3945516.60	1422877.24
MW-328-151	145.58	327.61	150.25	322.94	4.67	0.01	PVC	PVC	Natural pack		8.5	N	137.1	3945525.83	1422876.28
MW-329-15	5.40	474.58	14.34	465.64	8.94	0.01	PVC	PVC	3.5	14.8	7.0	Y	-1.6	3937284.38	1421278.22
MW-329-66	60.53	419.17	65.19	414.51	4.66	0.01	PVC	PVC	Natural pack		7.0	N	53.5	3937283.6	1421283.36
MW-330-150	145.36	351.89	150.02	347.23	4.66	0.01	PVC	PVC	Natural pack		12.0	N	133.4	3926206.19	1428288.44
MW-330-20	9.46	487.84	19.21	478.09	9.75	0.01	PVC	PVC	7.7	9.5	12.0	Y	-2.5	3926218.84	1428281.49
MW-330-65	60.26	437.02	64.91	432.37	4.65	0.01	PVC	PVC	Natural pack		12.0	N	48.3	3926212.39	1428284.78
MW-331-150	145.10	347.85	149.75	343.20	4.65	0.01	PVC	PVC	Natural pack		8.6	N	136.5	3927767.73	1429695.15
MW-332-15	5.53	476.49	15.32	466.70	9.79	0.01	PVC	PVC	3.0	15.7	7.0	y	-1.5	3937270.16	1428736.01
MW-332-41	36.34	445.48	40.89	440.93	4.55	0.01	PVC	PVC	Natural pack		7.0	N	29.3	3937270.67	1428725.15
MW-332-75	70.54	410.89	75.09	406.34	4.55	0.01	PVC	PVC	Natural pack		7.0	N	63.5	3937271.24	1428711.60
MW-332-110	105.51	376.06	110.06	371.51	4.55	0.01	PVC	PVC	Natural pack		7.0	N	98.5	3937271.08	1428718.59
MW-332-150	145.74	336.70	150.39	332.05	4.65	0.01	PVC	PVC	3.1	15.5	7.2	Y	138.5	3937270.37	1428731.02
MW-333-150	145.32	349.16	149.98	344.50	4.66	0.01	PVC	PVC	Natural pack		7.2	N	138.1	3922968.19	1430186.58
MW-333-16	6.09	488.33	15.83	478.59	9.74	0.01	PVC	PVC	Natural pack		5.5	N	0.6	3922961.12	1430188.05
MW-334-15	5.43	488.03	14.92	478.54	9.49	0.01	PVC	PVC	4.0	16.5	8.0	Y	-2.6	3927035.89	1429327.86
MW-334-65	60.57	432.43	65.23	427.77	4.66	0.01	PVC	PVC	4.0	18.0	8.5	Y	52.1	3927036.11	1429323.29
MW-334-85	80.54		85.07		4.53	0.01	PVC	PVC	75	85.07	7.5	N	73.04	3927037.16	1429314.83
MW-335-41	36.01	434.49	40.56	429.94	4.55	0.01	PVC	PVC	4.0	17.0	11.0	Y	25.0	3946145.20	1419928.02
MW-336-15	5.65		15.30		9.65	0.02	Stainless steel	PVC	3	15.33	7.5	Y	-1.85	3925763.56	1429752.45
MW-336-20	15.64		20.19		4.55	0.01	PVC	PVC	13.0	20.7	7.5	N	8.14	3925763.88	1429746.26

Table 3-1
Well Construction Details

Offsite Site Characterization Report - 2013 Addendum
North pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

	Well Screen								Filter Pack		WATER TABLE			ALASKA STATE PLANE	
Well	Depth to Top (feet BGS)	Top Elevation (feet MSL)	Depth to Bottom (feet BGS)	Bottom Elevation (feet MSL)	Length (feet)	Screen Slot Size (inches)	Material	Riser Material	Depth to Top (feet BGS)	Depth to Bottom (feet BGS)	Approx Depth (ft BGS)	In Screen	Feet above top of Screen	NAD83, ZONE 3 NORTHING	EASTING
MW-336-35	30.69		35.25		4.56	0.01	PVC	PVC	24.0	35.6	7.5	N	23.19	3925767.41	1429740.39
MW-338-15	5.89	477.49	15.48	467.90	9.59	0.01	PVC	PVC	3.1	15.4	7.0	Y	-1.1	3933055.54	1424634.92
MW-338-50	44.84	438.71	49.40	434.15	4.56	0.01	PVC	PVC	Natural pack		7.0	N	37.8	3933056.53	1424628.77
MW-339-15	5.34	474.43	14.94	464.83	9.60	0.01	PVC	PVC	5.0	15.0	10.0	Y	-4.7	3939785.23	1425645.56
MW-339-50	45.95	433.85	50.50	429.30	4.55	0.01	PVC	PVC	Natural pack		10.0	N	36.0	3939778.24	1425644.76
MW-340-18	7.86	471.08	17.46	461.48	9.60	0.01	PVC	PVC	5.0	18.0	12.0	N	-4.1	3938036.46	1430903.62
MW-340-65	60.53	418.82	65.09	414.26	4.56	0.01	PVC	PVC	Natural pack		12.0	N	48.5	3938051.84	1430905.94
MW-340-150	145.70	333.60	150.26	329.04	4.56	0.01	PVC	PVC	Natural pack		12.0	N	133.7	3938045.02	1430905.51
MW-341-15	5.61	474.97	15.18	465.40	9.57	0.01	PVC	PVC	4.0	15.5	10.0	Y	-4.4	3936403.00	1421617.07
MW-341-40	35.61	444.84	40.28	440.17	4.67	0.01	PVC	PVC	Natural pack		10.0	N	25.6	3936404.33	1421613.16
MW-342-15	5.40	477.49	15.00	467.89	9.60	0.01	PVC	PVC	4.0	15.0	7.0	Y	-1.6	3934213.82	1422873.08
MW-342-65	60.17	422.84	64.74	418.27	4.57	0.01	PVC	PVC	Natural pack		7.0	N	53.2	3934214.12	1422878.39
MW-343-15	4.55		14.15		9.60	0.01	PVC	PVC	3.5	15.0	4.5	Y	N/A	3936542.14	1428026.58
MW-343-50	45.74		50.32		4.58	0.01	PVC	PVC	Natural pack		4.5	N	41.24	3936542.50	1428031.46
MW-344-15	5.64	485.03	15.25	475.42	9.61	0.01	PVC	PVC	4.0	15.0	5.5	Y	N/A	3926973.37	1428698.43
MW-344-55	51.60		56.15		4.55	0.01	PVC	PVC	45	56.63	5.5	N	46.10	3926967.82	1428697.9
MW-344-75	70.79		75.34		4.55	0.01	PVC	PVC	65	75.65	5.5	N	65.29	3926970.71	1428702.91
MW-345-15	5.77	486.93	15.34	477.36	9.57	0.01	PVC	PVC	4	15.0	7.0	Y	N/A	3927056.25	1428877.68
MW-345-55	50.34		54.87		4.53	0.01	PVC	PVC	44	55.43	8.0	N	42.34	3927055.97	1428883.16
MW-345-75	70.98		75.00		4.02	0.01	PVC	PVC	64	75	8.0	N	62.98	3927061.21	1428881.21
MW-346-15	5.37		15.00		9.63	0.01	PVC	PVC	3.0	15.5	5.7	Y	N/A	3943140.80	1425712.83
MW-346-150	144.17		148.73		4.56	0.01	PVC	PVC	Natural pack		4.5	N	139.67	3943135.64	1425713.20
MW-346-65	59.60		64.16		4.56	0.01	PVC	PVC	Natural pack		5.8	N	53.80	3943130.73	1425713.68
MW-347-150	146.48		151.05		4.57	0.01	PVC	PVC	Natural pack		9.5	N	136.98	3939728.75	1428360.93
MW-347-20	10.20		19.80		9.60	0.01	PVC	PVC	7.6	20.4	12.0	Y	N/A	3939722.42	1428356.90
MW-347-65	60.20		64.80		4.60	0.01	PVC	PVC	Natural pack		12.0	N	48.20	3939728.76	1428364.88
MW-348-15	5.30		15.11		9.81	0.01	PVC	PVC	3.0	15.0	7.3	Y	N/A	3926037.27	1429537.47
MW-348-65	59.20		63.77		4.57	0.01	PVC	PVC	Natural pack		7.0	N	52.20	3926043.62	1429537.42
MW-349-15	4.98	479.94	14.60	470.32	9.62	0.01	PVC	PVC	3.6	15.0	6.0	Y	N/A	3933772.41	1426241.57
MW-349-45	40.40	444.45	44.95	439.90	4.55	0.01	PVC	PVC	35.0	45.5	6.0	N	34.40	3933774.54	1426236.89
MW-350-15	5.86		15.48		9.62	0.01	PVC	PVC	3.0	15.0	7.0	Y	N/A	3936446.66	1426044.58
MW-350-50	42.12		46.67		4.55	0.01	PVC	PVC	Natural pack		7.0	N	35.12	3936444.80	1426049.18
MW-351-150	145.74		150.25		4.51	0.01	PVC	PVC	139	150.83	8.3	N	137.44	3927226.08	1428320.28
MW-351-15	5.32		15.08		9.76	0.01	PVC	PVC	4	15.48	6.3	Y	-0.98	3927232.35	1428305.33
MW-351-55	50.60		55.12		4.52	0.01	PVC	PVC	44	55.68	8.3	N	42.30	3927228.1	1428314.81
MW-351-75	71.39		75.91		4.52	0.01	PVC	PVC	64	75	6.30	N	65.09	3927230.22	1428309.94
MW-352-15	5.52		15.17		9.65	0.01	PVC	PVC	2.4	15.6	9.0	Y	N/A	3943661.73	1423829.82
MW-352-40	33.28		37.87		4.59	0.01	PVC	PVC	Natural pack		9.0	N	24.28	3943661.39	1423825.02
MW-353-100	95.50		100.05		4.55	0.01	PVC	PVC	Natural pack		8.0	N	87.50	3936222.41	1423377.69
MW-353-15	5.50		14.50		9.00	0.01	PVC	PVC	3.0	15.5	8.0	Y	N/A	3936216.06	1423370.00
MW-353-65	60.03		64.63		4.60	0.01	PVC	PVC	Natural pack		7.8	N	52.28	3936219.34	1423374.04
MW-354-15	6.06		15.62		9.56	0.01	PVC	PVC	3	16.27	7.00	Y	-0.94		
MW-354-35	29.79		34.29		4.50	0.01	PVC	PVC	28	34.84	8.00	N	21.79		
MW-354-60	54.99		59.55		4.56	0.01	PVC	PVC	51	60.02	8.00	N	46.99		
MW-355-15	5.81		15.35		9.54	0.01	PVC	PVC	3	16.05	8.00	Y	-2.19		
MW-355-55	50.56		55.13		4.57	0.01	PVC	PVC	43	55.78	7.50	N	43.06		
MW-356-15	8.24		18.04		9.80	0.01	PVC	PVC	5	18.39	8.5	Y	-0.26	3941381.39	1429217.1
MW-356-65	60.68		65.24		4.56	0.01	PVC	PVC	54	65.77	9.0	N	51.68	3941376.9	1429218.74
MW-356-90	83.72		88.24		4.52	0.01	PVC	PVC	76	88.73	9.0	N	74.72	3941371.87	1429221.14
MW-357-15	5.49		15.27		9.78	0.01	PVC	PVC	3	15.59	8.5	Y	-3.01	3935720.9	1430665.73

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	Well Screen								Filter Pack		WATER TABLE			ALASKA STATE PLANE	
Well	Depth to Top (feet BGS)	Top Elevation (feet MSL)	Depth to Bottom (feet BGS)	Bottom Elevation (feet MSL)	Length (feet)	Screen Slot Size (inches)	Material	Riser Material	Depth to Top (feet BGS)	Depth to Bottom (feet BGS)	Approx Depth (ft BGS)	In Screen	Feet above top of Screen	NAD83, ZONE 3 NORTHING	EASTING
MW-357-150	145.47		149.97		4.50	0.01	PVC	PVC	139	150.46	8.5	Y	136.97	3935727.84	1430657.06
MW-357-65	60.93		65.44		4.51	0.01	PVC	PVC	8.5	66	8.5	N	52.43	3935724.61	1430661.02
MW-358-150	145.61		150.11		4.50	0.01	PVC	PVC	139	150.57	10.0	N	135.61		
MW-358-20	15.68		20.23		4.55	0.01	PVC	PVC	14	20.72	9.57	N	6.11		
MW-358-40	35.24		39.78		4.54	0.01	PVC	PVC	29	40.25	9.63	N	25.61		
MW-358-60	55.66		60.22		4.56	0.01	PVC	PVC	50	60.22	8.5	N	47.16		
MW-359-15	5.49		15.05		9.56	0.01	PVC	PVC	3.1	15.51	9.3	Y	-3.81		
MW-359-35	30.02		34.58		4.56	0.01	PVC	PVC	29	35.06	9.3	N	20.72		
MW-359-60	55.42		60.08		4.66	0.01	PVC	PVC	49	60.52	7.0	N	48.42		
MW-359-80	75.57		80.04		4.47	0.01	PVC	PVC	69	80.58	9.5	N	66.07		
MW-359-150	145.29		149.80		4.51	0.01	PVC	PVC	139	150.31	10.0	N	135.29		
MW-359-60	55.42		60.08		4.66	0.01	PVC	PVC	49	60.52	7.0	N	48.42		
MW-360-15	5.37		14.94		9.57	0.01	PVC	PVC	3	15.41	9.5	Y	-4.13		
MW-360-150	144.91		149.57		4.66	0.01	PVC	PVC	5	150.01	9.5	N	135.41		
MW-360-35	30.76		35.23		4.47	0.01	PVC	PVC	24.5	35.76	9.59	N	21.17		
MW-360-50	45.58		50.06		4.48	0.01	PVC	PVC	39	50.6	10.0	N	35.58		
MW-360-80	74.90		79.37		4.47	0.01	PVC	PVC	70	80.23	10.0	N	64.90		
MW-361-15	5.27		14.85		9.58	0.01	PVC	PVC	3.5	15.29	8.0	Y	-2.73		
MW-362-15	5.20		14.75		9.55	0.01	PVC	PVC	2.9	15.19	7.0	Y	-1.80		
MW-362-25	19.92		24.39		4.47	0.01	PVC	PVC	15	25.06	7.0	N	12.92		
MW-362-35	30.56		35.13		4.57	0.01	PVC	PVC	25	35.57	7.0	N	23.56		
MW-362-50	44.91		49.39		4.48	0.01	PVC	PVC	40	49.92	7.0	N	37.91		
MW-362-80	75.29		79.79		4.50	0.01	PVC	PVC	70	80.31	7.0	N	68.29		
MW-362-150	145.91		150.47		4.56	0.01	PVC	PVC	139	150.65	10.0	N	135.91		
MW-363-15	5.66		15.24		9.58	0.01	PVC	PVC	3	15.69	9.5	Y	-3.84		
MW-364-15	5.37		14.94		9.57	0.01	PVC	PVC	2.4	15.54	9.0	Y	-3.63		
MW-364-30	25.18		29.65		4.47	0.01	PVC	PVC	19	30.29	9.0	N	16.18		
MW-364-65	60.75		65.23		4.48	0.01	PVC	PVC	54	65.79	9.0	N	51.75		
MW-364-90	85.28		89.76		4.48	0.01	PVC	PVC	79	90.29	9.0	N	76.28		
MW-364-150	145.64		150.12		4.48	0.01	PVC	PVC	139	150.81	9.0	N	136.64		
MW-365-15						0.01	PVC	PVC				Y			
MW-366-15						0.01	PVC	PVC				Y			
MW-367-15	5.98		15.53		9.55	0.01	PVC	PVC	3	16.17	9.5	Y	-3.52		
MW-368-15	5.72		15.29		9.57	0.01	PVC	PVC	3	15.78	9.5	Y	-3.78		
MW-369-15						0.01	PVC	PVC				Y			
MW-369-55						0.01	PVC	PVC				N			
MW-369-75						0.01	PVC	PVC				N			
MW-370-15						0.01	PVC	PVC				Y			
MW-370-55						0.01	PVC	PVC				N			
MW-370-75	70.59		75.14		4.55	0.01	PVC	PVC	65	75.8	7.0	N	63.59		
MW-371-15						0.01	PVC	PVC				Y			
MW-371-55						0.01	PVC	PVC				N			
MW-371-75						0.01	PVC	PVC				N			
MW-371-PF						0.01	PVC	PVC				N			
PW_ID 1230	no screen- open casing					0.01	steel	steel			7.0			3933784.63	1426231.43
O-1	4.94	489.60	14.67	479.87	9.73	0.02	PVC	PVC	4.0	17.0	9.2	Y	-4.3	3925973.83	1429619.47
O-10	6.38	487.22	16.03	477.57	9.65	0.01	PVC	PVC	4.0	16.0	6.1	Y	0.3	3926386.30	1429760.78
O-11	6.41	488.29	15.90	478.80	9.49	0.01	PVC	PVC	3.6	15.5	7.8	Y	-1.4	3927247.94	1429025.71
O-12	6.79	485.83	16.60	476.02	9.81	0.01	PVC	PVC	3.0	15.5	9.0	Y	-2.2	3927268.21	1429161.41
O-12-65	60.75	432.31	65.31	427.75	4.56	0.01	PVC	PVC	Natural pack		7.0	N	53.75	3927268.19	1429167.30
O-13	5.68	486.23	15.49	476.42	9.81	0.01	PVC	PVC	3.0	14.7	8.0	Y	-2.3	3927268.35	1429254.10
O-14	5.12	490.14	14.91	480.35	9.79	0.01	PVC	PVC	4.0	16.0	8.0	Y	-2.9	3925995.33	1430224.22
O-15	5.19	490.36	14.97	480.58	9.78	0.01	PVC	PVC	4.0	16.0	8.0	Y	-2.8	3925553.75	1430177.50
O-16	4.41	489.18	14.20	479.39	9.79	0.01	PVC	PVC	4.0	16.0	9.0	Y	-4.6	3925819.74	1429033.87
O-17	4.87	488.73	14.56	479.04	9.69	0.01	PVC	PVC	4.0	16.5	7.5	Y	-2.6	3926546.15	1429036.74
O-18	5.15	487.94	14.85	478.24	9.70	0.01	PVC	PVC	4.0	16.0	9.0	Y	-3.9	3926309.43	1429007.34
O-19	5.15	488.12	14.87	478.40	9.72	0.01	PVC	PVC	4.0	16.0	8.0	Y	-2.9	3926814.98	1429229.93
O-2	4.88	488.84	14.61	479.11	9.73	0.02	PVC	PVC	3.0	18.6	11.3	Y	-6.4	3927114.04	1429130.05
O-19-55	49.47		53.94		4.47	0.01	PVC	PVC	45	55	8.5	N	40.97		
O-19-90	85.69		90.17		4.48	0.01	PVC	PVC	79	90.72	8.0	N	77.69		
O-20	5.64	488.65	15.44	478.85	9.80	0.01	PVC	PVC	3.0	18.0	8.5	Y	-2.9	3925863.81	1429729.04

Table 3-1
Well Construction Details

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North pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

	Well Screen								Filter Pack		WATER TABLE			ALASKA STATE PLANE	
	Depth to Top	Top Elevation	Depth to Bottom	Bottom Elevation	Length	Screen Slot Size		Riser	Depth to Top	Depth to Bottom	Approx Depth		Feet above top of	NAD83, ZONE 3	
Well	(feet BGS)	(feet MSL)	(feet BGS)	(feet MSL)	(feet)	(inches)	Material	Material	(feet BGS)	(feet BGS)	(ft BGS)	In Screen	Screen	NORTHING	EASTING
O-21	5.49	488.09	15.29	478.29	9.80	0.01	PVC	PVC	3.0	15.5	10.3	Y	-4.8	3925656.97	1429631.77
O-22	8.30	486.54	18.05	476.79	9.75	0.01	PVC	PVC	3.0	16.5	12.4	Y	-4.1	3926789.25	1430139.00
O-23	6.03	487.43	15.78	477.68	9.75	0.01	PVC	PVC	3.0	15.0	8.6	Y	-2.6	3927110.81	1429926.50
O-24	4.95	489.40	14.70	479.65	9.75	0.01	PVC	PVC	5.0	17.4	10.8	Y	-5.9	3927281.16	1429428.42
O-24-65	60.32		64.88		4.56	0.01	PVC	PVC	Natural pack		11.0	N	49.32	3927287.12	1429429.10
O-25	6.12	489.04	15.87	479.29	9.75	0.01	PVC	PVC	3.0	16.0	6.0	Y	0.1	3927402.44	1429242.45
O-5-65	59.58	433.37	64.15	428.80	4.57	0.01	PVC	PVC	Natural pack		7.0	N	52.58	3926947.60	1428824.90
O-26	4.67	489.26	14.42	479.51	9.75	0.01	PVC	PVC	3.0	18.2	10.9	Y	-6.2	3927363.19	1429037.48
O-26-65	60.86		65.42		4.56	0.01	PVC	PVC	Natural pack		8.4	N	52.42	3927370.10	1429035.34
O-27	7.08	487.92	16.83	478.17	9.75	0.01	PVC	PVC	4.0	15.8	9.0	Y	-1.9	3927278.05	1428804.68
O-27-65	60.98		65.53		4.55	0.01	PVC	PVC	54.0	66.2	8.0	N	53.0		
O-27-150	145.27		149.83		4.56	0.01	PVC	PVC	139.0	150.28	8.0	N	137.27		
O-28	4.55	487.94	14.30	478.19	9.75	0.01	PVC	PVC	4.0	16.5	8.0	Y	-3.5	3925637.58	1428886.20
O-29	7.87	488.37	17.62	478.62	9.75	0.01	PVC	PVC	4.5	16.5	7.5	Y	0.4	3926600.52	1430083.48
O-30	6.71	488.29	15.36	479.64	9.75	0.01	PVC	PVC	3.5	16.0	8.0	Y	-1.3	3926425.91	1430292.76
O-3	4.43	490.05	14.16	480.32	9.73	0.02	PVC	PVC	3.5	16.0	6.0	Y	-1.6	3927090.75	1429551.50
O-4	4.98	488.94	14.64	479.28	9.66	0.02	PVC	PVC	3.5	16.0	8.0	Y	-3.0	3927159.11	1428795.47
O-5	4.97	488.33	14.68	478.62	9.71	0.01	PVC	PVC	4.0	16.0	8.5	Y	-3.5	3926951.41	1428829.08
O-6	5.47	486.77	15.17	477.07	9.70	0.01	PVC	PVC	4.0	18.0	8.0	Y	-2.5	3926744.06	1428769.81
O-7	5.22	488.27	14.92	478.57	9.70	0.01	PVC	PVC	3.5	16.0	8.0	?	-2.8	3926757.84	1429941.88
O-8	5.75	488.23	15.45	478.53	9.70	0.01	PVC	PVC	4.0	16.0	8.0	Y	-2.3	3926131.00	1429895.90
O-9	5.03	488.81	14.73	479.11	9.70	0.01	PVC	PVC	4.0	18.0	9.0	Y	-4.0	3926505.32	1429912.51
O-31	5		15		10.00	0.02	Stainless Steel	PVC	4	16	7.5	Y	-2.50	3927266.76	1429326.59
O-32	6		16		10.00	0.02	Stainless Steel	PVC	4	17	10	Y	-4.00	3927043.28	1429214.60
O-33	6		16		10.00	0.02	Stainless Steel	PVC	4	18	8.7	Y	-2.70	3926714.93	1429442.08
O-34	6		16		10.00	0.02	Stainless Steel	PVC	5	18	8	Y	-2.00	3926268.90	1429394.51
O-35	5		15		10.00	0.02	Stainless Steel	PVC	3	18	7	Y	-2.00	3925985.05	1429404.33
O-36	6		16		10.00	0.02	Stainless Steel	PVC	4	18	8.9	Y	-2.90	3926763.54	1429779.47
O-37	6		16		10.00	0.02	Stainless Steel	PVC	4	18	7.5	Y	-1.50	3926618.61	1429780.51
O-38	5		15		10.00	0.02	Stainless Steel	PVC	3	18	6.8	Y	-1.80	3926444.05	1429913.39
R-14	?	?	?	?	?	NA	culvert		2.5	19.7	9.0	Y		3927108.36	1429010.00
R-14A	4.00	489.01	10.73	482.28	6.73	?	ABS	ABS			8.5	Y	-4.5	3927100.21	1429016.07
R-18	7.65	488.65	32.77	463.53	25.12	?	steel	steel						3926667.15	1429608.07
R-20R	3.80	491.14	19.70	475.24	15.90	0.03	ss	ss			9.0	?	?	3926382.77	1429577.80
R-21	4.17	488.53	24.17	468.53	20.00	?	steel	steel			9.0	?	?	3926960.05	1429035.68
R-22	4.65	?	24.65	?	20.00	?	steel	steel			9.0	Y	-4.4	3927061.93	1429008.20
R-3	?	?	?	?	?	NA	culvert				9.0	Y		3925550.08	1429397.48
R-32	?	?	?	?	?	NA	culvert		Natural pack		9.0	Y		3926473.43	1429438.03
R-32R	6		16		10.00	0.02	Stainless Steel	PVC	5	17	8.5	Y	-2.50	3926479.30	1429436.28
R-33	7.40	485.80	24.60	468.60	17.20	?	steel	steel			9.0	?	?	3925827.95	1429332.73
R-34	0.50	492.75	20.83	472.42	20.33	?	ss	steel			9.0	Y	-8.5	3926500.01	1429393.41
R-35R	4.00	488.87	39.00	453.87	35.00	0.01	ss	steel			9.0	?	?	3926840.14	1429455.05
R-38	?	?	?	?	?	NA	culvert				9.0	Y		3925496.45	1429474.75
R-39	6.25	487.09	25.50	467.84	19.25	?	steel	steel	Natural pack		9.0	N	-2.8	3927030.22	1429648.72
R-4	?	?	?	?	?	NA	culvert		Natural pack		12.0	Y		3925501.58	1429377.63
R-40	6.00	486.70	25.17	467.53	19.17	?	steel	steel	Natural pack		13.0	Y	-7.0	3927004.81	1429396.89
R-42	15.00	476.80	35.00	456.80	20.00	0.04	ss	steel	Natural pack		12.0	Y	3.0	3926974.24	1428686.38
R-43	5.84	487.44	40.98	452.30	35.14	0.008	ss	ss	Natural pack		7.0	Y	-1.2	3927046.41	1428881.33
R-44	6.00	488.48	40.78	453.70	34.78	0.008	ss	ss	Natural pack		9.0	Y	-3.0	3927111.88	1429149.46
R-45	7.26	485.80	32.25	460.81	24.99	0.008	ss	ss	Natural pack		7.0	Y	0.3	3927018.85	1429353.89

Table 3-1
Well Construction Details

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North pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

	Well Screen								Filter Pack		WATER TABLE			ALASKA STATE PLANE	
	Depth to Top	Top Elevation	Depth to Bottom	Bottom Elevation	Length	Screen Slot Size		Riser	Depth to Top	Depth to Bottom	Approx Depth		Feet above top of	NAD83, ZONE 3	
Well	(feet BGS)	(feet MSL)	(feet BGS)	(feet MSL)	(feet)	(inches)	Material	Material	(feet BGS)	(feet BGS)	(ft BGS)	In Screen	Screen	NORTHING	EASTING
R-46	6.00	488.18	30.88	463.30	24.88	0.008	ss	ss	Natural pack		8.0	Y	-2.0	3927033.10	1429663.67
R-5	?	?	?	?	?	NA	culvert				9.0	?	?	3925824.93	1429309.40
S-21	2.92	491.43	12.67	481.68	9.75	0.02	PVC	PVC			9.0	Y	-6.1	3926670.65	1429597.64
S-39	7.53	485.52	12.53	480.52	5.00	?	PVC	PVC			9.0	Y	-1.5	3927009.82	1429395.60
S-41R	9.76		14.28		4.52	0.01	PVC	PVC	7.5	15	7.5	N	2.26	3925833.81	1429139.24
S-43	3.37	490.71	12.70	481.38	9.33	?	PVC	PVC			9.0	Y	-5.6	3926779.68	1429530.33
S-44	3.16	489.40	12.64	479.92	9.48	?	PVC	PVC			9.0	Y	-5.8	3926922.12	1429493.51
S-50	3.88	490.05	13.56	480.37	9.68	0.02	PVC	PVC			9.0	Y	-5.1	3926779.29	1429065.48
S-51	4.75	488.23	14.43	478.55	9.68	0.02	PVC	PVC			9.0	Y	-4.3	3926824.07	1429045.61
S-54	10.00	483.98	15.00	478.98	5.00	0.02	PVC	PVC			12.0	Y	-2.0	3928055.37	1429680.65
S-9	4.88	487.35	18.88	473.35	14.00	0.01	PVC	PVC			7.5	Y	-2.6	3927494.32	1429112.46

Table 3-2
Total Organic Carbon Soil Analytical Data

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Location	Sample Name	Dup	Sample Date	Work Order	Depth	Total Organic Carbon
						%
MW-347-150	MW-347-150 (90.7-91.0)		8/5/2013	1138213	90.7-91.0	0.0301J
MW-347-150	MW-347-150 (148.4-148.7)		8/5/2013	1138213	148.4-148.7	0.0624
MW-347-65	MW-347-65 (35.5-36.5)		9/2/2013	1138375	35.5-36.5	0.0648
MW-347-65	MW-347-65 (62-63)		9/2/2013	1138375	62-63	0.0594
MW-350-50	MW-350-50(20-21.5)		8/18/2013	1138300	20-21.5	0.0542J
MW-350-50	MW-350-50(50-51.5)		8/18/2013	1138300	50-51.1	0.0783
MW-352-40	MW-352-40 (15-16.5)		9/2/2013	1138375	15-16.5	0.0599
MW-352-40	MW-352-40 (42.5-44)		9/2/2013	1138375	42.5-44	0.0825
MW-353-100	MW-353-100(50.0-51.5)		9/5/2013	1138413	50.0-51.5	0.0708
MW-353-100	MW-353-100(110-111.5)		9/5/2013	1138413	110-111.5	0.0386J
MW-353-65	MW-353-65(35-36.5)		9/6/2013	1138413	35-36.5	0.0522J
MW-353-65	MW-353-65(62-63.5)		9/6/2013	1138413	62-63.5	0.118

Acronyms and Abbreviations:
mg/kg = milligrams per kilogram
J = estimated concentration; detected above the detection limit (DL) but below the limit of quantitation (LOQ)
JL* = result is considered estimated, biased low

Table 5-1
Hydraulic Conductivity and Grain Size Summary

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Boring[a]	Sample ID	Sample Depth (ft)	Blow Count	Relative Density Classification	Grain Size Analysis Results								Soil Type	Hazen			Prugh			Barr
					Gravel Content (%)	Sand Content (%)	Fines Content (%)	D10 (mm)	D20 (mm)	D50 (mm)	D60 (mm)	Cu		K D10 (m/s)	K D10 (cm/s)	K D10 (ft/day)	K D50 (m/s)	K D50 (cm/s)	K D50 (ft/day)	K (ft/day)
MW-110-65	S-7	15.0-16.5	4	L	46.3	29.4	24.3	0.010	0.041	0.870	7.710	770	GM							1.2
MW-110-65	S-11	25.0-26.5	17	MD	62.3	33.1	4.6	0.160	0.230	7.320	10.220	64	GP							91
MW-110-65	S-13	30.0-31.5	22	MD	64.2	32.9	2.9	0.210	0.420	7.480	10.160	48	GP							170
MW-110-65	S-15	35.0-36.5	21	MD	54.4	41.3	4.3	0.170	0.270	5.430	7.350	43	GP							100
MW-110-65	S-20	62.5-64.0	63	VD	29.9	60.0	10.1	0.070	0.200	2.100	3.150	45	SP-SM							33
MW-144BR	S-17	92'-95'	29	D	48.0	50.9	1.1	2.220	2.800	4.570	5.870	2.6	SP	5.91E-02	5.91E+00	17000	4.30E-03	4.30E-01	1200	1800
MW-148-100	S-5	10.0-11.5	20	MD	61.0	33.9	5.1	0.160	0.380	7.760	11.480	72	GW-GM							96
MW-148-100	S-11	40.0-41.5	17	MD	64.2	33.1	2.7	0.260	0.940	7.700	10.530	41	GW							240
MW-148-100	S-13	60.0-61.5	20	MD	61.7	34.7	3.6	0.270	0.780	7.550	10.970	41	GW							190
MW-148-100	S-16	90.0-91.5	26	MD	63.0	31.6	5.4	0.200	0.860	7.840	11.620	58	GW-GM							120
MW-148-100	S-18	107.5-109.0	32	D	50.0	42.2	7.8	0.110	0.340	4.760	6.480	59	GW-GM							59
MW-148-80	S-1	77.5-79.0	21	MD	37.6	58.4	4.0	0.160	0.230	2.130	4.060	25	SP							85
MW-148D	S-13	150'-152'	50 for 6"	VD	22.0	72.8	5.2	0.110	0.180	0.280	0.350	3.2	SP-SM	1.09E-04	1.09E-02	31	1.10E-04	1.10E-02	31	26
MW-151C	S-151C-1	15' - 16.5'	14	MD	52.0	43.5	4.5	0.150	0.220	5.400	9.740	65	GP							87
MW-151C	S-151C-2	25' - 26.5'	23	MD	0.0	94.0	6.0	0.100	0.170	0.610	4.430	44	SP-SM							35
MW-151C	S-151C-3	40' - 41.5'	24	MD	2.0	95.3	2.7	0.110	0.160	0.220	0.250	2.3	SP	1.21E-04	1.21E-02	34	2.00E-04	2.00E-02	57	24
MW-152C	S-4	60'-62'	20	MD	55.0	39.7	5.3	0.190	0.370	5.800	8.690	46	GP-GM							97
MW-153	S-3	59' - 60'	50/3"	D	47.0	48.4	4.6	0.160	0.230	3.070	7.290	46	SP							84
MW-154B	S-154-1	75' 76.5'	22	MD	43.0	36.7	6.3	0.110	0.190	2.340	5.730	52	SP-SM							19
MW-154B	S-154-2	90' - 91.5'	30	MD	0.0	94.7	5.3	0.160	0.250	2.190	4.360	27	SP-SM							69
MW-154B	S-154-3	103.5' - 104'	50/6"	D	0.0	85.6	14.4	0.020	0.160	2.500	4.440	220	SM							4.5
MW-156B	S-156-1	20' - 21.5'	28	MD	51.0	43.4	5.6	0.130	0.230	4.940	8.270	64	GP-GM							71
MW-156B	S-156-2	55' - 56'	50	D	48.0	46.8	5.2	0.140	0.230	3.160	6.960	50	GP-GM							73
MW-157B	S-2	25'-27'	22	MD	38.0	56.1	5.9	0.130	0.190	0.590	3.340	26	SP-SM							41
MW-158B	S-12	60' - 60.5'	50/5"	D	56.0	41.1	2.9	0.250	0.330	5.880	8.550	34	GP							170
MW-159C	S-7	70'-72'	26	MD	42.0	54.1	3.9	0.170	0.270	2.470	5.140	30	SP							96
MW-160B	S-160-1	20' - 21'	18	MD	0.0	96.3	3.7	0.150	0.180	0.280	0.310	2.1	SP	2.25E-04	2.25E-02	64	3.10E-04	3.10E-02	88	30
MW-160B	S-160-2	38' - 39.5'	19	MD	59.0	38.4	2.6	0.370	0.640	6.840	9.900	27	GW							270
MW-160B	S-160-3	55' - 56.5'	19	MD	69.0	28.3	2.7	0.230	0.620	9.370	11.990	52	GP							210
MW-160B	S-160-4	70' - 71.5'	22	MD	64.0	33.3	2.7	0.270	0.820	9.760	13.600	50	GW							240
MW-160B	S-160-5	90' - 91.5'	59	D	44.0	50.9	5.1	0.160	0.270	2.860	5.990	37	SP-SM							80
MW-161-30	S-4	25.0-26.5	31	D	5.1	86.3	8.6	0.080	0.130	0.220	0.250	3.1	SP-SM				7.70E-05	7.70E-03	22	15
MW-161B	S-11	50' - 51.5'	77	D	74.0	24.6	1.4	0.320	2.710	10.910	14.210	44	GP							550
MW-162B	S-162-1	10' - 12'	26	MD	44.0	52.7	3.3	0.160	0.210	2.250	6.060	38	SP							93
MW-162B	S-162-2	30' - 32'	34	D	60.0	34.7	5.3	0.150	0.280	7.650	11.570	77	GP-GM							84
MW-162B	S-162-3	55' - 56.5'	20	MD	62.0	35.4	2.6	0.220	0.770	7.460	10.350	47	GP							210
MW-162B	S-162-4	65' - 66.1'	66	D	63.0	30.5	6.5	0.140	0.370	9.240	13.600	97	GW-GM							76
MW-163B	S	40' - 41.5'	50/2"	D	38.0	54.8	7.2	0.120	0.190	0.410	3.190	27	SP-SM							32
MW-164B	S	50' - 51.5'	18	MD	66.0	30.9	3.1	0.240	0.540	9.770	12.360	52	GP							190
MW-164C	S-1	50'-51.5'	19	MD	59.0	36.4	4.6	0.180	0.320	7.100	11.080	62	GP							100
MW168B	S-5	50'-52'	41	D	51.0	45.1	3.9	0.180	0.290	5.030	7.690	43	GP							110
MW-169B	S-1	50' - 51.5'	64	D	60.0	36.0	4.0	0.180	0.370	7.630	11.660	65	GW							120
MW-169C	S-1	60'-61.5	14	MD	68.0	30.1	1.9	0.190	0.380	10.370	15.450	81	GP							200
MW-170C	S-170C-3	55' - 56.5'	41	D	58.0	37.0	5.0	0.170	0.450	6.450	9.350	55	GP							100
MW-170C	S-170C-4	80' - 81.5'	26	MD	54.0	37.3	8.7	0.080	0.150	6.130	10.700	130	GP-GM							41
MW-170C	S-170C-5	95' - 96.5'	30	D	8.0	84.8	7.2	0.090	0.160	0.260	0.300	3.3	SP-SM				1.00E-04	1.00E-02	28	19
MW-170D	S-1	50' - 51.5'	31	D	68.0	27.2	4.8	0.180	0.400	11.620	15.830	88	SP							110
MW-174-15	S-1	0.0-1.5	12	MD	58.2	35.1	6.7	0.140	0.290	6.800	9.950	71	GW-GM							69
MW-174-15	S-2	2.5-4.5	5	L	2.8	10.4	86.8	NM	0.006	0.020	0.030	NM	ML							0.088
MW-174-15	S-3	5.0-7.0	8	L	11.3	27.0	61.7	0.010	0.013	0.050	0.070	7	ML							0.39
MW-174-15	S-4	7.5-9.5	23	MD	56.8	38.7	4.5	0.170	0.310	6.210	9.990	59	GP							100
MW-174-15	S-5	10.0-12.0	18	MD	58.0	34.1	7.9	0.100	0.250	6.970	10.970	110	GW-GM							54
MW-174-15	S-6	12.5-14.5	17	MD	69.2	24.0	6.8	0.100	0.300	12.960	31.400	310	GP-GM							65

Table 5-1
Hydraulic Conductivity and Grain Size Summary

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Boring[a]	Sample ID	Sample Depth (ft)	Blow Count	Relative Density Classification	Grain Size Analysis Results								Soil Type	Hazen			Prugh			Barr
					Gravel Content (%)	Sand Content (%)	Fines Content (%)	D10 (mm)	D20 (mm)	D50 (mm)	D60 (mm)	Cu		K D10 (m/s)	K D10 (cm/s)	K D10 (ft/day)	K D50 (m/s)	K D50 (cm/s)	K D50 (ft/day)	K (ft/day)
MW-174B	S-14	90' - 91.5'	32	D	33.0	60.1	6.9	0.120	0.250	2.040	3.350	28	SP-SM							54
MW-176A	S-1	15' - 16.5'	12	MD	61.0	36.0	3.0	0.180	0.390	7.830	11.380	63	GW							150
MW-176B	S-2	50' - 51.5'	13	MD	80.0	18.9	1.1	0.750	4.520	13.240	17.780	24	GP							1400
MW-176C	Sample	90' - 91.5'	33	D	45.0	51.0	4.0	0.190	0.270	3.250	6.500	34	SP							100
MW-177	S-14	90' - 91.5'	22	MD	14.0	80.2	5.8	0.110	0.340	0.280	0.330	3	GP	9.68E-05	9.68E-03	27	2.20E-04	2.20E-02	62	41
MW-178C	S-14	90' - 91.5'	43	D	57.0	40.3	2.7	0.210	0.170	6.770	10.590	50	GP							150
MW-179C	S-14	90' - 91.5'	28	MD	57.0	39.9	3.1	0.270	0.760	6.370	9.790	36	GW							210
MW-179D	S-4A	130'-131.1'	47	D	5.0	78.8	6.2	0.090	0.170	0.210	0.240	2.7	SP-SM				9.00E-05	9.00E-03	26	12
MW-181A	Sample	15' - 16.5'	14	MD	48.0	50.3	1.7	0.190	0.300	4.030	6.800	36	SP							170
MW-181B	Sample	50' - 51.5'	34	D	43.0	53.5	3.5	0.160	0.210	2.250	6.160	39	SP							91
MW-181C	S-10	150'-152'	32	D	38.0	57.6	4.4	0.170	0.290	1.590	4.030	24	SP							82
MW-182	S-1	15' - 16.5'	5	L	34.0	61.4	4.6	0.130	0.180	0.400	2.470	19	GP							38
MW-183	S-1	15' - 16.5'	6	L	18.0	76.4	5.6	0.100	0.160	0.280	0.340	3.4	SP-SM				2.20E-04	2.20E-02	62	23
MW-183B	S-4B	58'-59.5'	50 for 6"	VD	59.0	34.8	6.2	0.120	0.330	7.100	10.590	88	GW-GM							73
MW-184	S-1	44' - 44.5'	50/1"	D	26.0	68.4	5.6	0.140	0.210	0.350	0.410	2.9	SP-SM	1.57E-04	1.57E-02	44	1.60E-04	1.60E-02	45	32
MW-185A	S-1	15' - 16.5'	10	L	46.0	52.7	1.3	0.180	0.250	2.270	6.960	39	SP							150
MW-185B	S-1	50' - 51.5'	21	MD	47.0	50.0	3.0	0.170	0.240	3.450	6.460	38	SP							110
MW-185C	S-8	120'-122'	72	VD	28.0	67.3	4.7	0.150	0.200	0.370	0.680	4.5	SP	1.80E-04	1.80E-02	51	1.10E-04	1.10E-02	31	37
MW-186	B-1	10' - 11.5'	4	L	72.0	25.3	2.7	0.380	2.640	7.560	9.330	25	GP							350
MW-186	B-2	20' - 21.5'	5	L	74.0	24.1	1.9	0.240	2.680	10.800	13.620	57	GP							360
MW-186	B-3	30' - 31.5'	16	MD	57.0	38.6	4.4	0.160	0.280	6.470	9.990	62	GP							98
MW-186	B-4	40' - 41.5'	10	L	76.0	22.5	1.5	0.450	3.260	12.360	16.640	37	GP							700
MW-186	B-5	50' - 51.5'	23	MD	74.0	23.5	2.5	0.330	2.700	12.030	17.500	53	GP							360
MW-186	B-6	60' - 61.5'	59	D	51.0	44.8	4.2	0.160	0.240	4.920	7.650	48	GP							95
MW-186C	S-1	100' - 101.5'	41	D	53.0	42.2	4.8	0.200	0.730	5.440	8.080	40	GW							120
MW-186D	S-2	130'-131.5'	44	D	46.0	48.0	6.0	0.180	0.310	3.960	5.980	33	Sw-SM							79
MW-187	S-1	15' - 16.5'	29	MD	55.0	40.8	4.2	0.180	0.300	5.780	8.660	48	GP							110
MW-189A	S-1	15'-17'	21	MD	63.0	33.6	3.4	0.190	0.600	8.080	11.180	59	GP							160
MW-189B	S-12	60'-61.5'	44	D	46.0	50.1	3.9	0.170	0.270	2.960	6.540	38	SP							99
MW-190-150	S-11	80.0-81.5	39	D	42.6	47.9	9.5	0.080	0.190	2.290	6.030	75	SP-SM							38
MW-190-150	S-12	100.0-101.5	38	D	45.6	46.4	8.0	0.100	0.190	3.120	7.060	71	SP-SM							46
MW-190-150	S-13	115.0-116.5	64	VD	50.4	42.3	7.3	0.130	0.280	4.870	9.540	73	GP-GM							61
MW-190-150	S-14	130.0-131.5	33	D	48.2	44.4	7.4	0.130	0.380	4.230	6.720	52	GW-GM							64
MW-190-150	S-15	150.0-151.5	56	VD	35.1	60.3	4.6	0.110	0.280	0.730	2.460	22	SP-SM							53
MW-190A	S-1	14'-15.5'	11	MD	54.0	42.4	3.6	0.170	0.290	5.680	9.130	54	GP							120
MW-190B	S-10	60'-61.5'	21	MD	42.0	54.2	3.8	0.150	0.210	2.300	5.390	36	SP							84
MW-190BR	S-8R	40.0-41.5	19	MD	61.4	33.3	5.3	0.170	0.380	8.250	13.050	77	GP-GM							96
MW-190BR	S-10R	60.0-61.5	21	MD	9.4	78.4	12.2	0.050	0.130	0.330	0.400	8	SM				2.00E-05	2.00E-03	5.7	11
MW-191A	S-1	13'-15'	20	MD	59.0	36.3	4.7	0.160	0.290	6.900	10.160	64	GP							95
MW-191B	S-10	60'-61.5'	60	VD	56.0	38.6	5.4	0.150	0.300	6.040	8.870	59	GW-GM							84
MW-193A	S-8	15'-17'	2	VL	0.0	62.5	37.5	0.030	0.044	0.100	0.130	4.3	SM				2.00E-05	2.00E-03	5.7	2.4
MW-193B	S-10	58'-60'	50 for 6"	VD	5.0	90.5	4.5	0.160	0.220	0.330	0.380	2.4	SP	2.05E-04	2.05E-02	58	2.10E-04	2.10E-02	60	35
MW-194B	S-6	11'-13'	18	MD	51.0	43.4	5.6	0.150	0.310	4.910	7.290	49	GP-GM							81
MW-194B	S-8	30'-31.5'	19	MD	70.0	24.0	6.0	0.150	1.100	13.080	17.730	120	GP-GM							100
MW-195	S-8	14'-16'	17	MD	1.0	90.8	8.2	0.080	0.130	0.190	0.210	2.6	SP-SM				1.40E-04	1.40E-02	40	14
MW-195B	/-195B-150-150-	150'-151'	72	VD	46.0	47.1	6.9	0.130	0.310	3.740	6.070	47	SP-SM							64
MW-196	S-8	14'-16'	21	MD	51.0	45.1	3.9	0.150	0.230	5.070	9.520	63	GP							96
MW-197B	S-12	150'-152'	50-6"	VD	58.0	35.2	6.8	0.130	0.340	6.500	9.710	75	GW-GM							69
MW-198	S-8	150'-152'	34	D	27.0	67.9	5.1	0.160	0.250	0.560	0.820	5.1	SP-SM				1.60E-04	1.60E-02	45	47
MW-199	S-10-(PF-2)	150'-151.5'	37	D	46.0	47.2	6.8	0.130	0.290	3.400	6.390	49	SP-SM							63
MW-300	V-300-150-150-1	150'-150.5'	50-6"	VD	41.0	50.2	8.8	0.090	0.200	1.680	5.080	56	SP-SM							39
MW-302-110	S-7	110'-112'	39	D	43.0	47.1	9.9	0.080	0.270	2.580	5.390	67	SP-SM							41
MW-302-70	S-302-70-1	65'67'	33	D	60.0	32.8	7.2	0.130	0.280	8.360	13.010	100	GW-GM							64

Hydraulic Conductivity and Grain Size Summary

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Boring [a]	Sample ID	Sample Depth (ft)	Blow Count	Relative Density Classification	Grain Size Analysis Results								Soil Type	Hazen			Prugh			Barr
					Gravel Content (%)	Sand Content (%)	Fines Content (%)	D10 (mm)	D20 (mm)	D50 (mm)	D60 (mm)	Cu		K D10 (m/s)	K D10 (cm/s)	K D10 (ft/day)	K D50 (m/s)	K D50 (cm/s)	K D50 (ft/day)	K (ft/day)
MW-302-80	S-302-80-1	75'-77'	19	MD	62.0	32.0	6.0	0.140	0.270	9.390	13.880	99	SM							75
MW-303-130	S-9A	130'-131'	50 for 5"	VD	47.0	48.3	4.7	0.160	0.270	3.460	6.610	41	SP							88
MW-303-130	S-9B	131'-132'	50 for 5"	VD	36.0	50.0	14.0	0.040	0.180	0.840	3.290	82	SM							11
MW-303-70	S-1&2	65'-67'&70'-72'	20&16	MD	49.0	45.5	5.5	0.170	0.300	4.440	6.820	40	GP-GM							84
MW-303-80	S-303-80-1	75'-77'	57	VD	38.0	49.4	12.6	0.040	0.170	0.810	3.770	94	SM							12
MW-304-150	S-2	150'-152'	46	D	52.0	39.3	8.7	0.100	0.310	5.140	7.960	80	GW-GM							52
MW-304-70	S-1	65'-67'	48	D	58.0	35.3	6.7	0.150	0.340	6.820	10.630	71	GW-GM							73
MW-304-80	S-304-80-1	75'-77'	29	MD	56.0	37.6	6.4	0.150	0.300	6.420	10.220	68	GP							73
MW-305-80	MW-305-80-1	75'-77'	30	Md	55.0	37.6	7.4	0.120	0.320	5.950	9.580	80	GP							62
MW-305A	S-6	100'-102'	39	D	44.0	51.7	4.3	0.150	0.240	3.020	5.820	39	SP							85
MW-306-70	S-306-70-1	65'-67'	21	MD	49.0	45.7	5.3	0.160	0.410	4.500	6.300	39	GW-GM							92
MW-306-70	S-14	70'-72'	66	VD	30.0	64.4	5.6	0.130	0.190	0.390	0.920	7.1	SP-SM				2.00E-05	2.00E-03	5.7	34
MW-306-80	S-306-80-1	75'-77'	32	D	66.0	28.0	6.0	0.150	0.370	10.280	14.180	95	SM							83
MW-306A	S-150	150'-152'	61	VD	45.0	49.9	5.1	0.160	0.290	3.090	5.750	36	SP-SM							83
MW-307	S-9	110.0'-111.5'	35	D	47.0	45.0	8.0	0.110	0.280	3.820	5.960	54	GP-GM							54
MW-332-110	S-10N	80.0-81.5	23	MD	54.1	40.2	5.7	0.160	0.310	5.590	8.310	52	GP-GM							82
MW-332-110	S-12N	110.0-111.5	22	MD	47.0	47.4	5.6	0.160	0.310	4.030	6.140	38	SP-SM							81
MW-332-41	S-8N	40.0-41.5	67	VD	65.7	30.5	3.5	0.200	0.550	9.380	12.560	63	GP							150
MW-332-75	S-9N	60.0-61.5	25	MD	62.9	32.4	4.7	0.220	0.850	9.370	14.450	66	GW							140
MW-332-75	S-10N	75.3-76.5	30	MD	2.4	90.6	7.0	0.090	0.140	0.200	0.220	2.4	SP-SM				1.30E-04	1.30E-02	37	16
MW-334-85	S-2	6.5-8.0	12	MD	0.4	29.4	69.4	0.010	0.020	0.050	0.060	6	ML							0.42
MW-334-85	S-4	75.0-76.5	32	D	58.0	37.0	5.0	0.170	0.300	7.260	11.370	67	GP							94
MW-334-85	S-5	82.5-84.0	54	VD	30.2	64.3	55.0	0.150	0.220	0.560	1.840	12	GP-GM							44
MW-336-15	S-2	2.5-4.0	29	MD	53.7	38.5	7.8	0.100	0.250	5.530	8.360	84	GP-GM							54
MW-336-15	S-5	10.0-11.5	16	MD	49.1	46.4	4.5	0.160	0.240	4.260	7.470	47	GP							90
MW-336-20	S-7	12.5-14.0	13	MD	55.8	41.2	3.0	0.220	0.340	6.210	9.740	44	GP							160
MW-336-20	S-9	17.5-19.0	14	MD	62.7	32.6	4.7	0.160	0.290	8.610	14.420	90	GW							96
MW-336-35	S-1	32.0-33.5	35	D	64.7	30.8	4.5	0.190	0.600	8.780	12.310	65	GP							130
MW-336-55	S-14 Top	30.0-30.9	21	MD	51.8	41.3	6.9	0.180	0.410	16.540	21.770	120	GP							77
MW-336-55	S-14 Bottom	30.9-31.5	21	MD	51.8	41.3	6.9	0.110	0.210	5.290	9.720	88	GP-GM							57
MW-336-55	S-15	40.0-41.5	31	D	58.7	36.5	4.8	0.170	0.370	6.580	9.550	56	GW							100
MW-336-55	S-16	50.0-51.5	6	L	54.9	42.5	2.6	0.180	0.270	5.720	8.350	46	GP							140
MW-336-55	S-17	51.5-53.0	21	MD	65.9	30.7	3.4	0.220	0.860	7.940	10.690	49	GP							180
MW-337-20	S-3	7.5-9.5	29	MD	53.9	41.7	4.4	0.180	0.330	5.520	8.050	45	GP							110
MW-337-20	S-5	12.5-14.5	13	MD	53.2	42.8	4.0	0.150	0.250	5.390	7.980	53	GP							97
MW-337-20	S-7	17.5-19.5	24	MD	71.0	24.4	4.6	0.160	0.510	12.690	16.780	100	GP							120
MW-338-15	HS-1	2.5-4.0	40	D	0.0	41.6	58.4	0.020	0.041	0.070	0.080	4	ML							1.3
MW-338-15	HS-2	5.0-6.5	50 (6)	D	37.5	44.6	17.9	0.050	0.080	0.230	3.290	66	SM							8.8
MW-338-15	HS-3	7.5-9.0	42	D	68.1	28.0	3.9	0.210	1.000	11.120	16.250	77	GP							170
MW-338-15	HS-5	12.5-14.0	20	MD	39.1	58.0	2.9	0.180	0.280	6.740	9.310	52	SP							130
MW-338-15	HS-6	14.5-16.0	18	MD	55.8	41.5	2.7	0.180	0.260	5.660	7.660	43	GP							140
MW-338-50	S-7	20.0-21.5	11	MD	71.3	26.5	2.2	0.250	1.600	12.020	17.050	68	GP							310
MW-338-50	S-8	25.0-26.5	11	MD	41.0	54.9	4.1	0.140	0.200	0.920	4.950	35	SP							61
MW-338-50	S-9	30.0-31.5	25	MD	60.7	36.4	2.9	0.210	0.390	7.010	10.000	48	GW							160
MW-338-50	S-10	50.0-51.5	80	VD	57.6	36.8	5.6	0.150	0.300	7.280	11.710	78	GP-GM							82
MW-339-15	S-6N	15.0-16.5	17	MD	58.1	38.3	3.6	0.180	0.320	6.760	10.290	57	GP							120
MW-339-50	S-3	7.5-9.0	18	MD	50.4	38.5	11.1	0.060	0.180	4.820	6.960	120	GP-GM							27
MW-339-50	S-5	12.5-14.0	24	MD	38.9	57.3	3.8	0.120	0.180	0.520	3.910	33	SP							46
MW-339-50	S-7	20.0-21.5	14	MD	50.4	46.5	3.1	0.170	0.280	4.810	6.810	40	GP							120
MW-339-50	S-8	25.0-26.5	22	MD	59.0	37.4	3.6	0.190	0.310	7.290	10.720	56	GP							130
MW-339-50	S-12	55.0-56.0	50 (4")	D	66.2	29.9	3.9	0.240	1.100	8.690	11.670	49	GP							180
MW-340-150	S-5	12.5-14.0	11	MD	47.3	49.5	3.2	0.320	1.000	4.270	5.680	18	SW							220
MW-340-150	S-10	35.0-36.5	29	MD	57.9	38.0	4.1	0.180	0.390	6.520	9.690	54	GW							120

Table 5-1
Hydraulic Conductivity and Grain Size Summary

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Boring [a]	Sample ID	Sample Depth (ft)	Blow Count	Relative Density Classification	Grain Size Analysis Results								Soil Type	Hazen			Prugh			Barr
					Gravel Content (%)	Sand Content (%)	Fines Content (%)	D10 (mm)	D20 (mm)	D50 (mm)	D60 (mm)	Cu		K D10 (m/s)	K D10 (cm/s)	K D10 (ft/day)	K D50 (m/s)	K D50 (cm/s)	K D50 (ft/day)	K (ft/day)
MW-340-150	S-14	90.0-91.5	21	MD	57.3	36.7	6.0	0.170	0.650	6.770	11.580	68	GW							95
MW-340-150	S-16	130.0-131.5	45	D	49.2	44.0	6.8	0.150	0.380	4.530	6.720	45	GW-GM							72
MW-340-150	S-17	150.0-151.5	36	D	49.2	44.3	6.5	0.160	0.500	4.560	6.610	41	GW							81
MW-340-65	S-12N	65.0-66.5	17	MD	43.4	51.8	4.8	0.150	0.230	2.600	5.710	38	SP							77
MW-341-40	S-1	3.0-4.0	31	D	0.0	56.4	43.6	0.020	0.039	0.080	0.100	5	SM							1.4
MW-341-40	S-2	5.0-6.5	50 (5")	MD	0.0	55.4	44.6	0.010	0.018	0.090	0.120	12	SM							0.57
MW-341-40	S-4	10.0-11.5	13	MD	57.7	38.9	3.4	0.230	0.360	6.440	9.540	41	GP							150
MW-341-40	S-8	30.0-31.5	19	MD	56.8	39.6	3.6	0.180	0.310	6.100	8.820	49	GP							120
MW-341-40	S-9	43.0-43.8	36-50 (3")	D	72.8	22.2	5.0	0.210	1.700	16.090	24.730	120	GP							150
MW-343-50	S-1	2.5-4.0	4	VL	0.0	26.3	73.7	NM	0.005	0.030	0.040	NM	ML							0.1
MW-343-50	S-2	5.0-6.5	10	L	62.3	33.2	4.5	0.170	0.380	8.090	11.930	70	GW							110
MW-343-50	S-4	10.0-11.5	13	MD	56.6	39.9	3.5	0.160	0.250	6.730	11.240	70	GP							110
MW-343-50	S-6	20.0-21.5	24	MD	62.4	34.2	3.4	0.200	0.450	8.490	11.710	59	GW							150
MW-343-50	S-8	30.0-31.5	12	MD	62.4	34.2	3.4	0.270	0.450	7.630	10.360	38	GW							170
MW-344-55	S-1N	17.0-19.0	10	MD	60.2	36.6	3.2	0.170	0.340	7.510	10.960	64	GW							130
MW-344-55	S-2N	22.0-24.0	14	MD	37.6	57.5	4.9	0.140	0.190	0.400	3.060	22	SP							40
MW-344-55	S-3N	27.0-29.0	35	D	49.6	43.7	6.7	0.120	0.230	4.560	7.260	61	GP-GM							61
MW-344-55	S-5N	45.0-47.0	29	MD	68.6	27.7	3.7	0.230	1.210	11.160	15.740	68	GP							190
MW-344-55	S-6N	53.0-55.0	28	MD	63.2	33.3	3.5	0.190	0.440	9.100	13.590	72	GW							140
MW-344-75	S-1	6.0-8.0	29	MD	62.6	31.0	6.4	0.140	0.280	5.210	7.470	53	GP-GM							71
MW-344-75	S-3	20.0-22.0	17	MD	62.0	34.0	4.0	0.150	0.280	8.410	13.290	89	GP							100
MW-344-75	S-5	30.0-32.0	49	D	46.8	49.3	3.9	0.160	0.230	1.910	6.740	42	SP							85
MW-344-75	S-8	60.0-62.0	46	D	52.9	41.6	5.5	0.130	0.220	5.750	10.780	83	GP-GM							72
MW-344-75	S-9	70.0-72.0	64	VD	55.5	38.5	6.0	0.160	0.370	6.420	10.730	67	GW-GM							83
MW-345-15	S-1	7.5-9.0	8	L	69.2	27.9	2.9	0.220	0.650	10.700	15.020	68	GP							200
MW-345-15	S-2	10.0-11.5	16	MD	55.5	38.5	6.0	0.110	0.210	7.030	12.350	110	GP-GM							63
MW-345-15	S-3	12.5-13.5	24	MD	2.7	79.8	17.5	0.040	0.080	0.160	0.180	4.5	SM				2.80E-05	2.80E-03	7.9	5.2
MW-345-15	S-5	15.0-16.5	25	MD	60.5	36.1	3.4	0.170	0.300	8.570	13.150	77	GP							120
MW-345-55	S-3	20.0-21.5	13	MD	35.5	60.6	3.9	0.160	0.200	0.380	1.340	8.4	SP				1.90E-05	1.90E-03	5.4	44
MW-345-55	S-5	30.0-31.5	17	MD	61.0	35.7	3.3	0.220	0.570	7.100	10.170	46	GW							170
MW-345-55	S-6	40.0-41.5	13	MD	64.5	32.1	3.4	0.190	0.370	8.820	11.830	62	GW							140
MW-345-55	S-7B	50.7-51.5	29	MD	0.3	88.7	11.0	0.060	0.100	0.170	0.190	3.2	SP-SM				6.80E-05	6.80E-03	19	8.8
MW-345-55	S-8	52.5-54.0	26	MD	26.4	67.9	5.7	0.100	0.160	0.260	0.350	3.5	SP-SM				1.40E-05	1.40E-03	4	23
MW-345-75	S-1	60.0-61.5	27	MD	63.4	30.3	6.3	0.120	0.350	8.420	11.980	100	GP-GM							74
MW-345-75	S-2	70.0-71.5	22	MD	58.2	36.8	5.1	0.170	0.680	6.460	9.380	55	GP-GM							110
MW-345-75	S-3	72.5-74.0	25	MD	50.5	44.5	5.0	0.180	0.350	4.840	7.150	40	GP							97
MW-346-150	S-2	5.0-6.5	3	VL	41.3	51.6	7.1	0.100	0.230	2.260	5.050	51	SP-SM							51
MW-346-150	S-5	15.0-16.5	14	MD	43.2	52.6	4.2	0.180	0.280	2.450	5.370	30	SP							95
MW-346-150	S-9	50.0-51.5	57	VD	51.3	45.0	3.7	0.019	0.310	4.980	7.180	380	GP							6.6
MW-346-150	S-12	110.0-111.5	27	MD	57.3	39.2	3.5	0.260	0.500	6.960	11.370	44	GP							170
MW-346-150	S-14	145.0-146.5	58	VD	48.9	42.5	8.6	0.100	0.280	4.270	7.280	73	GP-GM							51
MW-346-65	S-1	10.0-11.5	10	MD	49.4	47.9	2.7	0.180	0.290	4.510	6.350	35	GP							140
MW-346-65	S-1	10.0-11.5	10	MD	49.4	47.9	2.7	0.180	0.290	4.510	6.350	35	GP							140
MW-346-65	S-2	30.0-31.5	17	MD	17.5	78.1	4.4	0.130	0.190	0.330	0.380	2.9	SP	1.69E-04	1.69E-02	48	2.20E-04	2.20E-02	62	32
MW-346-65	S-2	30.0-31.5	17	MD	17.5	78.1	4.4	0.130	0.190	0.330	0.380	2.9	SP	1.69E-04	1.69E-02	48	2.80E-04	2.80E-02	79	32
MW-346-65	S-3	62.5-64.0	35	D	43.2	51.4	5.4	0.150	0.260	2.600	5.500	37	SP-SM							73
MW-346-65	S-3	62.5-64.0	35	D	43.2	51.4	5.4	0.150	0.260	2.600	5.500	37	SP-SM							73
MW-347-150	S-2	5.0-6.5	7	L	14.1	19.5	66.4	0.010	0.021	0.050	0.070	7	ML							0.45
MW-347-150	S-5	15.0-16.5	9	L	0.0	84.4	15.6	0.050	0.085	0.170	0.190	3.8	SM				6.60E-05	6.60E-03	19	6.8
MW-347-150	S-9	50.0-51.5	55	VD	0.0	88.5	11.5	0.060	0.090	0.150	0.170	2.8	SM				6.00E-05	6.00E-03	17	7.9
MW-347-150	S-12	110.0-111.5	53	VD	39.1	53.3	7.6	0.100	0.200	2.240	4.460	45	SP-SM							46
MW-347-150	S-14	147.5-148.8	77 (9")	VD	53.5	40.6	5.9	0.170	0.450	5.280	7.110	42	GW-GM							88
MW-347-20	S-1	12.0-14.0	3	VL	0.2	61.9	37.9	0.020	0.040	0.090	0.100	5	SM							1.5

Table 5-1
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Flint Hills Resources Alaska, LLC

Boring [a]	Sample ID	Sample Depth (ft)	Blow Count	Relative Density Classification	Grain Size Analysis Results								Soil Type	Hazen			Prugh			Barr
					Gravel Content (%)	Sand Content (%)	Fines Content (%)	D10 (mm)	D20 (mm)	D50 (mm)	D60 (mm)	Cu		K D10 (m/s)	K D10 (cm/s)	K D10 (ft/day)	K D50 (m/s)	K D50 (cm/s)	K D50 (ft/day)	K (ft/day)
MW-347-65	S-1	35.0-37.0	16	MD	43.6	44.4	12.0	0.050	0.120	2.530	6.380	130	SM							18
MW-347-65	S-2	61.0-63.0	29	MD	55.0	37.7	7.3	0.120	0.330	6.020	9.660	81	GW-GM							63
MW-348-15	S-1&2	6.0-14.0	25, 26	MD	61.4	32.6	6.0	0.150	0.350	7.660	10.750	72	GW-GM							81
MW-348-65	S-1	2.5-4.0	29	MD	57.6	37.9	4.5	0.190	0.350	6.080	8.430	44	GW							110
MW-348-65	S-2	5.0-6.5	29	MD	56.8	36.0	7.2	0.120	0.280	6.320	9.580	80	GP-GM							62
MW-348-65	S-5	15.0-16.5	18	MD	64.3	33.3	2.4	0.180	0.400	8.180	11.070	62	GP							170
MW-348-65	S-6	20.0-21.5	28	MD	62.0	33.6	4.4	0.150	0.340	7.700	10.630	71	GP							100
MW-348-65	S-9	35.0-36.5	27	MD	66.0	31.8	2.2	0.270	0.850	9.050	12.570	47	GP							280
MW-348-65	S-10	50.0-51.5	36	D	61.5	34.5	4.0	0.190	0.400	7.660	10.970	58	GW							130
MW-348-65	S-11	62.5-64.0	31	D	73.1	24.2	2.7	0.240	1.700	18.610	37.850	160	GP							270
MW-349-15	S-4N	12.5-14.0	8	L	58.2	36.8	5.0	0.170	0.340	6.950	11.260	66	GP							97
MW-349-45	S-2	5.0-6.5	5	L	0.0	26.8	73.2	0.010	0.020	0.050	0.060	6	ML							0.41
MW-349-45	S-3	7.5-9.0	21	MD	63.5	28.8	7.7	0.110	0.580	8.760	12.680	120	GP-GM							69
MW-349-45	S-4	10.0-11.5	11	MD	63.0	33.8	3.2	0.250	0.430	8.060	11.810	47	GW							170
MW-349-45	S-6	20.0-21.5	20	MD	60.2	35.0	4.8	0.180	0.370	6.800	9.670	54	GW							100
MW-349-45	S-7	25.0-26.5	12	MD	59.9	35.8	4.3	0.190	0.390	6.910	9.950	52	GW							120
MW-349-45	S-9	50.0-51.0	86 for 12"	VD	62.0	32.3	5.7	0.170	0.590	6.890	9.390	55	GP-GM							98
MW-350-15	S-1	9.0-10.5	25	MD	50.5	42.1	7.4	0.120	0.300	4.840	6.930	58	GW-GM							61
MW-350-50	S-3	7.5-9.0	13	MD	19.0	60.0	21.0	0.040	0.065	0.160	0.210	5.3	SM				2.00E-05	2.00E-03	5.7	4.9
MW-350-50	S-5	12.5-14.0	21	MD	52.2	43.2	4.6	0.160	0.280	5.290	8.700	54	GP							94
MW-350-50	S-9	25.0-26.5	24	MD	54.7	40.6	4.7	0.160	0.260	5.970	9.670	60	GP							91
MW-350-50	S-10	30.0-31.5	13	MD	58.6	36.8	4.6	0.160	0.300	7.050	11.320	71	GP							97
MW-350-50	S-11	50.0-51.5	50 (6")	D	51.4	41.4	7.5	0.090	0.180	5.260	11.340	130	GP-GM							50
MW-351-150	S-2	60.0-61.5	34	D	66.9	29.5	3.6	0.230	0.920	10.640	16.640	72	GP							180
MW-351-150	S-5	90.0-91.5	26	MD	57.9	37.8	4.3	0.220	0.560	6.640	10.060	46	GW							130
MW-351-150	S-8A	120.0-120.9	32	D	1.3	94.4	4.3	0.120	0.170	0.260	0.300	2.5	SP	1.44E-04	1.44E-02	41	1.50E-04	1.50E-02	43	25
MW-351-150	S-8B	120.9-121.5	32	D	48.4	44.1	7.5	0.130	0.400	4.290	6.330	49	GW-GM							64
MW-351-150	S-9	130.0-131.5	58	VD	49.8	43.7	6.5	0.150	0.320	4.690	7.200	48	GP-GM							72
MW-351-150	S-11	150.0-151.5	43	D	59.2	35.4	5.4	0.190	0.750	6.900	10.180	54	GW-GM							110
MW-351-55	S-2	52.5-54.0	31	D	66.9	29.5	3.6	0.230	0.920	1064.000	16.610	72	GP							180
MW-351-75	S-3	12.5-14.5	13	MD	16.4	80.9	2.7	0.160	0.200	0.320	0.350	2.2	SP	2.82E-04	2.82E-02	80	4.00E-04	4.00E-02	110	40
MW-351-75	S-6	25.0-27.0	21	MD	62.6	33.6	3.8	0.170	0.300	8.800	13.310	78	GW							120
MW-351-75	S-8	40.0-42.0	39	D	50.0	44.2	5.8	0.160	0.280	4.760	7.980	50	GP-GM							79
MW-351-75	S-9	50.0-52.0	48	D	55.5	39.8	4.7	0.180	0.330	6.180	9.880	55	GP							100
MW-351-75	S-11	71.0-73.0	29	MD	56.6	38.3	5.1	0.180	0.460	6.280	9.570	53	GW-GM							100
MW-352-40	S-3	7.5-9.0	13	MD	47.2	45.6	7.2	0.100	0.180	3.730	6.430	64	GP-GM							50
MW-352-40	S-4&5	10.4-13.6	8, 9	L	7.4	87.7	4.9	0.110	0.160	0.220	0.250	2.3	SP	1.21E-04	1.21E-02	34	2.30E-04	2.30E-02	65	21
MW-352-40	S-8	25.0-26.5	13	MD	69.6	28.0	2.4	0.200	0.410	11.410	16.140	81	GP							190
MW-352-40	S-9	30.0-31.5	15	MD	63.5	33.3	3.2	0.200	0.410	7.600	10.540	53	GP							150
MW-352-40	S-10	42.5-44.0	50 (5")	D	83.4	14.4	2.2	1.320	5.960	32.350	38.430	29	GW							880
MW-353-100	S-4&5	10.5-14.0	18, 16	MD	57.5	38.0	4.5	0.170	0.320	6.630	10.290	61	GP							100
MW-353-100	S-6&7	15.0-21.5	16	MD	58.6	37.7	3.7	0.180	0.320	7.300	11.290	63	GP							120
MW-353-100	S-9	30.0-31.5	16	MD	56.6	39.6	3.8	0.230	0.390	5.870	8.120	35	GP							140
MW-353-100	S-12	90.0-91.5	42	D	49.0	45.1	5.9	0.160	0.330	4.400	6.960	44	GP-GM							80
MW-353-100	S-13	110.0-111.5	50 (6")	VD	56.5	37.2	6.3	0.140	0.440	6.240	9.510	68	GW-GM							80
MW-353-15	S-1	10.0-11.5	13	MD	57.3	37.3	5.4	0.150	0.230	6.530	9.860	66	GP-GM							78
MW-353-65	S-1	35.0-36.5	24	MD	66.4	30.4	3.2	0.240	0.590	9.850	14.040	59	GP							190
MW-353-65	S-2	62.0-63.5	32	D	59.7	34.9	5.4	0.160	0.320	7.600	11.250	70	GP							88
MW-354-15	S-2a	7.0-7.7	7	MD	49.6	44.8	5.6	0.120	0.210	4.530	6.210	52	GP-GM							67
MW-354-15	S-2-b	7.7-9.0	7	MD	6.2	84.1	7.7	0.080	0.100	0.180	0.200	2.5	SP-SM				1.10E-04	1.10E-02	31	11
MW-354-15	S-3	9.0-11.0	17	MD	69.8	26.9	3.3	0.170	0.640	10.460	13.770	81	GP							160
MW-354-15	S-4	11.0-13.0	18	MD	59.8	34.8	5.4	0.160	0.390	7.170	10.780	67	GW-GM							92
MW-354-35	S-1	7.5-9.0	13	MD	46.8	48.9	4.3	0.160	0.250	3.250	6.440	40	SP							90

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Boring[a]	Sample ID	Sample Depth (ft)	Blow Count	Relative Density Classification	Grain Size Analysis Results								Soil Type	Hazen			Prugh			Barr
					Gravel Content (%)	Sand Content (%)	Fines Content (%)	D10 (mm)	D20 (mm)	D50 (mm)	D60 (mm)	Cu		K D10 (m/s)	K D10 (cm/s)	K D10 (ft/day)	K D50 (m/s)	K D50 (cm/s)	K D50 (ft/day)	K (ft/day)
MW-354-35	S-2	10.0-11.5	15	MD	77.5	20.6	1.9	0.290	3.640	15.850	20.230	70	GP							440
MW-354-60	S-6	12.5-14.0	20	MD	53.5	42.3	4.2	0.170	0.290	5.530	8.550	50	GP							100
MW-354-60	S-9	24.0-25.5	18	MD	56.2	39.6	4.2	0.160	0.250	6.250	9.680	61	GP							98
MW-354-60	S-10	30.5-32.0	32	D	69.0	27.1	3.9	0.190	1.110	11.410	15.530	82	GP							160
MW-354-60	S-11	42.0-43.5	21	MD	59.8	36.5	3.7	0.190	0.480	7.150	11.140	59	GW							140
MW-354-60	S-13	62.3-63.5	30	D	67.3	28.2	4.5	0.170	0.810	9.300	13.310	78	GP							130
MW-355-15	S-1	7.0-8.5	15	MD	55.4	37.9	6.7	0.130	0.290	5.840	8.550	66	GP-GM							67
MW-355-15	S-2	15.0-16.5	5	L	35.1	55.6	9.3	0.080	0.130	0.330	1.050	13	SP-SM							19
MW-355-55	S-5	10.0-11.5	4	L	49.3	44.5	6.2	0.120	0.220	4.430	6.480	54	GP-GM							63
MW-355-55	S-6	12.5-14.0	5	L	12.5	80.6	6.9	0.090	0.140	0.220	0.260	2.9	SP-SM				1.90E-04	1.90E-02	54	17
MW-355-55	S-9	25.0-26.5	8	L	20.2	70.6	9.2	0.080	0.120	0.230	0.280	3.5	SP-SM				1.30E-04	1.30E-02	37	15
MW-355-55	S-11	40.0-41.5	26	MD	59.5	36.7	3.8	0.200	0.350	6.900	9.990	50	GP							130
MW-355-55	S-13	55.0-56.5	24	MD	49.1	46.8	4.1	0.160	0.240	4.280	7.290	46	GP							96
MW-356-15	S-1	12.5-14.0	6	L	52.0	45.7	2.3	0.240	0.350	5.060	6.870	29	GP							190
MW-356-90	S-3	7.5-9.0	16	MD	5.4	89.4	5.2	0.120	0.170	0.270	0.300	2.5	SP-SM	1.15E-04	1.15E-02	33	2.20E-04	2.20E-02	62	24
MW-356-90	S-4	10.0-11.5	9	L	58.5	38.3	3.2	0.220	0.370	6.820	10.200	46	GP							150
MW-356-90	S-7	20.0-21.5	17	MD	63.5	33.0	3.5	0.200	0.400	9.130	13.330	67	GW							140
MW-356-90	S-9	30.0-31.5	19	MD	61.5	34.4	4.1	0.210	0.420	8.410	12.340	59	GW							130
MW-356-90	S-15	90.0-91.5	74	VD	50.9	42.4	6.7	0.150	0.400	4.910	7.100	47	GW-GM							74
MW-357-15	S-4	10-10.5	5	L	9.0	61.0	30.0	0.020	0.040	0.140	0.180	9	SM							1.8
MW-357-15	S-6	15.0-16.5	14	MD	48.9	47.2	3.9	0.180	0.280	4.220	7.080	39	GP							110
MW-357-150	S-8	25.0-26.5	17	MD	57.6	37.1	5.3	0.160	0.330	6.550	9.990	62	GP-GM							89
MW-357-150	S-13	90.0-91.5	24	MD	55.2	39.7	5.1	0.170	0.320	6.060	9.690	57	GP-GM							93
MW-357-150	S-14	110.0-111.5	33	D	52.7	38.6	8.7	0.100	0.320	5.530	9.720	97	GP-GM							53
MW-357-150	S-15	130.0-131.5	77 (12")	VD	19.1	76.4	4.5	0.170	0.250	0.410	0.550	3.2	SP	2.89E-04	2.89E-02	82	2.20E-04	2.20E-02	62	43
MW-357-150	S-16	147.5-149.0	36	D	41.1	52.2	6.7	0.090	0.160	1.300	5.120	57	SP-SM							41
MW-357-65	S-11	62.5-64.0	24	MD	67.6	29.1	3.3	0.210	0.790	10.020	13.970	67	GP							180
O-1	S-5	15' - 16.5'	46	D	61.0	33.8	5.2	0.160	0.310	8.630	12.670	79	GW-GM							90
O-11	S-8	14'-16'	13	MD	61.0	36.4	2.6	0.200	0.390	7.670	11.080	55	GW							170
O-12-65	S-3	7.5-9.5	8	L	5.6	69.1	25.3	0.030	0.058	0.120	0.140	4.7	SM				2.00E-05	2.00E-03	5.7	3
O-12-65	S-6	15.5-16.5	11	MD	24.4	72.9	2.7	0.160	0.220	0.340	0.380	2.4	SP	2.82E-04	2.82E-02	80	4.00E-04	4.00E-02	110	44
O-12-65	S-8	25.0-26.5	45	D	70.9	25.8	3.3	0.230	0.800	14.210	18.700	81	GP							200
O-12-65	S-10	40.0-41.5	22	MD	59.1	37.6	3.3	0.180	0.310	6.850	10.220	57	GP							130
O-12-65	S-12	62.5-64.0	56	VD	62.7	33.5	3.8	0.180	0.440	10.060	15.830	88	GW							130
O-13	PO-7	12'-15.2'	33	D	66.0	27.4	6.6	0.110	0.320	9.510	12.810	120	GP-GM							68
O-14	PO-11-12	10'-14'	28	MD	57.0	38.1	4.9	0.150	0.260	6.190	8.920	59	GP							87
O-15	PO-14	10'-14'	18	MD	66.0	32.2	1.8	0.210	0.600	9.950	14.040	67	GP							250
O-16	S-6	10'-14'	21	MD	56.0	40.0	4.0	0.160	0.280	6.480	10.090	63	GP							100
O-17	S-8	14'-16'	15	MD	48.0	48.7	3.3	0.170	0.290	4.130	6.230	37	GP							120
O-18	S-7	14'-15'	31	D	50.0	44.2	5.8	0.110	0.200	4.500	7.620	69	GP-GM							62
O-2	S-5	15' - 16.5'	7	L	62.0	34.3	3.7	0.180	0.340	6.920	9.560	53	GW							120
O-20	S-8	14'-16'	28	MD	52.0	40.2	7.8	0.100	0.240	3.950	6.500	65	GP-GM							52
O-21	S-8	14'-16'	30	D	59.0	33.7	7.3	0.090	0.180	3.530	8.170	91	GP-GM							48
O-24-65	S-6	12.5-14.0	9	L	53.0	37.2	9.8	0.080	0.200	5.440	8.570	110	GW-GM							41
O-24-65	S-7	15.0-16.5	10	L	61.6	29.3	9.1	0.080	0.220	7.820	10.950	140	GP-GM							45
O-24-65	S-10	30.0-31.5	25	MD	70.2	26.5	3.3	0.180	0.600	11.700	18.890	100	GP							160
O-24-65	S-11	50.0-51.5	35	D	62.3	33.9	3.8	0.220	0.540	8.440	12.720	58	GW							150
O-24-65	S-12	62.0-63.5	27	MD	71.0	26.1	2.9	0.210	1.000	9.510	12.160	58	GP							210
O-26-65	S-5	10.0-11.5	5	L	0.2	91.8	8.0	0.080	0.110	0.190	0.210	2.6	SP-SM				2.00E-04	2.00E-02	57	13
O-26-65	S-6	12.5-14.0	13	MD	52.0	44.5	3.5	0.160	0.260	5.180	7.990	50	GP							110
O-26-65	S-9	25.0-26.5	5	L	50.4	47.6	2.0	0.200	0.300	4.840	7.700	39	GP							170
O-26-65	S-10	30.0-31.5	2	VL	18.6	77.0	4.4	0.150	0.210	0.330	0.380	2.5	SP	2.48E-04	2.48E-02	70	4.00E-04	4.00E-02	110	35
O-26-65	S-12	62.5-64.0	15	MD	54.3	42.4	3.3	0.270	0.550	5.400	7.300	27	GW							180

Table 5-1
Hydraulic Conductivity and Grain Size Summary

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Boring [a]	Sample ID	Sample Depth (ft)	Blow Count	Relative Density Classification	Grain Size Analysis Results									Soil Type	Hazen			Prugh			Barr
					Gravel Content (%)	Sand Content (%)	Fines Content (%)	D10 (mm)	D20 (mm)	D50 (mm)	D60 (mm)	Cu			K D10 (m/s)	K D10 (cm/s)	K D10 (ft/day)	K D50 (m/s)	K D50 (cm/s)	K D50 (ft/day)	K (ft/day)
O-3	S-5	15' - 16.5'	4	L	0.0	55.1	44.9	0.030	0.040	0.080	0.100	3.3		SM				2.30E-05	2.30E-03	6.5	2.1
O-4	S-5	15' - 16.5'	19	MD	28.0	69.3	2.7	0.150	0.200	0.360	0.420	2.8		SP	2.25E-04	2.25E-02	64	4.20E-04	4.20E-02	120	43
S-41R	S-2	2.5-4.0	5	L	0.3	41.3	58.4	0.010	0.020	0.060	0.080	8		ML							0.51
S-41R	S-4	7.5-9.0	19	MD	59.6	35.2	5.2	0.160	0.340	7.470	11.510	72		GW-GM							92
S-41R	S-5	10.0-11.5	15	MD	58.4	36.7	4.9	0.180	0.340	6.41	9.810	55		GW							100
S-41R	S-6	12.5-14.0	19	MD	55.9	38.2	5.9	0.160	0.340	6.390	10.360	65		GW-GM							82
S-41R	S-7	15.0-16.5	9	L	63.4	34.3	2.3	0.230	0.360	8.650	12.610	55		GW							200

Footnotes:
a. Well names in ***bold italics*** are located offsite, others are onsite.

Acronyms and Abbreviations:
L = loose
MD = medium dense
D = dense
VD = very dense

Table 5-2
Summary of Hydraulic Conductivity Values from Grain Size Analyses

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Hydraulic Conductivity Range [a]	Number of Samples	Percentage of Samples
0.1 to 0.99 ft/day (-1 to 0)	7	2.20%
1.0 to 9.9 ft/day (0 to 1)	17	5.20%
10 to 99 ft/day (1 to 2)	222	68.50%
100 to 999 ft/day (2 to 3)	75	23.10%
1,000 to 9,999 ft/day (3 to 4)	2	0.60%
>10,000 ft/day (> 4)	1	0.30%

Footnotes:
a. Log base 10 of range indicated in parentheses.

Table 5-3

Ranges of Hydraulic Conductivity based on Barr (2001) and Specific Yield as a Function of Hydraulic Conductivity based on USBR (1993) for the Various Soil Types Identified by the Grain Size Analyses

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Soil Classification		Number of Samples	Hydraulic Conductivity (ft/day)		Specific Yield (fraction by volume)	
Group Symbol	Group Name		Maximum	Minimum	Maximum	Minimum
GP	Poorly graded gravel	102	1400	6.6	0.33	0.16
GW	Well-graded gravel	40	880	81	0.33	0.28
GP-GM	Poorly graded to silty gravel	45	110	27	0.3	0.23
GW-GM	Well graded to silty gravel	30	120	41	0.3	0.25
GM	Silty gravel	1	1.2	1.2	0.077	0.077
SP	Poorly graded sand	38	1800	21	0.32	50.9
SW	Well-graded sand	1	220	220	0.34	0.34
SP-SM	Poorly graded to silty sand	40	83	8.8	0.28	0.17
SW-SM	Well graded to silty sand	1	79	79	0.28	0.28
SM	Silty sand	19	83	0.57	0.28	0.043
ML	Silt	8	1.3	0.088	0.081	0.03

Table 5-4
Summary of Aquifer Parameter Estimates from the 2011 Recovery Well Pumping Test

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Observation Wells	Parameter				
	T	S	Sy	Kz/Kr	Kx
	(m^2/day)	(unit less)	(unit less)	(unit less)	(m/day)
Recovery and Pumping Phases:					
MW-186A, MW-186B MW-186C	1.86E+04	1.53E-05	0.029	0.062	410
Other observation wells combined with MW-186b and MW-186c:					
MW-111, MW-186B, MW-186C	2.04E+04	1.53E-05	0.024	0.04	450
MW-113, MW-186B, MW-186C	2.00E+04	1.50E-05	0.016	0.011	440
MW-125, MW-186B, MW-186C	1.88E+04	1.50E-05	0.022	0.014	410
MW-130, MW-186B, MW-186C	1.94E+04	1.50E-05	0.022	0.023	420
MW-135, MW-186B, MW-186C	1.90E+04	1.50E-05	0.025	0.03	420
O-2, MW-186b, MW-186c	1.62E+04	1.50E-03	0.032	0.054	350
Other observation wells combined with MW-186b:					
MW-111, MW-186B	1.75E+04	1.50E-03	0.027	0.28	380
MW-113, MW-186B	1.86E+04	1.50E-05	0.018	0.015	410
MW-125, MW-186B	1.76E+04	1.50E-05	0.023	0.017	380
MW-130, MW-186B	1.73E+04	1.50E-05	0.022	0.04	380
MW-135, MW-186B	1.65E+04	1.50E-03	0.022	0.058	360
O-2, MW-186B	1.43E+04	1.50E-03	0.021	1	310
Pumping Phase with correction for continued recovery:					
MW-186A, MW-186B MW-186C	2.06E+04	1.50E-05	0.017	0.066	450
Mean value	1.82E+04		0.023	0.122	398
Minimum Value	1.43E+04		0.016	0.011	310
Maximum Value	2.06E+04		0.032	1	450
With recharge boundary at Tanana River (for discussion purposes only):					
MW-186A, MW-186C	1.80E+04	1.50E-05	0.049	0.05	450

Acronyms and Abbreviations:
m^2/day = square meter per day

Table 5-5
Summary of Single Well Pumping Test Analyses

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well Name	Well Depth (ft bgs)	Transmissivity [a] (ft^2/d)	Screen Top (ft bgs)	Screen Bottom (ft bgs)	Saturated Screen Length [b] (ft)	Hydraulic Conductivity (ft/d)
MW-101	61	645	56	61	5	130
MW-101A	23	627	17.8	22.8	5	130
MW-102	71.5	503	61.5	71.5	10	50
MW-118	43	1365	38.5	43	4.5	300
MW-127	24.5	1096	20	24.5	4.5	240
MW-131	24.5	1360	20	24.5	4.5	300
MW-139[c]	25	2610	5.7	25	14	190
MW-143[c]	19.5	7231	50.9	19.5	10	720
MW-144A[c]	24.7	1039	5.7	24.7	14	74
MW-144B	90	1840	84.9	89.5	4.6	400
MW-154A	75.5	42960	71	75	4	10,700
MW-154B	95	1405	90.2	94.8	4.6	310
MW-186B	60.8	1045	50.7	60.4	9.7	110
MW-186C	100.8	4035	90.7	100.3	9.6	420
Geometric Mean of the Hydraulic Conductivities (all tests)						270
Geometric Mean of the Hydraulic Conductivities (excluding MW-154A)						200
Minimum Hydraulic Conductivity						50
Maximum Hydraulic Conductivity						10,700
Standard Deviation of Hydraulic Conductivity (all tests)						2,800
Standard Deviation of Hydraulic Conductivity (excluding MW-154A)						180

Footnotes:

a. Estimated from AQTESOLV using the Theis solution.
b. Based on static water level and well construction information.
c. Estimate based on Theis unconfined analysis.

Acronyms and Abbreviations:

fbgs = feet below ground surface
ft^2/d = squared feet per day
ft/d = feet per day

Table 5-6
Single Well Tracer Test Results

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well ID	Measured Well Depth (ft btoc)	Screen Length (ft)	2011 Hydraulic Conductivity Values from Single Well Pump Tests (ft/day) [b]	Aquifer Flux from SWTTs (q_A) (ft/day)
MW-101 [a]	64.59	5	130	0.022 - 0.25
MW-101A	27.79	5	130	0.37
MW-102	68.15	10	50	*NC*
MW-131 [a]	26.66	4.5	300	0.05 - 0.16
MW-139	26.95	19.3	190	0.17
MW-142	22.49	14	*NA*	0.04
MW-143	22.85	14.8	720	0.061
MW-144A	25.81	19	74	0.013
MW-145	22.82	14.3	*NA*	0.02
MW-150A	10.46	4.4	*NA*	0.01
MW-151A	14.64	5	*NA*	0.12
MW-152A	15.76	4.4	*NA*	0.066
MW-154A [a]	78.38	4	10,700	0.04 - 0.57
MW-154B [a]	97.57	4.6	310	0.008 - 0.13
MW-155A	14.21	9.7	*NA*	0.039
MW-170A	14.51	9.8	*NA*	0.044

Footnotes:

a. Well column was likely not fully mixed. Therefore, a range of estimates are provided.

b. Single well pump tests were conducted during Additional Site Characterization Activities in 2011.

Acronyms and Abbreviations:

NA = not available

NC = test not complete

Table 5-7
Summary of Results of the 2013 Recovery Systems Start-Up Test Analyses and NPR Production Well Analysis

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well	Parameter †	Mean Value	Minimum Value	Maximum Value	Number of Solutions
R-42	T (m^2/day)	14,700	9,060	23,000	8
	K (m/day)	320	200	500	
	Sc (unit less)	0.01	0.0026	0.088	
	Ss (1/m)	2.20E-04	5.70E-05	1.90E-03	
	Kz/Kr (unit less)	0.03	0.006	0.12	
R-43	T (m^2/day)	15,100	10,250	22,200	7
	K (m/day)	330	220	490	
	Sc (unit less)	0.0031	0.0022	0.004	
	Ss (1/m)	6.80E-05	4.80E-05	8.70E-05	
	Kz/Kr (unit less)	0.024	0.0081	0.05	
R-44	T (m^2/day)	16,700	11,600	22,400	5
	K (m/day)	370	250	490	
	Sc (unit less)	0.011	0.0055	0.024	
	Ss (1/m)	2.40E-04	1.20E-04	5.20E-04	
	Kz/Kr (unit less)	0.025	0.0033	0.07	
R-45	T (m^2/day)	9,000	4,080	18,000	4
	K (m/day)	200	90	390	
	Sc (unit less)	0.0208	0.00108	0.05	
	Ss (1/m)	4.50E-04	2.40E-05	1.10E-03	
	Kz/Kr (unit less)	0.035	0.012	0.12	
NPR-1, 2	T (m^2/day)	15,900			1
	K (m/day)	350			
	Sc (unit less)	0.0035			
	Ss (1/m)	7.70E-05			
	Kz/Kr (unit less)	0.031			

Acronyms and Abbreviations:
† = Parameter definitions
T = transmissivity
K = hydraulic conductivity (horizontal)
Sc = storage coefficient
Ss = specific storage
Kz/Kr = anisotropy (vertical K / radial or horizontal K)

Table 5-8
Summary of Well Nests Monitored with Data Loggers in which Vertical Gradients are Quantified

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Wells (Shallower Deeper)	Sense of Gradient	Agreement with Manual Measurements [a]
MW-164A-15 MW-164C-60	Upward	NM
MW-179A-15 MW-179B-50	Upward	NM
MW-181A-15 MW-181C-150	Upward	NM
MW-181B-50 MW-181C-150	Upward	NM
MW-186B-60 MW-186C-100	Upward	Agree
MW-186E-75 MW-186C-100	Upward	Agree
MW-304-15 MW-304-125	Upward	Agree
MW-304-15 MW-304-150	Upward	Agree
MW-306-15 MW-306-150	Downward	Agree
MW-309-15 MW-309-66	Upward	Agree
MW-310-15 MW-310-110	Upward	Agree
MW-318-20 MW-318-135	Downward	Agree
MW-326-20 MW-326-150	Upward	NM
MW-333-16 MW-333-150	Upward	NM
S-43 MW-175-90	Upward	NM

Footnotes:
[a.] Manual measurements may be at other times than data logger results.

Table 5-9A
Summary of Groundwater Elevations Based on Manual Measurements with Concurrent Surveys in Selected offsite Nested Wells

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well ID	3/18/2013	4/19/2013	5/20/2013	6/19/2013	7/25/2013	8/20/2013	9/23/2013	10/21/2013
MW-148A-15	NM	482.91	483.25	484.03	484.21	484.23	483.45	482.65
MW-148B-30	NM	482.9	483.21	484.03	484.21	484.23	483.4	482.62
MW-148C-55	NM	482.95	483.24	484.06	484.24	484.28	483.44	482.64
MW-148D-150	NM	482.95	483.22	484.05	484.24	484.27	483.42	482.64
MW-160AR-15	NM	478.77	479.26	479.56	479.43	479.33	479.24	478.66
MW-160B-90	NM	478.84	479.23	479.64	479.51	479.45	479.27	478.71
MW-162A-15	476.04	Frozen	Frozen	Frozen	Frozen	50.9	476.52	476.01
MW-162B-65	475.98	476.04	Frozen	Frozen	Frozen	476.38	476.49	475.9
MW-318-20	481.74	481.66	481.53	Frozen	Frozen	Frozen	481.76	481.07
MW-318-135	481.64	481.57	481.39	482.94	483.29	483.45	481.63	480.96

Table 5-9B
Summary of Manually Measured Vertical Head Differences †
in Selected Offsite Nested Wells

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well ID	3/18/2013	4/19/2013	5/20/2013	6/19/2013	7/25/2013	8/20/2013	9/23/2013	10/21/2013
MW-148A-15								
MW-148B-30	NM	0.01	0.04	0	0	0	0.05	0.03
MW-148C-55	NM	-0.05	-0.03	-0.03	-0.03	-0.05	-0.04	-0.02
MW-148D-150	NM	0	0.02	0.01	0	0.01	0.02	0
MW-160AR-15								
MW-160B-90	NM	-0.07	0.03	-0.08	-0.08	-0.12	-0.03	-0.05
MW-162A-15						50.9		
MW-162B-65	0.06	Frozen	Frozen	Frozen	Frozen	0.04	0.03	0.11
MW-318-20								
MW-318-135	0.1	0.09	0.14	Frozen	Frozen	Frozen	0.13	0.11

General Notes:
† Head in shallower well minus head in deeper well. Negative numbers indicate an upward component of flow.
Errors associated with these calculated head differences are ±0.02 feet.

Table 5-10A
Summary of Groundwater Elevations Based on Manual Measurements with Concurrent Surveys in Selected Onsite Nested Wells

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well ID	3/18/2013	4/19/2013	5/20/2013	6/19/2013	7/25/2013	8/20/2013	9/23/2013	10/21/2013
MW-186A-15	484.14	484.11	484.38	485.11	485.38	485.4	484.25	483.65
MW-186B-60	484.22	484.21	484.52	485.33	485.59	485.64	484.42	483.83
MW-186E-75	484.24	484.22	484.53	485.38	485.65	485.71	484.46	483.88
MW-186C-100	484.27	484.25	484.57	485.46	485.73	485.77	484.52	483.92
MW-186D-135	NM	484.31	484.6	485.52	485.77	485.84	484.57	483.98
MW-304-15	Frozen	Frozen	Frozen	484.81	485.03	485.09	483.94	483.39
MW-304-80	NM	483.69	483.99	484.85	485.07	50.9	483.99	483.41
MW-304-125	483.81	483.71	484	484.87	485.06	485.14	483.96	483.4
MW-304-150	483.79	483.71	484.01	484.87	485.06	485.13	483.95	483.4
MW-306-15	483.62	483.53	483.84	484.63	484.8	484.86	483.82	483.3
MW-306-80	NM	483.49	483.79	484.57	484.78	484.82	483.76	483.21
MW-306-150	483.54	483.45	483.75	484.55	484.72	484.8	483.74	483.19

Table 5-10B
Summary of Manually Measured Vertical Head Differences †
in Selected Onsite Nested Wells

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well ID	3/18/2013	4/19/2013	5/20/2013	6/19/2013	7/25/2013	8/20/2013	9/23/2013	10/21/2013
MW-186A-15								
MW-186B-60	-0.08	-0.1	-0.14	-0.22	-0.21	-0.24	-0.17	-0.18
MW-186E-75	-0.02	-0.01	-0.01	-0.05	-0.06	-0.07	-0.04	-0.05
MW-186C-100	-0.03	-0.03	-0.04	-0.08	-0.08	-0.06	-0.06	-0.04
MW-186D-135	NM	-0.06	-0.03	-0.06	-0.04	-0.07	-0.05	-0.06
MW-304-15								
MW-304-80	Frozen	Frozen	Frozen	-0.04	-0.04	50.9	-0.05	-0.02
MW-304-125	NM	-0.02	-0.01	-0.02	0.01	-0.01	0.03	0.01
MW-304-150	0.02	0	-0.01	0	0	0.01	0.01	0
MW-306-15								
MW-306-80	NM	0.04	0.05	0.06	0.02	0.04	0.06	0.09
MW-306-150	NM	0.04	0.04	0.02	0.06	0.02	0.02	0.02

General Notes:
† Head in shallower well minus head in deeper well. Negative numbers indicate an upward component of flow.
Errors associated with these calculated head differences are ±0.02 feet.

Table 5-11
Summary of Vertical Head Differences in Nested Wells During the 2013 Startup Aquifer Testing (Table 18 of Barr, 2013b)

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well ID	6/3/2013		6/6/2013		Change‡
	Hydraulic Head	Head Difference†	Hydraulic Head	Head Difference	
MW-174-15	486.33		486.43		
MW-174A-50	486.29	0.04	486.42	0.01	0.03
MW-174B-90	486.22	0.07	486.35	0.07	0
MW-179A-15	Frozen				
MW-179B-50	Frozen				
MW-179C-90	Frozen				
MW-179D-135	Frozen				
MW-186A-15	485.75		485.52		
MW-186B-60	485.86	-0.11	485.8	-0.28	0.17
MW-186E-75	485.82	0.04	485.82	-0.02	0.06
MW-186C-100	485.86	-0.04	485.91	-0.09	0.05
MW-186D-135	485.89	-0.03	485.95	-0.04	0.01
MW-197A-65	485.94		485.94		
MW-197B-150	486	-0.06	486.05	-0.11	0.05
MW-304-15	485.15		485.23		
MW-304-125	485.18	-0.04	485.27	-0.04	0.01
MW-304-150	485.19	-0.01	485.29	-0.02	0.01
MW-306-15	484.89		485		
MW-306-150	484.81	0.08	484.94	0.06	0.02
MW-309-15	485.74		485.77		
MW-309-66	485.74	0	485.82	-0.05	0.05
MW-309-150	485.72	0.02	485.82	0	0.02
MW-310-15	485.54		485.77		
MW-310-110	485.86	-0.32	485.98	-0.21	-0.11
MW-334-15	485.78		485.27		
MW-334-65	485.82	-0.04	485.81	-0.54	0.51
O-5	485.85		485.75		
MW-199-150	485.85	0	495.95	-0.2	0.2

General Notes:
S-32 is nested with MW-307, but MW-307 was frozen.

Acronyms and Abbreviations:
† = Head in shallower well minus head in deeper well. Negative numbers indicate an upward component of flow. Errors associated with these calculated head differences are ±0.02 feet.
‡ = Head difference on 6/3 minus head difference on 6/6. Positive numbers indicate an amplified head difference due to the recovery system. Errors associated with these calculated head difference changes are ±0.028 feet.

Table 5-12
Summary of Vertical Head Differences in Nested Wells at 2440 Tanana Drive

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well ID	8/22/2013		10/21/2013	
	Hydraulic Head	Head Difference†	Hydraulic Head	Head Difference†
Suprapermafrost Wells				
MW-349-15	477.76		477.12	
MW-349-45	477.69	0.07	477.05	0.07
Subpermafrost Well				
PW_ID_1230	477.99	-0.3	476.92	0.13

Acronyms and Abbreviations:

† Head in shallower well minus head in deeper well. Negative numbers indicate an upward component of flow. Errors associated with these calculated head differences are ±0.02 feet.

Table 7-1
2013 Deep Private Well Construction Details

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well ID	Reported Well Depth (ft bgs)	Top of Permafrost [(a)] (ft bgs)	Bottom of Permafrost [(a)] (ft bgs)	Distance between bottom of permafrost and bottom of well (ft)	Permafrost Thickness (ft)	Casing Diameter (inches)	Intake Length (ft above base of well [(b)])	Intake Interval (ft bgs)	Heat Tape	Installation Year
Perimeter Private Well Locations										
PW-1458	30	--	--	--	--	1	--	--	--	--
PW-0972	236	17	230	6	213	4	5	--	yes	1984
PW-0259	287	16	204	83	188	6	--	282-287	--	--
PW-0332	266	3	92	174	89	4	5	--	yes	1985
PW-1343	94	12	71	23	59	4	5	--	yes	1984
Internal Private Well Locations										
PW-1230	231	33	205	26	172	--	--	--	--	--
PW-1626	305	--	--	--	--	--	--	--	--	1976
PW-1099	140	23	105	35	82	6	5	--	--	2012
PW-0217	238	6	215	23	209	6	5	--	--	1986
PW-1155	215	5	205	10	200	6	--	--	yes	2000
PW-0358	105	20	103	2	83	5	--	--	--	1995
PW-0658	196	12	180	16	168	--	--	--	yes	1981
PW-0466	122	5	110	12	105	4	--	117-122	--	2004
PW-0464	98	25	90	8	65	6	--	--	yes	2000
PW-0463	89	22	70	19	48	6	--	--	--	1996
PW-0943	120	36	105	15	69	--	--	--	yes	--
PW-0932	255	19	146	109	127	4	6	--	yes	1986
PW-0297	24	--	--	--	--	2	--	--	--	--
PW-0296	220	20	210	10	190	5	--	--	--	1985
PW-1109	305	8	228	77	220	6	5	--	yes	1985

General Notes:
All construction details from well logs generated by drillers at the time of well installation.

Footnotes:
a. Permafrost depths as reported in well logs at the time of installation.
b. Perforations assumed to be at base of well.

Acronyms and Abbreviations:
--- = unknown or not applicable
ft = feet
bgs = below ground surface

Table 7-2
2013 Deep Private Well Field Parameter Results

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well ID	Sampling Date	Temperature (˚C)	DO (mg/L)	Conductivity (µS/cm)	pH	ORP (mV)	Water Clarity	Notes
Perimeter Private Well Locations								
PW-1458	6/20/2013	3.0	0.25	252.0	7.18	-94.0	Clear	
PW-1458	9/5/2013	4.8	0.30	259.5	7.08	-66.9	Clear	
PW-0972	3/17/2013	1.0	0.11	188.0	7.43	-170.0	Clear	
PW-0972	6/20/2013	2.9	0.73	187.5	7.35	-195.0	Clear	
PW-0972	9/5/2013	1.5	0.45	179.3	7.33	-172.5	Clear	
PW-0259	4/4/2013	4.2	0.63	193.0	7.69	-200.8	Initially turbid, finally clear	
PW-0259	6/19/2013	4.5	0.58	193.2	7.53	-188.2	Clear	
PW-0332	4/19/2013	2.6	0.06	208.2	7.65	-161.6	Clear	Owner purged well prior to arrival washing cars
PW-0332	6/20/2013	2.5	0.18	187.6	7.57	-176.6	Clear	
PW-0332	9/24/2013	2.0	1.31	207.2	7.34	-184.7	Clear	
PW-1343	3/20/2013	0.6	0.14	271.9	7.08	-87.3	Clear	
PW-1343	6/13/2013	1.5	0.55	332.3	6.92	19.0	Clear	
PW-1343	9/10/2013	0.6	0.65	289.8	6.88	-65.8	Clear	
Internal Private Well Locations								
PW-1230	3/11/2013	5.2	0.09	230.6	8.09	-294.0	Initially gas bubbles and sediment, finally clear	
PW-1230	3/28/2013	2.0	0.06	212.2	8.16	-295.9	Initially gas bubbles and turbidity, dark brown, finally slightly turbid	
PW-1230	6/27/2013	2.5	0.06	201.7	8.08	-250.3	Black to very turbid to slightly turbid, finally turbid	
PW-1230	9/12/2013	1.9	0.16	185.8	7.95	-271.7	Very turbid to turbid	
PW-1626	10/16/2013	1.0	2.00	184.3	7.10	-208.0	Initially clear, finally slightly turbid	
PW-1099	3/12/2013	0.4	0.14	184.0	7.07	-109.1	Clear	
PW-1099	6/4/2013	1.1	0.16	209.9	7.20	-140.3	Clear	
PW-1099	9/26/2013	0.8	0.41	201.5	6.81	-106.4	Clear	
PW-0217	3/11/2013	0.5	0.13	229.5	7.33	-171.2	Initially turbid, finally clear	
PW-0217	6/5/2013	1.0	0.16	260.5	7.40	-189.5	Clear	

Table 7-2
2013 Deep Private Well Field Parameter Results

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well ID	Sampling Date	Temperature (˚C)	DO (mg/L)	Conductivity (µS/cm)	pH	ORP (mV)	Water Clarity	Notes
PW-0217	9/5/2013	1.2	0.56	227.4	7.51	-256.9	Clear	
PW-1155	3/18/2013	0.8	0.13	233.4	7.25	-123.1	Clear	
PW-1155	6/5/2013	1.4	0.14	256.8	7.69	-203.6	Clear	
PW-1155	9/11/2013	1.0	0.63	235.1	7.08	-193.1	Clear	
PW-0358	3/25/2013	0.6	0.13	171.9	7.27	-88.2	Turbid to slightly turbid	Debris created from steaming/thawing well was cleared with purging
PW-0358	6/12/2013	1.0	0.30	202.4	7.15	-168.4	Clear	
PW-0358	9/10/2013	1.0	0.33	182.6	7.01	-160.8	Turbid	
PW-0658	3/18/2013	0.6	0.15	228.5	7.55	-163.5	Clear	
PW-0658	6/12/2013	0.8	0.16	248.9	7.24	-169.1	Clear	
PW-0658	9/11/2013	0.8	0.51	241.4	7.05	-149.7	Clear	
PW-0466	4/18/2013	0.6	0.10	244.1	7.15	-95.4	Clear	
PW-0466	6/12/2013	0.8	0.23	250.0	6.98	-119.7	Clear	
PW-0466	9/9/2013	0.7	0.44	226.3	6.95	-119.3	Clear	
PW-0464	3/28/2013	0.3	0.10	176.1	7.42	-142.5	Initially gas bubbles and turbidity, finally clear	
PW-0464	6/27/2013	0.6	0.25	184.2	7.15	-158.8	Clear	
PW-0464	9/25/2013	0.5	1.64	198.6	6.92	-128.5	Clear	
PW-0463	4/4/2013	1.0	0.12	180.0	7.25	-119.2	Clear	FHRA arranged to repair broken spigot; water flows in off position
PW-0463	6/27/2013	1.0	0.20	184.9	7.30	-166.6	Clear	
PW-0463	9/12/2013	1.2	0.25	191.4	7.19	-135.5	Clear	
PW-0943	3/12/2013	0.6	0.06	241.2	7.01	-123.9	Clear	
PW-0943	6/6/2013	0.7	0.07	261.5	6.96	-140.5	Clear	
PW-0943	9/11/2013	0.6	0.40	250.1	6.91	-132.0	Clear	
PW-0932	3/20/2013	0.9	0.08	184.4	7.82	-206.1	Clear	
PW-0932	6/19/2013	1.1	0.06	189.7	7.98	-190.6	Clear	
PW-0932	9/16/2013	1.1	0.33	205.0	7.32	-188.8	Clear	
PW-0297	3/21/2013	0.2	0.13	216.6	6.99	-81.0	Initially sediment, finally clear	
PW-0297	6/13/2013	1.6	0.29	267.4	7.07	-78.7	Clear	
PW-0297	9/12/2013	2.0	0.24	254.4	6.93	-93.7	Initially slightly turbid, finally clear	

Table 7-2
2013 Deep Private Well Field Parameter Results

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well ID	Sampling Date	Temperature (˚C)	DO (mg/L)	Conductivity (µS/cm)	pH	ORP (mV)	Water Clarity	Notes
PW-0296	3/21/2013	0.6	0.10	199.8	7.36	-170.6	Initially sediment, finally clear	
PW-0296	6/13/2013	0.8	0.16	234.2	7.33	-192.2	Clear	
PW-0296	9/12/2013	0.7	0.34	213.1	7.09	-178.0	Clear	
PW-1109	3/13/2013	0.5	0.11	407.3	6.74	-82.3	Clear	
PW-1109	3/13/2013	0.5	0.11	407.3	6.74	-82.3	Clear	
PW-1109	6/5/2013	0.9	0.18	442.0	6.96	-65.9	Clear	
PW-1109	9/9/2013	0.9	0.45	400.0	6.67	-104.8	Clear	

General Notes:

All reported parameter values are last measured values following stabilization and immediately prior to sampling.

Acronyms and Abbreviations:

ft = feet
bgs = below ground surface
˚C = degrees celcius
DO = dissolved oxygen
mg/L = milligrams per liter
µS/cm = microsemens per centimeter
ORP = oxidation-reduction potential
mV = millivolts

Table 7-3
2013 Deep Private Well Analytical Results

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

PW ID	Well Depth	Zone	Sample Type	Sample Date	Sulfolane	Alkalinity	Ammonia as N	Calcium	Chloride	CO3 Alkalinity	HCO3 Alkalinity	Dissolved Iron	Magnesium	Manganese	Methane	Nitrate/Nitrite Total [a]	Nitrate	Nitrite	OH Alkalinity	Potassium	Sodium	Sulfate	Total Iron	Total Manganese	Total Organic Carbon
					µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PW-0217	238	>160	PS	03/11/2013	173	157	<0.0620	46.5	11.0	<6.20	157	4.96	11.0	0.830	0.11	--	<0.0620	0.0930J	<6.20	4.10	10.2	23.7	12.7	0.862	2.65
PW-0217	238	>160	PS	06/05/2013	163	152	0.0830J	46.8	10.7	<6.20	152	12.9	10.9	0.891	0.0830	--	0.0490J	<0.0620	<6.20	4.16	9.97	23.3	13.5	0.886	2.49
PW-0217	238	>160	PS	09/05/2013	152	148	0.0859J	45.8	10.0	<6.20	148	12.8	10.7	0.833	0.0990	--	<0.0620	<0.0620	<6.20	4.09	9.49	21.7	14.1	0.842	2.58
PW-0259	287	>160	PS	04/04/2013	<6.74	132	0.245	37.2	1.47	<6.20	132	5.41	8.86	0.815	0.025	--	0.0620JL*	0.0595JL*	<6.20	2.90	4.18	16.9	5.57	0.849	2.33
PW-0259	287	>160	PS	06/19/2013	<6.20	134	0.152	37.7	1.63	<6.20	134	4.55	8.81	0.845	0.0210	--	0.0600J	<0.0620	<6.20	2.91	4.11	16.6	5.76	0.870	2.40
PW-0296	220	>160	PS	03/21/2013	11.9	155	0.0951J	44.8	3.12	<6.20	155	6.44	9.95	0.624	0.059	--	0.0590J	<0.0620	<6.20	3.08	4.17	22.2	6.59	0.620	2.39
PW-0296	220	>160	PS	06/13/2013	12.6	140	0.119	51.1	3.20	<6.20	140	6.85	11.1	0.659	0.0390	--	0.0600J	<0.0620	<6.20	3.51	4.65	22.8	7.17	0.667	2.48
PW-0296	220	>160	DUP	06/13/2013	12.5	150	0.120	52.2	3.19	<6.20	150	6.91	11.2	0.673	0.0430	--	0.0590J	<0.0620	<6.20	3.54	4.71	22.9	7.13	0.669	2.48
PW-0296	220	>160	PS	09/12/2013	11.2	147	0.109	48.3	3.05	<6.20	147	6.47	10.6	0.645	0.0560	--	<0.0620	<0.0620	<6.20	3.33	4.57	22.2	6.60	0.643	2.29
PW-0297 [b]	24	10-55	PS	03/21/2013	9.12J	172	0.217	52.3	7.20	<6.20	172	2.52	12.7	1.47	0.069	--	0.0620J	<0.0620	<6.20	3.95	7.77	24.3	2.46	1.43	3.41
PW-0297 [b]	24	10-55	PS	06/13/2013	10.5	170	0.197	55.4	7.92	<6.20	170	2.08	13.0	1.44	0.0230	--	0.0590J	<0.0620	<6.20	4.09	8.74	25.7	3.02	1.45	3.83
PW-0297 [b]	24	10-55	PS	09/12/2013	10.0J	172	0.166	53.5	8.61	<6.20	172	1.96	12.9	1.40	0.0180	--	<0.0620	<0.0620	<6.20	4.08	8.11	24.1	2.09	1.43	3.33
PW-0332	266	>160	PS	04/19/2013	<6.66J§	150J§	0.0994J§	<0.300J§	1.05J§	<6.20J§	150J§	<0.156J§	<0.0300J§	0.000477J§	0.080§	--	<0.0620J§	0.0645J§	<6.20J§	<0.300J§	77.7J§	15.8J§	0.192J§	0.000949J§	1.18J§
PW-0332	266	>160	PS	06/20/2013	<6.20	143	0.103	43.8	0.958	<6.20	143	2.16	8.87	0.368	0.00860	--	0.0590J	<0.0620	<6.20	3.14	4.63	15.6	2.16	0.378	1.13
PW-0332	266	>160	PS	09/24/2013	<6.20	143	0.0956J	44.2	0.944	<6.20	143	2.47	9.13	0.351	0.00940	--	0.0440J	0.0310J	<6.20	3.25	4.62	15.3	2.94	0.365	<1.69B*
PW-0358	105	90-160	PS	03/25/2013	73.8	113	0.181	39.5	3.90	<6.20	113	4.22	8.88	0.433	0.019	--	0.0570J	0.0530J	<6.20	3.05	4.17	23.3	8.00	0.610	3.70
PW-0358	105	90-160	PS	06/12/2013	80.2	116	0.0848J	44.1	2.53	<6.20	116	3.73	9.09	0.599	0.0180	--	0.0600J	<0.0620	<6.20	3.26	4.20	32.5	4.42	0.603	1.25
PW-0358	105	90-160	PS	09/10/2013	88.7	120	0.0331J	39.5	2.62	<6.20	120	4.67	8.88	0.582	0.0290	--	<0.0620	<0.0620	<6.20	3.11	4.24	24.5	5.93	0.570	<1.75B*
PW-0463	89	55-90	PS	04/04/2013	27.9	124	0.207	41.6	3.57	<6.20	124	1.70	9.09	0.647	0.020	--	<0.0620	0.0510J	<6.20	3.09	4.52	29.4	1.77	0.638	1.41
PW-0463	89	55-90	PS	06/27/2013	33.2	124	0.0999J	43.5	3.68	<6.20	124	2.21	9.27	0.667	0.00910	<0.0620J*	--	--	<6.20	3.16	4.56	28.4	2.94	0.684	1.29
PW-0463	89	55-90	PS	09/12/2013	34.7	122	0.0656J	42.7	3.82	<6.20	122	2.08	9.07	0.670	0.0280	--	<0.0620	<0.0620	<6.20	3.06	4.39	28.5	2.17	0.676	<1.39B*
PW-0464	98	55-90	PS	03/28/2013	40.3	126	0.0459J	41.4	4.07	<6.20	126	1.16	9.17	0.581	0.031	--	0.0560J	0.0520J	<6.20	3.02	4.41	28.5	2.17	0.592	1.57
PW-0464	98	55-90	PS	06/27/2013	44.2	126	0.0967J	43.2	4.01	<6.20	126	1.68	9.22	0.624	0.0260	<0.0620J*	--	--	<6.20	3.09	4.45	29.7	1.74	0.639	1.43
PW-0464	98	55-90	PS	09/25/2013	45.3	127	0.0688J	45.1	4.01JH*	<6.20	127	1.35	9.70	0.620	0.0350	--	<0.0620	<0.0620	<6.20	3.17	4.60	28.8	1.62	0.619	1.88
PW-0466	122	90-160	DUP	04/18/2013	23.9	162	0.176	51.6	6.13	<6.20	162	2.86	11.5	0.749	0.061	--	<0.0620	<0.0620	<6.20	3.41	4.69	26	2.97	0.765	2.85
PW-0466	122	90-160	PS	04/18/2013	23.1	159	0.186	51.0	6.28	<6.20	159	2.84	11.0	0.738	0.078	--	0.0440J	<0.0620	<6.20	3.34	4.43	26.4	3.00	0.753	2.95
PW-0466	122	90-160	PS	06/12/2013	26.8	157	0.0895J	55.5	6.36	<6.20	157	3.17	12.0	0.762	0.0580	--	0.0600J	<0.0620	<6.20	3.60	4.77	25.9	3.14	0.754	2.90
PW-0466	122	90-160	PS	09/09/2013	29.5	164	0.111	52.6	6.54	<6.20	164	3.06	12.0	0.741	0.0970	--	<0.0620	<0.0620	<6.20	3.53	4.76	25.6	3.19	0.759	3.89
PW-0466	122	90-160	DUP	09/09/2013	29.0	164	0.0923J	54.0	6.51	<6.20	164	3.10	12.3	0.749	0.0810	--	<0.0620	<0.0620	<6.20	3.57	4.85	25.4	3.20	0.770	3.92
PW-0658	196	>160	PS	03/18/2013	48.4	169	0.139	48.4	7.40	<6.20	169	6.92	12.1	0.673	0.089	--	0.0610J	<0.0620	<6.20	3.65	4.49	15.2	9.25	0.693	3.43
PW-0658	196	>160	PS	06/12/2013	51.1	164	0.0646J	53.5	7.41	<6.20	164	7.00	12.3	0.691	0.0860	--	0.0580J	<0.0620	<6.20	3.94	4.62	14.6	7.92	0.672	3.63
PW-0658	196	>160	PS	09/11/2013	63.7	173	0.0597J	52.9	7.59	<6.20	173	7.24	12.3	0.748	0.120	--	<0.0620	<0.0620	<6.20	3.73	4.49	15.3	7.50	0.735	4.37
PW-0932	255	>160	PS	03/20/2013	5.09J	139	<0.124B*	46.1	2.93	<6.20	139	5.54	9.95	0.543	0.044	--	0.0560J	<0.0620	<6.20	3.37	4.48	23	7.01	0.554	1.90
PW-0932	255	>160	PS	06/19/2013	5.04J	138	0.0921J	42.4	2.95	<6.20	138	4.24	9.08	0.527	0.0270	--	0.0940J	<0.0620	<6.20	3.13	4.23	24.6	4.40	0.509	1.84
PW-0932	255	>160	PS	09/16/2013	8.05J	135	0.0845J	44.2	3.19	<6.20	135	3.45	9.90	0.536	0.0290	--	<0.100B*	0.0590J	<6.20	3.36	4.42	24.9	3.66	0.534	2.05
PW-0943	120	90-160	PS	03/12/2013	25.7	167	0.157	47.8	6.62	<6.20	167	12.3	13.2	1.08	0.0090	--	0.0750J	<0.100B*	<6.20	3.33	4.86	20.6	15.6	1.06	4.13
PW-0943	120	90-160	PS	06/06/2013	25.8	174	0.149	50.1	6.94	<6.20	174	16.6	13.1	1.14	0.0660	--	0.0315J	<0.0620	<6.20	3.43	4.73	23.1	17.3	1.12	4.17
PW-0943	120	90-160	PS	09/11/2013	30.3	167	0.114	50.6	7.35	<6.20	167	15.6	13.8	1.12	0.0640	--	0.0660J	<0.0620	<6.20	3.51	5.09	20.4	16.7	1.07	4.89
PW-0972	236	>160	PS	03/17/2013	<6.74	121	0.0724J	36.5	2.67	<6.20	121	4.10	10.6	0.880	0.011	--	0.0600J	<0.0620	<6.20	2.97	4.25	30.9	4.06	0.838	1.51
PW-0972	236	>160	PS	06/20/2013	<6.50	121	0.0400J	37.6	2.30	<6.20	121	4.20	10.1	0.895	0.0110	--	0.0850J	<0.0620	<6.20	3.01	4.22	30.3	4.57	0.884	1.40
PW-0972	236	>160	DUP	06/20/2013	<6.46	123	0.0465J	37.0	2.27	<6.20	123	4.19	10.1	0.884	0.0110	--	0.0960J	<0.0620	<6.20	2.96	4.16	30	4.38	0.883	1.41
PW-0972	236	>160	PS	09/05/2013	<6.32	119	0.116	37.2	2.41	<6.20	119	4.36	10.4	0.859	0.0170	--	<0.0620	<0.0620	<6.20	3.02	4.17	29.3	4.35	0.830	2.39
PW-1099	140	90-160	DUP	03/12/2013	105	124	0.105	39.6	3.18	<6.20	124	3.01	11.2	0.737	0.010J*	--	0.0630J	<0.0620	<6.20	2.98	4.24	31.6	3.52	0.762	1.75
PW-1099	140	90-160	PS	03/12/2013	107	123	0.0997J	38.6	3.20	<6.20	123	3.14	11.0	0.740	0.074J*	--	0.0670J	<0.0620	<6.20	2.92	4.16	31.7	3.42	0.734	1.73
PW-1099	140	90-160	PS	06/04/2013	103	125	<0.0620	41.5	<0.0620	<6.20	125	4.48	11.6	0.777	0.00960	--	<0.0620	<0.0620	<6.20	3.21	4.40	<0.0620	4.51	0.781	1.67
PW-1099	140	90-160	PS	09/26/2013	97.2	124	0.0527J	40.3	3.03	<6.20	124	2.68	11.1	0.694	0.0100JL*	--	0.0555J	<0.0620	<6.20	3.05	4.16	31.1	2.68	0.695	2.01
PW-1099	140	90-160	DUP	09/26/2013	104	124	0.0495J	39.3	3.02	<6.20	124	2.78	10.8	0.713	0.00980JL*	--	<0.0620	<0.0620	<6.20	2.97	4.07	31	2.76	0.717	1.90
PW-1109	305	>160	PS	03/13/2013	24.6	266	0.243	69.8	55.9	<6.20	266	6.43	22.7	1.80	0.30	--	<0.110B*	0.314J*	<6.20	5.70	30.0	13.4	6.57	1.82	5.39
PW-1109	305	>160	PS	06/05/2013	26.5	262	0.202	70.9	54.8	<6.20	262	7.29	22.3	1.88	0.210	--	0.0480J	<0.0620	<6.20	5.75	29.2	13	6.65	1.81	5.42
PW-1109	305	>160	PS	09/09/2013	26.2	259	0.229	71.5	53.3	<6.20	259	6.28	22.6	1.76	0.270	--	<0.0620	<0.0620	<6.20	5.65	29.1	13.5	6.21	1.72	6.63
PW-1155	215	>160	PS	03/18/2013	162	155	0.144	48.0	6.89	<6.20	155	8.27	11.4	0.651	0.15	--	0.0610J	<0.0620	<6.20	3.66	6.18	28.7	8.74	0.660	2.68
PW-1155	215	>160	PS	06/05/2013	166	155	0.0855J	49.0	6.44	<6.20	155	11.9	11.3	0.705	0.0970	--	0.0490J	<0.0620	<6.20	3.80	6.19	24.7	13.0	0.713	2.65
PW-1155	215	>160	PS	09/11/2013	172	148	0.0604J	43.1	7.20	<6.20	148	11.1	10.1	0.652	0.0650	--	0.0580J	<0.0620	<6.20	3.37	5.54	26.3	9.96	0.588	3.08
PW-1230	231	>160	PS	03/11/2013	558	134	0.289	41.8	12.4	<6.20	134	3.88	11.8	0.862	1.4	--	<0.0620	0.122	<6.20	3.10	4.73	18.2	37.2	1.06	1.81
PW-1230 [c]	231	>160	DUP	03/28/2013	497	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PW-1230 [c]	231	>160	PS	03/28/2013	517	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PW-1230	231	>160	PS	06/27/2013	603	113	0.615	36.6	17.3	<6.20	113	5.29	11.7	0.556	0.00930	<0.0620J*	--	--	<6.20	3.20	4.76	17.5	122	1.10	3.28
PW-1230	231	>160	PS	09/12/2013	652	101	<0.0620	35.8	16.5	<6.20	101	4.52	11.5	0.474	0.0710	--	<0.0620	<0.0620	<6.20	3.37	5.01	16.6	78.9	0.915	2.93
PW-1343	94	55-90	PS	03/20/2013	<6.66	202	<0.100B*	66.3	23.7	<6.20	202	1.62	14.9	0.272	0.049	--	<0.100J*	0.0890J*	<6.20	3.94	10.6	17.7	2.08	0.301	2.51
PW-1343	94	55-90	PS	06/13/2013	<6.20	196	<0.0620	<0.300	25.2	<6.20	196	<0.156	<0.0300	0.000395J	0.0460	--	0.0660J	<0.0620	<6.20	0.177J	129	17.9	<0.156	0.000467J	2.06
PW-1343	94	55-90	PS	09/10/2013	<6.40	205	<0.0620	64.4	25.0	<6.20	205	1.35	15.0	0.297	0.0320	--	<0.0620	<0.0620	<6.20	3.91	10.8	17.3	1.42	0.301	2.54
PW-1458 [b]	30	10-55	PS	06/20/2013	<6.66	170	0.118	50.5	14.7	<6.20	170	0.787	13.6	1.75	0.0470	--	0.0670J	<0.0620	<6.20	3.68	8.10	26.4	0.849	1.77	2.31
PW-1458 [b]	30	10-55	PS	09/05/2013	<6.40	163	0.0557J	52.4	12.7	<6.20	163	0.646	14.5	1.65	0.0290	--	<0.0620	<0.0620	<6.20	4.15	8.56	27.3	0.687	1.73	1.59

Table 7-3
2013 Deep Private Well Analytical Results

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

PW ID	Well Depth	Zone	Sample Type	Sample Date	Sulfolane	Alkalinity	Ammonia as N	Calcium	Chloride	CO3 Alkalinity	HCO3 Alkalinity	Dissolved Iron	Magnesium	Manganese	Methane	Nitrate/Nitrite Total [a]	Nitrate	Nitrite	OH Alkalinity	Potassium	Sodium	Sulfate	Total Iron	Total Manganese	Total Organic Carbon
					µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PW-1626	305	>160	PS	10/16/2013	307	122	0.0651J	43.1	5.17	<6.20	122	2.77	10.8	0.480	0.0130	--	<0.0620	0.0320J	<6.20	3.74	6.02	32.5	16.3	0.543	<1.51B*

Footnotes:
a. Laboratory performed total analysis for samples received outside of hold time due to delivery truck delay
b. Garden well location.
c. Location was resampled to verify sulfolane results from the sample collected on 3/11/2013

Acronyms and Abbreviations:
PW ID = Private Well Identification Number
§ = result biased. Sample location was downstream of a water-treatment system. The sample was collected from the appropriate spigot during the second and third quarter sampling events.
J = result is estimated; analyte was detected below the limit of quantitation (LOQ)
JL* = results is considered an estimate, biased low; flag applied by SWI based on sample-handling or analytical QC issues, see data-review checklist for detail
JH* = results is considered an estimate, biased high; flag applied by SWI based on sample-handling or analytical QC issues, see data-review checklist for detail
B* = result is considered non-detect; flag applied by SWI based on analytical QC issues, see data-review checklist for details
µg/L = micrograms per liter
< = analyte not detected; limit of detection listed
DUP = duplicate sample
PF = project sample

Table 7-4
2013 Deep Private Well Groundwater Types

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Well ID	Temperature (˚C)	DO (mg/L)	Specific Conductivity (µS/cm)	pH	ORP (mV)
Type A Q1 Average	0.6	0.1	339.6	6.9	-84.8
Type A Q1 Standard Deviation	0.1	0.0	95.7	0.2	3.5
Type B Q1 Average	1.4	0.2	186.5	7.5	-160.8
Type B Q1 Standard Deviation	1.4	0.2	13.4	0.4	70.6
Type C Q1 Average	0.8	0.1	220.6	7.3	-144.0
Type C Q1 Standard Deviation	0.7	0.0	20.0	0.2	40.6
Q1 Average	**1.0**	**0.1**	**220.6**	**7.3**	**-144.0**
Q1 Standard Deviation	1.0	0.1	54.2	0.3	55.4
Type A Q2 Average	1.0	0.2	326.0	7.1	-103.1
Type A Q2 Standard Deviation	0.1	0.0	164.1	0.2	52.6
Type B Q2 Average	1.9	0.4	212.0	7.3	-156.1
Type B Q2 Standard Deviation	1.5	0.3	8.2	0.4	33.5
Type C Q2 Average	1.4	0.2	240.9	7.3	-155.5
Type C Q2 Standard Deviation	0.8	0.1	28.9	0.3	44.6
Q2 Average	**1.6**	**0.2**	**239.3**	**7.3**	**-151.0**
Q2 Standard Deviation	1.0	0.2	63.1	0.3	61.5
Type A Q3 Average	0.8	0.6	344.9	6.8	-85.3
Type A Q3 Standard Deviation	0.2	0.1	77.9	0.1	27.6
Type B Q3 Average	1.1	0.7	189.1	7.2	-169.1
Type B Q3 Standard Deviation	0.5	0.7	8.4	0.4	56.0
Type C Q3 Average	1.5	0.5	232.0	7.1	-156.3
Type C Q3 Standard Deviation	1.3	0.3	19.5	0.2	55.5
Q3 Average	**1.3**	**0.6**	**228.0**	**7.1**	**-153.5**
Q3 Standard Deviation	1.0	0.5	51.7	0.3	57.0
Type A Average	0.8	0.3	357.2	6.9	-64.5
Type A Standard Deviation	0.4	0.2	69.2	0.1	43.4
Type B Average	1.5	0.4	190.1	7.4	-170.3
Type B Standard Deviation	1.2	0.5	10.8	0.4	53.8
Type C Average	1.2	0.3	231.5	7.3	-152.2
Type C Standard Deviation	1.0	0.3	24.0	0.3	46.1
Overall Average	**1.3**	**0.3**	**229.5**	**7.2**	**-149.6**
Overall Standard Deviation	1.0	0.4	56.1	0.3	57.1

Acronyms and Abbreviations:
˚C = degrees celsius
DO = dissolved oxygen
mg/L = milligrams per liter
µS/cm = microsiemens per centimeter
mV = millivolts

Table 7-5
Offsite Initial Phase 8 Groundwater Analytical Results

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Proposed Well ID [1]	Location [2]	Proximity	Zone	Sample Name	Sample Type	Sample Date	Sulfolane µg/L
MW-148E	MW-148-80	Off-site	55-90	MW-148-80		10/31/2013	13.6
MW-148F	MW-148-100	Off-site	55-90	MW-148-100		10/31/2013	<6.66
8-O	MW-160AR-15	Off-site	Water Table	MW-160AR		5/14/2013	<6.20
	MW-160AR-15	Off-site	Water Table	MW-260AR	DUP	5/14/2013	<6.20
8-AE	MW-161-30	Off-site	10-55	MW-161-30		5/13/2013	210
8-Z	MW-190BR-60	Off-site	10-55	MW-190BR		5/24/2013	<6.20
	MW-190-150	Off-site	90-160	MW-190-150		6/4/2013	<6.20
8-X	MW-332-41	Off-site	10-55	MW-332-41		5/17/2013	<6.20
	MW-332-41	Off-site	10-55	MW-432-41	DUP	5/17/2013	<6.20
	MW-332-75	Off-site	55-90	MW-332-75		5/17/2013	<6.20
	MW-332-110	Off-site	90-160	MW-332-110		5/17/2013	25.7
8-Q	MW-338-15	Off-site	Water Table	MW-338-15		5/13/2013	56.2
	MW-338-50	Off-site	10-55	MW-338-50		5/13/2013	46.1
8-AB	MW-339-15	Off-site	Water Table	MW-339-15		5/14/2013	57.0
	MW-339-50	Off-site	10-55	MW-339-50		5/14/2013	35.4
8-Y	MW-340-18	Off-site	Water Table	MW-340-18		5/16/2013	<6.20
	MW-340-65	Off-site	10-55	MW-340-65		5/16/2013	<6.20
	MW-340-150	Off-site	90-160	MW-340-150		5/16/2013	<6.20
8-T	MW-341-15	Off-site	Water Table	MW-341-15		5/24/2013	121
	MW-341-40	Off-site	10-55	MW-341-40		5/24/2013	93.6
8-R	MW-342-15	Off-site	Water Table	MW-342-15		6/4/2013	158
	MW-342-65	Off-site	10-55	MW-342-65		6/4/2013	159
	MW-342-65	Off-site	10-55	MW-442-65	DUP	6/4/2013	168
8-W	MW-343-15	Off-Site	Water Table	MW-343-15		9/26/2013	<6.32
	MW-343-50	Off-site	10-55	MW-343-50		6/25/2013	<6.42
8-AC	MW-346-15	Off-Site	Water Table	MW-346-15		9/26/2013	7.19J
	MW-346-65	Off-Site	10-55	MW-446-65	DUP	9/26/2013	21.6
	MW-346-65	Off-Site	10-55	MW-346-65		9/26/2013	22.7
	MW-346-150	Off-Site	90-160	MW-346-150		9/26/2013	<6.20
8-AA	MW-347-20	Off-Site	Water Table	MW-347-20		9/27/2013	12.9
	MW-347-65	Off-Site	10-55	MW-347-65		9/27/2013	27.4
	MW-347-150	Off-site	90-160	MW-347-150		9/27/2013	9.57J
8-AF	MW-349-15	Off-site	Water Table	MW-349-15		8/16/2013	59.3
	MW-349-45	Off-site	10-55	MW-349-45		8/16/2013	58.4
8-V	MW-350-15	Off-site	Water Table	MW-350-15		9/27/2013	30.3
	MW-350-50	Off-site	10-55	MW-350-50		9/27/2013	47.7
8-AD	MW-352-15	Off-site	Water Table	MW-352-15		9/30/2013	5.10J
	MW-352-40	Off-site	10-55	MW-352-40		9/30/2013	8.73J
8-S	MW-353-15	Off-site	Water Table	MW-353-15		9/25/2013	157
	MW-353-65	Off-site	10-55	MW-353-65		9/25/2013	204
	MW-353-100	Off-site	90-160	MW-353-100		9/25/2013	198
8-BA	MW-356-15	Off-site	Water Table	MW-356-15		10/21/2013	<6.20
	MW-356-65	Off-site	10-55	MW-356-65		10/21/2013	<6.66
	MW-356-90	Off-site	55-90	MW-356-90		10/21/2013	<6.82
	MW-356-90	Off-site	55-90	MW-456-90	DUP	10/21/2013	<6.88

Table 7-5
Offsite Initial Phase 8 Groundwater Analytical Results

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Proposed Well ID [1]	Location [2]	Proximity	Zone	Sample Name	Sample Type	Sample Date	Sulfolane µg/L
8-BB	MW-357-15	Off-site	Water Table	MW-357-15		10/31/2013	<6.74
	MW-357-65	Off-site	10-55	MW-357-65		10/31/2013	<6.74
	MW-357-150	Off-site	90-160	MW-357-150		10/31/2013	<6.66

Footnotes:

a. Well names were proposed in the Revised 2013 Offsite Site Characterization Work Plan (ARCADIS 2013) for planning purposes only. Permanent well names were applied upon installation.

b. Well depths are noted at the end of each location ID.

Acronyms and Abbreviations:

DUP = quality-control field-duplicate sample

µg/L = micrograms per liter

J = estimated concentration; detected above the detection limit (DL) but below the limit of quantitation (LOQ)

Table 7-6
Total Organic Carbon Analytical Results in Offsite Groundwater Monitoring Wells

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Location Name	Zone	Proximity	Sample Name	Sample Date	Sample Type	Analyte	Display	Units
MW-148A-15	Water Table	Off-site	MW-148A	3/7/2011		Total Organic Carbon	9.56	mg/L
MW-148A-15	Water Table	Off-site	MW-148A	4/8/2011		Total Organic Carbon	10.2	mg/L
MW-148A-15	Water Table	Off-site	MW-148A	8/18/2011		Total Organic Carbon	11.1	mg/L
MW-148A-15	Water Table	Off-site	MW-148A	10/11/2011		Total Organic Carbon	15.4	mg/L
MW-148A-15	Water Table	Off-site	MW-148A	5/3/2012		Total Organic Carbon	11.4	mg/L
MW-148A-15	Water Table	Off-site	MW-148A	10/22/2012		Total Organic Carbon	15.8	mg/L
MW-148A-15	Water Table	Off-site	MW-148A	5/6/2013		Total Organic Carbon	12.6	mg/L
MW-148B-30	10-55	Off-site	MW-148B	3/7/2011		Total Organic Carbon	3.41	mg/L
MW-148B-30	10-55	Off-site	MW-148B	4/8/2011		Total Organic Carbon	3.44	mg/L
MW-148B-30	10-55	Off-site	MW-248B	8/12/2011	DUP	Total Organic Carbon	3.57	mg/L
MW-148B-30	10-55	Off-site	MW-148B	8/12/2011		Total Organic Carbon	3.66	mg/L
MW-148B-30	10-55	Off-site	MW-148B	10/11/2011		Total Organic Carbon	3.30	mg/L
MW-148B-30	10-55	Off-site	MW-148B	5/1/2012		Total Organic Carbon	3.12	mg/L
MW-148B-30	10-55	Off-site	MW-148B	11/11/2012		Total Organic Carbon	3.02	mg/L
MW-148B-30	10-55	Off-site	MW-148B	4/15/2013		Total Organic Carbon	2.95	mg/L
MW-151A-15	Water Table	Off-site	MW-151A	2/10/2011		Total Organic Carbon	1.80	mg/L
MW-151A-15	Water Table	Off-site	MW-251A	5/25/2011	DUP	Total Organic Carbon	2.26	mg/L
MW-151A-15	Water Table	Off-site	MW-151A	5/25/2011		Total Organic Carbon	2.27	mg/L
MW-151A-15	Water Table	Off-site	MW-151A	8/9/2011		Total Organic Carbon	2.53	mg/L
MW-151A-15	Water Table	Off-site	MW-151A	10/11/2011		Total Organic Carbon	2.92	mg/L
MW-151A-15	Water Table	Off-site	MW-151A	4/30/2012		Total Organic Carbon	3.27	mg/L
MW-151A-15	Water Table	Off-site	MW-151A	11/10/2012		Total Organic Carbon	2.10J*	mg/L
MW-151A-15	Water Table	Off-site	MW-151A	3/7/2013		Total Organic Carbon	1.93	mg/L
MW-151B-25	10-55	Off-site	MW-151B	2/18/2011		Total Organic Carbon	1.94	mg/L
MW-151B-25	10-55	Off-site	MW-151B	5/25/2011		Total Organic Carbon	1.81	mg/L
MW-151B-25	10-55	Off-site	MW-151B	8/9/2011		Total Organic Carbon	2.24	mg/L
MW-151B-25	10-55	Off-site	MW-151B	10/11/2011		Total Organic Carbon	2.29	mg/L
MW-151B-25	10-55	Off-site	MW-151B	4/30/2012		Total Organic Carbon	2.19	mg/L
MW-151B-25	10-55	Off-site	MW-151B	11/10/2012		Total Organic Carbon	1.71	mg/L
MW-151B-25	10-55	Off-site	MW-151B	4/15/2013		Total Organic Carbon	1.69	mg/L
MW-152A-15	Water Table	Off-site	MW-152A	8/8/2011		Total Organic Carbon	3.33	mg/L
MW-152A-15	Water Table	Off-site	MW-152A	10/11/2011		Total Organic Carbon	2.50	mg/L
MW-152A-15	Water Table	Off-site	MW-152A	7/31/2012		Total Organic Carbon	2.52	mg/L
MW-152A-15	Water Table	Off-site	MW-152A	11/9/2012		Total Organic Carbon	2.11	mg/L
MW-152B-25	10-55	Off-site	MW-152B	8/8/2011		Total Organic Carbon	2.26	mg/L
MW-152B-25	10-55	Off-site	MW-152B	10/11/2011		Total Organic Carbon	2.15	mg/L
MW-152B-25	10-55	Off-site	MW-152B	11/9/2012		Total Organic Carbon	1.81	mg/L

Table 7-6
Total Organic Carbon Analytical Results in Offsite Groundwater Monitoring Wells

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Location Name	Zone	Proximity	Sample Name	Sample Date	Sample Type	Analyte	Display	Units
MW-156A-15	Water Table	Off-site	MW-156A	3/7/2011		Total Organic Carbon	6.97	mg/L
MW-156A-15	Water Table	Off-site	MW-256A	8/9/2011	DUP	Total Organic Carbon	8.11	mg/L
MW-156A-15	Water Table	Off-site	MW-156A	8/9/2011		Total Organic Carbon	7.84	mg/L
MW-156A-15	Water Table	Off-site	MW-156A	10/11/2011		Total Organic Carbon	10.1	mg/L
MW-156A-15	Water Table	Off-site	MW-156A	4/27/2012		Total Organic Carbon	4.46	mg/L
MW-156A-15	Water Table	Off-site	MW-256A	10/31/2012	DUP	Total Organic Carbon	8.08	mg/L
MW-156A-15	Water Table	Off-site	MW-156A	10/31/2012		Total Organic Carbon	8.09	mg/L
MW-156A-15	Water Table	Off-site	MW-156A	3/9/2013		Total Organic Carbon	4.27	mg/L
MW-156B-50	10-55	Off-site	MW-156B	3/7/2011		Total Organic Carbon	1.80	mg/L
MW-156B-50	10-55	Off-site	MW-156B	8/10/2011		Total Organic Carbon	2.42	mg/L
MW-156B-50	10-55	Off-site	MW-156B	10/11/2011		Total Organic Carbon	1.82	mg/L
MW-156B-50	10-55	Off-site	MW-156B	10/31/2012		Total Organic Carbon	1.72	mg/L
MW-156B-50	10-55	Off-site	MW-156B	3/9/2013		Total Organic Carbon	1.66	mg/L
MW-157A-15	Water Table	Off-site	MW-157	2/18/2011		Total Organic Carbon	2.66	mg/L
MW-157A-15	Water Table	Off-site	MW-157	4/12/2011		Total Organic Carbon	3.13	mg/L
MW-157A-15	Water Table	Off-site	MW-157	8/8/2011		Total Organic Carbon	3.29	mg/L
MW-157A-15	Water Table	Off-site	MW-157A	10/11/2011		Total Organic Carbon	3.41	mg/L
MW-157A-15	Water Table	Off-site	MW-157A	4/27/2012		Total Organic Carbon	2.53	mg/L
MW-157A-15	Water Table	Off-site	MW-157A	10/31/2012		Total Organic Carbon	2.66	mg/L
MW-157A-15	Water Table	Off-site	MW-257A	4/12/2013	DUP	Total Organic Carbon	2.73	mg/L
MW-157A-15	Water Table	Off-site	MW-157A	4/12/2013		Total Organic Carbon	2.51	mg/L
MW-158A-15	Water Table	Off-site	MW-158A	3/8/2011		Total Organic Carbon	18.2	mg/L
MW-158A-15	Water Table	Off-site	MW-158A	3/10/2011		Total Organic Carbon	16.8	mg/L
MW-158A-15	Water Table	Off-site	MW-158A	8/10/2011		Total Organic Carbon	25.2	mg/L
MW-158A-15	Water Table	Off-site	MW-158A	10/11/2011		Total Organic Carbon	34.4	mg/L
MW-158A-15	Water Table	Off-site	MW-258A	4/28/2012	DUP	Total Organic Carbon	14.0	mg/L
MW-158A-15	Water Table	Off-site	MW-158A	4/28/2012		Total Organic Carbon	14.1	mg/L
MW-158A-15	Water Table	Off-site	MW-258A	7/31/2012	DUP	Total Organic Carbon	15.7	mg/L
MW-158A-15	Water Table	Off-site	MW-158A	7/31/2012		Total Organic Carbon	15.3	mg/L
MW-158A-15	Water Table	Off-site	MW-158A	11/9/2012		Total Organic Carbon	15.4	mg/L
MW-158B-60	10-55	Off-site	MW-158B	3/10/2011		Total Organic Carbon	2.05	mg/L
MW-158B-60	10-55	Off-site	MW-158B	7/31/2012		Total Organic Carbon	1.67	mg/L
MW-159A-15	Water Table	Off-site	MW-259	4/15/2011	DUP	Total Organic Carbon	3.00	mg/L
MW-159A-15	Water Table	Off-site	MW-159	4/15/2011		Total Organic Carbon	2.52	mg/L
MW-159A-15	Water Table	Off-site	MW-159	8/10/2011		Total Organic Carbon	4.80	mg/L
MW-159A-15	Water Table	Off-site	MW-159A	10/11/2011		Total Organic Carbon	5.29	mg/L
MW-159A-15	Water Table	Off-site	MW-159A	4/28/2012		Total Organic Carbon	2.62	mg/L

Table 7-6
Total Organic Carbon Analytical Results in Offsite Groundwater Monitoring Wells

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North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Location Name	Zone	Proximity	Sample Name	Sample Date	Sample Type	Analyte	Display	Units
MW-159A-15	Water Table	Off-site	MW-159A	10/31/2012		Total Organic Carbon	4.37	mg/L
MW-159A-15	Water Table	Off-site	MW-159A	4/12/2013		Total Organic Carbon	2.40	mg/L
MW-160B-90	55-90	Off-site	MW-160B	7/31/2012		Total Organic Carbon	1.42	mg/L
MW-161A-15	Water Table	Off-site	MW-161A	3/8/2011		Total Organic Carbon	3.36	mg/L
MW-161A-15	Water Table	Off-site	MW-161A	5/25/2011		Total Organic Carbon	3.51	mg/L
MW-161A-15	Water Table	Off-site	MW-261A	8/6/2011	DUP	Total Organic Carbon	3.58	mg/L
MW-161A-15	Water Table	Off-site	MW-161A	8/6/2011		Total Organic Carbon	3.70	mg/L
MW-161A-15	Water Table	Off-site	MW-161A	10/11/2011		Total Organic Carbon	3.44	mg/L
MW-161A-15	Water Table	Off-site	MW-261A	10/11/2011	DUP	Total Organic Carbon	4.01	mg/L
MW-161A-15	Water Table	Off-site	MW-161A	5/3/2012		Total Organic Carbon	3.41	mg/L
MW-161A-15	Water Table	Off-site	MW-161A	10/22/2012		Total Organic Carbon	3.19	mg/L
MW-161A-15	Water Table	Off-site	MW-161A	5/3/2013		Total Organic Carbon	3.22	mg/L
MW-161B-50	10-55	Off-site	MW-161B	10/11/2011		Total Organic Carbon	3.10	mg/L
MW-161B-50	10-55	Off-site	MW-161B	5/1/2012		Total Organic Carbon	11.2	mg/L
MW-161B-50	10-55	Off-site	MW-161B	10/25/2012		Total Organic Carbon	2.20	mg/L
MW-161B-50	10-55	Off-site	MW-261B	5/3/2013	DUP	Total Organic Carbon	2.40	mg/L
MW-161B-50	10-55	Off-site	MW-161B	5/3/2013		Total Organic Carbon	2.37	mg/L
MW-162A-15	Water Table	Off-site	MW-162A	2/18/2011		Total Organic Carbon	5.79	mg/L
MW-162A-15	Water Table	Off-site	MW-262A	3/10/2011	DUP	Total Organic Carbon	6.46	mg/L
MW-162A-15	Water Table	Off-site	MW-162A	3/10/2011		Total Organic Carbon	6.54	mg/L
MW-162A-15	Water Table	Off-site	MW-162A	8/6/2011		Total Organic Carbon	8.05	mg/L
MW-162A-15	Water Table	Off-site	MW-162A	10/11/2011		Total Organic Carbon	7.94	mg/L
MW-162A-15	Water Table	Off-site	MW-162A	10/31/2012		Total Organic Carbon	7.62	mg/L
MW-162B-65	10-55	Off-site	MW-162B	2/18/2011		Total Organic Carbon	2.30	mg/L
MW-162B-65	10-55	Off-site	MW-162B	3/10/2011		Total Organic Carbon	2.17	mg/L
MW-162B-65	10-55	Off-site	MW-162B	8/6/2011		Total Organic Carbon	2.54	mg/L
MW-162B-65	10-55	Off-site	MW-162B	10/11/2011		Total Organic Carbon	2.26	mg/L
MW-162B-65	10-55	Off-site	MW-162B	10/31/2012		Total Organic Carbon	2.09	mg/L
MW-163A-15	Water Table	Off-site	MW-163A	2/25/2011		Total Organic Carbon	2.24	mg/L
MW-163A-15	Water Table	Off-site	MW-163A	3/9/2011		Total Organic Carbon	2.72	mg/L
MW-163A-15	Water Table	Off-site	MW-163A	4/12/2011		Total Organic Carbon	2.86	mg/L
MW-163A-15	Water Table	Off-site	MW-163A	8/5/2011		Total Organic Carbon	3.84	mg/L
MW-163A-15	Water Table	Off-site	MW-163A	10/11/2011		Total Organic Carbon	3.29	mg/L
MW-163A-15	Water Table	Off-site	MW-163A	4/26/2012		Total Organic Carbon	2.75	mg/L
MW-163A-15	Water Table	Off-site	MW-163A	10/30/2012		Total Organic Carbon	2.79	mg/L
MW-163A-15	Water Table	Off-site	MW-263A	5/3/2013	DUP	Total Organic Carbon	2.50	mg/L
MW-163A-15	Water Table	Off-site	MW-163A	5/3/2013		Total Organic Carbon	2.74	mg/L

Table 7-6
Total Organic Carbon Analytical Results in Offsite Groundwater Monitoring Wells

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North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Location Name	Zone	Proximity	Sample Name	Sample Date	Sample Type	Analyte	Display	Units
MW-163B-40	10-55	Off-site	MW-163B	3/9/2011		Total Organic Carbon	2.31	mg/L
MW-163B-40	10-55	Off-site	MW-163B	10/11/2011		Total Organic Carbon	2.50	mg/L
MW-164A-15	Water Table	Off-site	MW-164A	2/24/2011		Total Organic Carbon	3.94	mg/L
MW-164A-15	Water Table	Off-site	MW-164A	3/10/2011		Total Organic Carbon	4.62	mg/L
MW-164A-15	Water Table	Off-site	MW-164A	4/6/2011		Total Organic Carbon	4.40	mg/L
MW-164A-15	Water Table	Off-site	MW-164A	8/9/2011		Total Organic Carbon	13.3	mg/L
MW-164A-15	Water Table	Off-site	MW-164A	10/11/2011		Total Organic Carbon	5.71	mg/L
MW-164A-15	Water Table	Off-site	MW-164A	4/26/2012		Total Organic Carbon	4.94	mg/L
MW-164A-15	Water Table	Off-site	MW-164A	10/25/2012		Total Organic Carbon	7.11	mg/L
MW-164A-15	Water Table	Off-site	MW-164A	5/2/2013		Total Organic Carbon	5.25	mg/L
MW-164B-50	10-55	Off-site	MW-164B	3/10/2011		Total Organic Carbon	3.48	mg/L
MW-165A-15	Water Table	Off-site	MW-165A	2/24/2011		Total Organic Carbon	3.29	mg/L
MW-165A-15	Water Table	Off-site	MW-165A	8/9/2011		Total Organic Carbon	3.91	mg/L
MW-165A-15	Water Table	Off-site	MW-165A	10/11/2011		Total Organic Carbon	3.99	mg/L
MW-165A-15	Water Table	Off-site	MW-165A	4/26/2012		Total Organic Carbon	11.3	mg/L
MW-165A-15	Water Table	Off-site	MW-165A	10/26/2012		Total Organic Carbon	4.48	mg/L
MW-166A-15	Water Table	Off-site	MW-166A	10/11/2011		Total Organic Carbon	7.28	mg/L
MW-166A-15	Water Table	Off-site	MW-166A	10/8/2012		Total Organic Carbon	6.26	mg/L
MW-166B-30	10-55	Off-site	MW-166B	10/11/2011		Total Organic Carbon	5.16	mg/L
MW-166B-30	10-55	Off-site	MW-266B	10/23/2012	DUP	Total Organic Carbon	4.56	mg/L
MW-166B-30	10-55	Off-site	MW-166B	10/23/2012		Total Organic Carbon	4.71	mg/L
MW-167A-15	Water Table	Off-site	MW-167A	2/24/2011		Total Organic Carbon	5.52	mg/L
MW-167A-15	Water Table	Off-site	MW-167A	3/9/2011		Total Organic Carbon	6.25	mg/L
MW-167A-15	Water Table	Off-site	MW-167A	4/7/2011		Total Organic Carbon	7.12	mg/L
MW-167A-15	Water Table	Off-site	MW-167A	8/5/2011		Total Organic Carbon	7.34	mg/L
MW-167A-15	Water Table	Off-site	MW-167A	10/11/2011		Total Organic Carbon	5.87	mg/L
MW-167A-15	Water Table	Off-site	MW-167A	4/25/2012		Total Organic Carbon	5.53	mg/L
MW-167A-15	Water Table	Off-site	MW-167A	10/25/2012		Total Organic Carbon	5.95	mg/L
MW-167A-15	Water Table	Off-site	MW-167A	5/2/2013		Total Organic Carbon	6.08	mg/L
MW-167B-35	10-55	Off-site	MW-167B	2/24/2011		Total Organic Carbon	5.30	mg/L
MW-167B-35	10-55	Off-site	MW-167B	3/9/2011		Total Organic Carbon	5.82	mg/L
MW-167B-35	10-55	Off-site	MW-167B	4/7/2011		Total Organic Carbon	6.26	mg/L
MW-167B-35	10-55	Off-site	MW-167B	8/5/2011		Total Organic Carbon	6.28	mg/L
MW-167B-35	10-55	Off-site	MW-167B	10/11/2011		Total Organic Carbon	5.48	mg/L
MW-167B-35	10-55	Off-site	MW-167B	4/25/2012		Total Organic Carbon	5.42	mg/L
MW-167B-35	10-55	Off-site	MW-167B	10/25/2012		Total Organic Carbon	5.75	mg/L
MW-167B-35	10-55	Off-site	MW-167B	5/2/2013		Total Organic Carbon	5.32	mg/L

Table 7-6
Total Organic Carbon Analytical Results in Offsite Groundwater Monitoring Wells

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North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Location Name	Zone	Proximity	Sample Name	Sample Date	Sample Type	Analyte	Display	Units
MW-168A-15	Water Table	Off-site	MW-168	2/25/2011		Total Organic Carbon	3.52	mg/L
MW-168A-15	Water Table	Off-site	MW-168	10/11/2011		Total Organic Carbon	3.81	mg/L
MW-168A-15	Water Table	Off-site	MW-168A	10/26/2012		Total Organic Carbon	3.97	mg/L
MW-169A-15	Water Table	Off-site	MW-169A	4/27/2012		Total Organic Carbon	2.42	mg/L
MW-169A-15	Water Table	Off-site	MW-269A	10/23/2012	DUP	Total Organic Carbon	2.34	mg/L
MW-169A-15	Water Table	Off-site	MW-169A	10/23/2012		Total Organic Carbon	2.34	mg/L
MW-169A-15	Water Table	Off-site	MW-169A	3/22/2013		Total Organic Carbon	1.82	mg/L
MW-169C-60	10-55	Off-site	MW-169C	4/27/2012		Total Organic Carbon	1.72	mg/L
MW-169C-60	10-55	Off-site	MW-169C	10/23/2012		Total Organic Carbon	1.72JH*	mg/L
MW-169C-60	10-55	Off-site	MW-169C	3/22/2013		Total Organic Carbon	2.45	mg/L
MW-170A-15	Water Table	Off-site	MW-170A	3/6/2011		Total Organic Carbon	5.00	mg/L
MW-170A-15	Water Table	Off-site	MW-170A	4/7/2011		Total Organic Carbon	6.01	mg/L
MW-170A-15	Water Table	Off-site	MW-170A	8/8/2011		Total Organic Carbon	6.54	mg/L
MW-170A-15	Water Table	Off-site	MW-170A	10/11/2011		Total Organic Carbon	8.47	mg/L
MW-170A-15	Water Table	Off-site	MW-270A	10/11/2011	DUP	Total Organic Carbon	7.31	mg/L
MW-170A-15	Water Table	Off-site	MW-170A	4/30/2012		Total Organic Carbon	5.83	mg/L
MW-170A-15	Water Table	Off-site	MW-170A	10/31/2012		Total Organic Carbon	6.23	mg/L
MW-170A-15	Water Table	Off-site	MW-270A	5/6/2013	DUP	Total Organic Carbon	5.70	mg/L
MW-170A-15	Water Table	Off-site	MW-170A	5/6/2013		Total Organic Carbon	5.69	mg/L
MW-171A-15	Water Table	Off-site	MW-171A	3/4/2011		Total Organic Carbon	6.98	mg/L
MW-171A-15	Water Table	Off-site	MW-171A	3/4/2011		Total Organic Carbon	7.00	mg/L
MW-171A-15	Water Table	Off-site	MW-171A	4/7/2011		Total Organic Carbon	6.76	mg/L
MW-171A-15	Water Table	Off-site	MW-171A	8/5/2011		Total Organic Carbon	10.9	mg/L
MW-171A-15	Water Table	Off-site	MW-171A	10/11/2011		Total Organic Carbon	10.7	mg/L
MW-171A-15	Water Table	Off-site	MW-271A	4/26/2012	DUP	Total Organic Carbon	6.05	mg/L
MW-171A-15	Water Table	Off-site	MW-171A	4/26/2012		Total Organic Carbon	6.21	mg/L
MW-171A-15	Water Table	Off-site	MW-171A	10/30/2012		Total Organic Carbon	10.5	mg/L
MW-171A-15	Water Table	Off-site	MW-271A	4/1/2013	DUP	Total Organic Carbon	5.33	mg/L
MW-171A-15	Water Table	Off-site	MW-171A	4/1/2013		Total Organic Carbon	5.49	mg/L
MW-171B-40	10-55	Off-site	MW-271B	3/4/2011	DUP	Total Organic Carbon	4.11	mg/L
MW-171B-40	10-55	Off-site	MW-171B	3/4/2011		Total Organic Carbon	4.09	mg/L
MW-171B-40	10-55	Off-site	MW-171B	3/4/2011		Total Organic Carbon	4.07	mg/L
MW-171B-40	10-55	Off-site	MW-171B	4/7/2011		Total Organic Carbon	4.30	mg/L
MW-171B-40	10-55	Off-site	MW-171B	8/5/2011		Total Organic Carbon	3.76	mg/L
MW-171B-40	10-55	Off-site	MW-171B	10/11/2011		Total Organic Carbon	3.35	mg/L
MW-171B-40	10-55	Off-site	MW-171B	4/26/2012		Total Organic Carbon	3.43	mg/L
MW-171B-40	10-55	Off-site	MW-171B	10/30/2012		Total Organic Carbon	3.39	mg/L

Table 7-6
Total Organic Carbon Analytical Results in Offsite Groundwater Monitoring Wells

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Location Name	Zone	Proximity	Sample Name	Sample Date	Sample Type	Analyte	Display	Units
MW-171B-40	10-55	Off-site	MW-171B	4/2/2013		Total Organic Carbon	3.46	mg/L
MW-182A-15	Water Table	Off-site	MW-182A	10/11/2011		Total Organic Carbon	5.25	mg/L
MW-182A-15	Water Table	Off-site	MW-182A	4/25/2012		Total Organic Carbon	5.07	mg/L
MW-182A-15	Water Table	Off-site	MW-182A	10/19/2012		Total Organic Carbon	8.14JL*	mg/L
MW-182A-15	Water Table	Off-site	MW-182A	5/2/2013		Total Organic Carbon	5.00	mg/L
MW-193A-15	Water Table	Off-site	MW-193A	4/27/2012		Total Organic Carbon	7.27	mg/L
MW-193A-15	Water Table	Off-site	MW-193A	10/18/2012		Total Organic Carbon	5.00	mg/L
MW-193A-15	Water Table	Off-site	MW-193A	5/7/2013		Total Organic Carbon	6.15J*	mg/L
MW-193B-60	10-55	Off-site	MW-193B	4/27/2012		Total Organic Carbon	2.06	mg/L
MW-193B-60	10-55	Off-site	MW-193B	10/18/2012		Total Organic Carbon	2.02	mg/L
MW-193B-60	10-55	Off-site	MW-293B	5/7/2013	DUP	Total Organic Carbon	1.87	mg/L
MW-193B-60	10-55	Off-site	MW-193B	5/7/2013		Total Organic Carbon	1.76	mg/L

Acronyms and Abbreviations:
mg/L = milligrams per liter

Table 7-7
Total Organic Carbon Analytical Results in Private Wells with Point of Entry Treatment Systems

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Date	Category	Location	TOC (mg/L)
12/15/2010	In Home Pilot	PW-1098	4.29 JH
12/15/2010	In Home Pilot	PW-1098	2.84 JH
2/16/2011	In Home Pilot	PW-1098	1.590
2/23/2011	In Home Pilot	PW-1098	1.970
3/2/2011	In Home Pilot	PW-1098	2.570
3/9/2011	In Home Pilot	PW-1098	1.840
3/16/2011	In Home Pilot	PW-1098	2.620
3/23/2011	In Home Pilot	PW-1098	3.190
3/30/2011	In Home Pilot	PW-1098	3.000
4/6/2011	In Home Pilot	PW-1098	2.730
4/13/2011	In Home Pilot	PW-1098	2.550
4/20/2011	In Home Pilot	PW-1098	2.440
4/27/2011	In Home Pilot	PW-1098	2.670
5/4/2011	In Home Pilot	PW-1098	2.510
5/11/2011	In Home Pilot	PW-1098	2.590
6/8/2011	In Home Pilot	PW-1098	2.140
7/11/2011	In Home Pilot	PW-1098	3.050
8/9/2011	In Home Pilot	PW-1098	3.060
10/12/2011	In Home Pilot	PW-1098	2.280
11/14/2011	In Home Pilot	PW-1098	3.040
2/16/2011	In Home Pilot	PW-0657	3.630
2/23/2011	In Home Pilot	PW-0657	3.920
3/2/2011	In Home Pilot	PW-0657	4.880
3/9/2011	In Home Pilot	PW-0657	4.930
3/16/2011	In Home Pilot	PW-0657	5.060
3/23/2011	In Home Pilot	PW-0657	5.670
3/30/2011	In Home Pilot	PW-0657	5.610
4/6/2011	In Home Pilot	PW-0657	4.930
4/13/2011	In Home Pilot	PW-0657	4.920
4/20/2011	In Home Pilot	PW-0657	4.760
4/27/2011	In Home Pilot	PW-0657	5.230
5/4/2011	In Home Pilot	PW-0657	5.520
5/11/2011	In Home Pilot	PW-0657	5.140
6/8/2011	In Home Pilot	PW-0657	4.810
7/11/2011	In Home Pilot	PW-0657	4.990
8/9/2011	In Home Pilot	PW-0657	4.930
10/12/2011	In Home Pilot	PW-0657	5.700
11/14/2011	In Home Pilot	PW-0657	4.630
2/16/2011	In Home Pilot	PW-0157	1.620
2/23/2011	In Home Pilot	PW-0157	1.650
3/2/2011	In Home Pilot	PW-0157	2.020
3/9/2011	In Home Pilot	PW-0157	1.970
3/16/2011	In Home Pilot	PW-0157	2.030
3/23/2011	In Home Pilot	PW-0157	2.380
3/30/2011	In Home Pilot	PW-0157	2.780
4/6/2011	In Home Pilot	PW-0157	2.200
4/13/2011	In Home Pilot	PW-0157	2.150
4/20/2011	In Home Pilot	PW-0157	2.000
4/27/2011	In Home Pilot	PW-0157	2.180
5/4/2011	In Home Pilot	PW-0157	2.090
5/11/2011	In Home Pilot	PW-0157	2.140

Table 7-7
Total Organic Carbon Analytical Results in Private Wells with Point of Entry Treatment Systems

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Date	Category	Location	TOC (mg/L)
6/8/2011	In Home Pilot	PW-0157	1.770
7/11/2011	In Home Pilot	PW-0157	2.020
8/9/2011	In Home Pilot	PW-0157	2.210
10/12/2011	In Home Pilot	PW-0157	2.810
11/14/2011	In Home Pilot	PW-0157	2.100
2/16/2011	In Home Pilot	PW-0232	1.560
2/23/2011	In Home Pilot	PW-0232	1.700
3/2/2011	In Home Pilot	PW-0232	2.100
3/9/2011	In Home Pilot	PW-0232	1.970
3/16/2011	In Home Pilot	PW-0232	2.090
3/23/2011	In Home Pilot	PW-0232	3.040
4/6/2011	In Home Pilot	PW-0232	2.200
4/13/2011	In Home Pilot	PW-0232	2.110
4/20/2011	In Home Pilot	PW-0232	2.060
4/27/2011	In Home Pilot	PW-0232	2.450
5/4/2011	In Home Pilot	PW-0232	1.950
5/11/2011	In Home Pilot	PW-0232	2.250
2/16/2011	In Home Pilot	PW-0225	1.470
2/23/2011	In Home Pilot	PW-0225	1.440
3/16/2011	In Home Pilot	PW-0225	1.860
3/23/2011	In Home Pilot	PW-0225	2.170
3/30/2011	In Home Pilot	PW-0225	2.200
4/6/2011	In Home Pilot	PW-0225	2.030
4/13/2011	In Home Pilot	PW-0225	1.960
4/20/2011	In Home Pilot	PW-0225	1.860
4/27/2011	In Home Pilot	PW-0225	1.990
5/4/2011	In Home Pilot	PW-0225	1.890
5/11/2011	In Home Pilot	PW-0225	1.880
1/26/2011	Accelerated Pilot 1	PW-1348	2.500
1/27/2011	Accelerated Pilot 1	PW-1348	3.200
1/27/2011	Accelerated Pilot 1	PW-1348	2.300
1/27/2011	Accelerated Pilot 1	PW-1348	2.500
1/28/2011	Accelerated Pilot 1	PW-1348	2.600
1/28/2011	Accelerated Pilot 1	PW-1348	2.300
1/28/2011	Accelerated Pilot 1	PW-1348	2.300
1/29/2011	Accelerated Pilot 1	PW-1348	2.200
1/29/2011	Accelerated Pilot 1	PW-1348	2.200
1/29/2011	Accelerated Pilot 1	PW-1348	3.400
1/30/2011	Accelerated Pilot 1	PW-1348	2.400
1/30/2011	Accelerated Pilot 1	PW-1348	2.100
1/30/2011	Accelerated Pilot 1	PW-1348	2.100
1/31/2011	Accelerated Pilot 1	PW-1348	2.100
1/31/2011	Accelerated Pilot 1	PW-1348	2.100
1/31/2011	Accelerated Pilot 1	PW-1348	2.500
2/1/2011	Accelerated Pilot 1	PW-1348	2.400
2/1/2011	Accelerated Pilot 1	PW-1348	3.600
2/1/2011	Accelerated Pilot 1	PW-1348	2.500
2/2/2011	Accelerated Pilot 1	PW-1348	2.700
2/2/2011	Accelerated Pilot 1	PW-1348	2.600
2/16/2011	Accelerated Pilot 2	PW-1348	3.200
2/17/2011	Accelerated Pilot 2	PW-1348	2.700

Table 7-7
Total Organic Carbon Analytical Results in Private Wells with Point of Entry Treatment Systems

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Date	Category	Location	TOC (mg/L)
2/18/2011	Accelerated Pilot 2	PW-1348	2.300
2/19/2011	Accelerated Pilot 2	PW-1348	2.200
2/20/2011	Accelerated Pilot 2	PW-1348	2.200
2/21/2011	Accelerated Pilot 2	PW-1348	2.500
2/22/2011	Accelerated Pilot 2	PW-1348	2.100
2/23/2011	Accelerated Pilot 2	PW-1348	2.700
2/24/2011	Accelerated Pilot 2	PW-1348	2.700
2/25/2011	Accelerated Pilot 2	PW-1348	2.900
2/26/2011	Accelerated Pilot 2	PW-1348	2.800
2/27/2011	Accelerated Pilot 2	PW-1348	2.600
2/28/2011	Accelerated Pilot 2	PW-1348	2.600
3/1/2011	Accelerated Pilot 2	PW-1348	2.400
3/2/2011	Accelerated Pilot 2	PW-1348	2.400
3/3/2011	Accelerated Pilot 2	PW-1348	2.300
3/4/2011	Accelerated Pilot 2	PW-1348	2.400
3/5/2011	Accelerated Pilot 2	PW-1348	2.600
3/6/2011	Accelerated Pilot 2	PW-1348	2.400
3/7/2011	Accelerated Pilot 2	PW-1348	2.600
12/15/2011	Treatment System Port A	PW-0648	5.9
12/15/2011	Treatment System Port B	PW-0648	5.4
12/15/2011	Treatment System Port C	PW-0648	2.7
12/15/2011	Treatment System Port D	PW-0648	1.8
12/15/2011	Kitchen	PW-0648	1
12/16/2011	Treatment System Port A	PW-1315	1.6
12/16/2011	Treatment System Port B	PW-1315	0.85
12/16/2011	Treatment System Port C	PW-1315	1.1
12/16/2011	Treatment System Port D	PW-1315	ND
12/16/2011	Mop	PW-1315	ND
12/16/2011	Kitchen	PW-1315	ND
12/15/2011	Tank	PW-0543	1.8
12/15/2011	Tub	PW-0543	1.8
12/15/2011	Kitchen	PW-0543	1.6
12/16/2011	Tank	PW-1376	1.7
12/16/2011	Kitchen	PW-1376	4.7
12/16/2011	Bathroom	PW-1376	1.5
12/16/2011	Treatment System Port A	PW-0504	13.6
12/16/2011	Treatment System Port B	PW-0504	2.9
12/16/2011	Treatment System Port C	PW-0504	ND
12/16/2011	Treatment System Port D	PW-0504	ND
12/16/2011	Kitchen	PW-0504	ND

Acronyms and Abbreviations:
JH = estimated result, biased high due to quality control sample failures.

Table 7-8
Total Organic Carbon Analytical Results in the Deep Private Well Monitoring Program

Offsite Site Characterization Report - 2013 Addendum
North Pole Refinery, North Pole, Alaska
Flint Hills Resources Alaska, LLC

Location Name	Sample Name	Sample Date	Sample Type	Analyte	Display	Units
PW-0217	290190	3/10/2011		Total Organic Carbon	2.87	mg/L
PW-0217	290190	3/11/2013		Total Organic Carbon	2.65	mg/L
PW-0217	290190	6/5/2013		Total Organic Carbon	2.49	mg/L
PW-0259	296406	4/4/2013		Total Organic Carbon	2.33	mg/L
PW-0259	296406	6/19/2013		Total Organic Carbon	2.40	mg/L
PW-0296	296937	3/21/2013		Total Organic Carbon	2.39	mg/L
PW-0296	296937	6/13/2013		Total Organic Carbon	2.48	mg/L
PW-0296	296937D	6/13/2013	DUP	Total Organic Carbon	2.48	mg/L
PW-0297	296937.1	3/21/2013		Total Organic Carbon	3.41	mg/L
PW-0297	296937.1	6/13/2013		Total Organic Carbon	3.83	mg/L
PW-0332	301671	4/19/2013		Total Organic Carbon	1.18J§*	mg/L
PW-0332	301671	6/20/2013		Total Organic Carbon	1.13	mg/L
PW-0355	302058	3/11/2011		Total Organic Carbon	2.63	mg/L
PW-0358	302082D	3/10/2011	DUP	Total Organic Carbon	1.57	mg/L
PW-0358	302082	3/10/2011		Total Organic Carbon	1.53	mg/L
PW-0358	302082	3/25/2013		Total Organic Carbon	3.70	mg/L
PW-0358	302082	6/12/2013		Total Organic Carbon	1.25	mg/L
PW-0359	302091	3/11/2011		Total Organic Carbon	2.63	mg/L
PW-0463	315192	4/4/2013		Total Organic Carbon	1.41	mg/L
PW-0463	315192	6/27/2013		Total Organic Carbon	1.29	mg/L
PW-0464	315206	3/28/2013		Total Organic Carbon	1.57	mg/L
PW-0464	315206	6/27/2013		Total Organic Carbon	1.43	mg/L
PW-0466	315290D	4/18/2013	DUP	Total Organic Carbon	2.85	mg/L
PW-0466	315290	4/18/2013		Total Organic Carbon	2.95	mg/L
PW-0466	315290	6/12/2013		Total Organic Carbon	2.90	mg/L
PW-0649	333778	3/12/2011		Total Organic Carbon	4.05	mg/L
PW-0658	333883	3/18/2013		Total Organic Carbon	3.43	mg/L
PW-0658	333883	6/12/2013		Total Organic Carbon	3.63	mg/L
PW-0659	333891	3/11/2011		Total Organic Carbon	1.71	mg/L
PW-0932	391409	3/20/2013		Total Organic Carbon	1.90	mg/L
PW-0932	391409	6/19/2013		Total Organic Carbon	1.84	mg/L
PW-0943	391565	3/12/2013		Total Organic Carbon	4.13	mg/L
PW-0943	391565	6/6/2013		Total Organic Carbon	4.17	mg/L
PW-0972	395200	3/17/2013		Total Organic Carbon	1.51	mg/L
PW-0972	395200D	6/20/2013	DUP	Total Organic Carbon	1.41	mg/L
PW-0972	395200	6/20/2013		Total Organic Carbon	1.40	mg/L
PW-1099	429724.1D	3/12/2013	DUP	Total Organic Carbon	1.75	mg/L
PW-1099	429724.1	3/12/2013		Total Organic Carbon	1.73	mg/L
PW-1099	429724.1	6/4/2013		Total Organic Carbon	1.67	mg/L
PW-1109	429929	3/13/2013		Total Organic Carbon	5.39	mg/L
PW-1109	429929	6/5/2013		Total Organic Carbon	5.42	mg/L
PW-1155	445657	3/18/2013		Total Organic Carbon	2.68	mg/L
PW-1155	445657	6/5/2013		Total Organic Carbon	2.65	mg/L
PW-1230	502774	3/11/2013		Total Organic Carbon	1.81	mg/L
PW-1230	502774	6/27/2013		Total Organic Carbon	3.28	mg/L
PW-1343	563579	3/20/2013		Total Organic Carbon	2.51	mg/L
PW-1343	563579	6/13/2013		Total Organic Carbon	2.06J§*	mg/L
PW-1458	395200.1	6/20/2013		Total Organic Carbon	2.31	mg/L

Acronyms and Abbreviations:
mg/L = milligrams per liter

ARCADIS

ARCADIS

Figures

LEGEND:

FHRA PROPERTY BOUNDARY

0 0.5 Miles

GRAPHIC SCALE

Note:
Image provided courtesy of Pictometry International 2012

FLINT HILLS RESOURCES ALASKA, LLC
NORTH POLE REFINERY, NORTH POLE, ALASKA

OFFSITE SITE CHARACTERIZATION REPORT – 2013 ADDENDUM

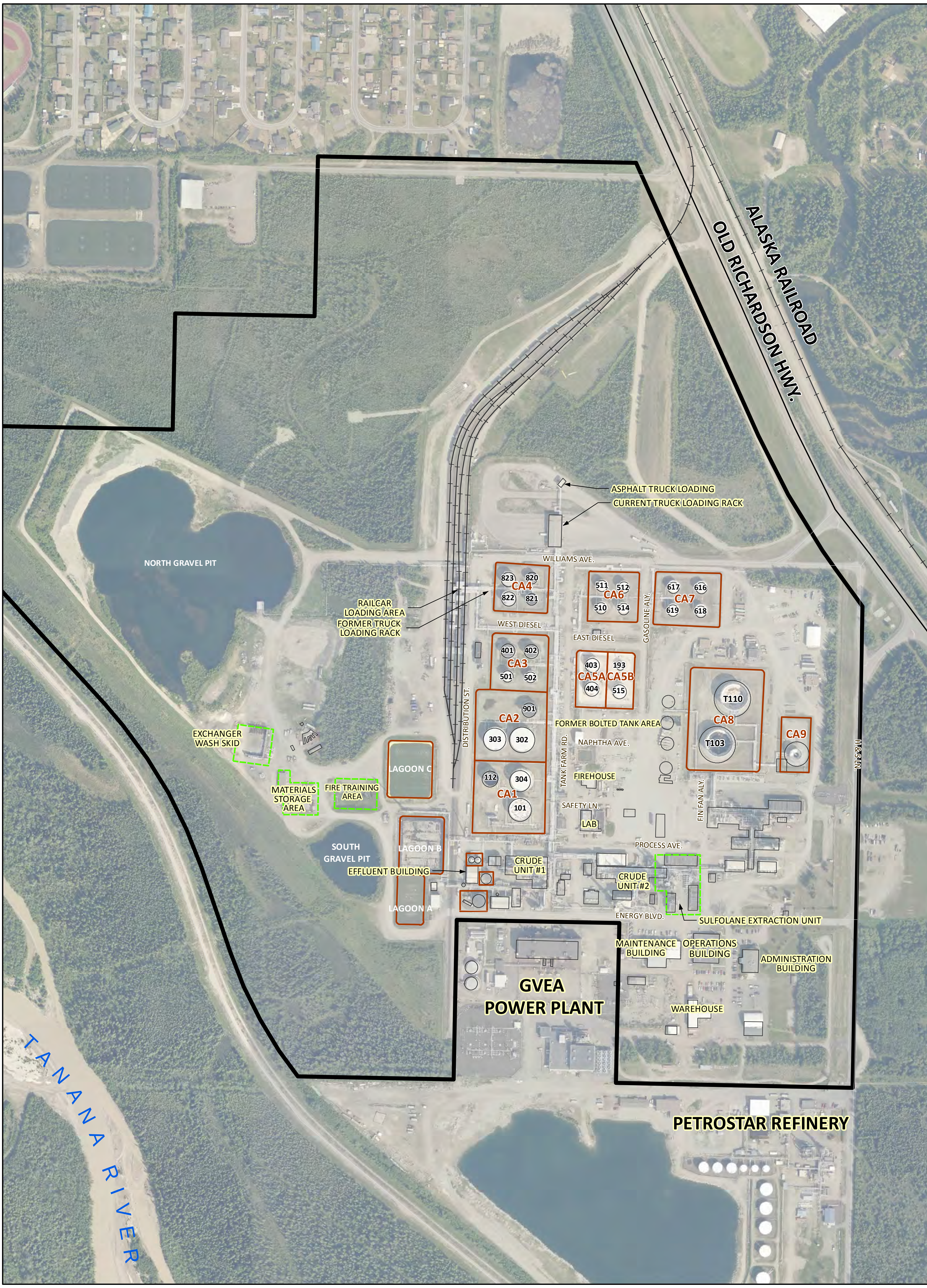
SITE LOCATION

ARCADIS

FIGURE
2-1

CITY: HIGHLANDS RANCH, CO DIV/GROUP: ENV/IM DB: BGriffith LD: G FRANCE
Path: W:\GISPrj\GISPROJECTS_ENV\FHR_AK\NorthPoleRefinery\SiteCharacterization2013\2013 Addendum\OFFSITE\Fig 2-1 SiteLocation.mxd Date: 12/4/2013 Time: 10:50:13 AM

CITY: HIGHLANDS RANCH, CO DIV/GROUP: ENV/IM DB: BGRIFFITH LD: G FRANCE
PATH: W:\GISPRJ\GISPROJECTS_ENV\FHR_AK\NORTHPOLEREFINERY\SITECHARACTERIZATION2013\2013 ADDENDUM\ONSITE\FIG 2-2 CURRENTSITEFEATURES.MXD DATE: 12/16/2013 TIME: 10:37:07 AM



Legend

- Bermed Containment Areas (CA)
- Approximate Area
- FHRA Property Boundary

Notes:

GVEA: Golden Valley Electrical Authority
Image provided courtesy of Pictometry International 2012

0 400 800
SCALE IN FEET

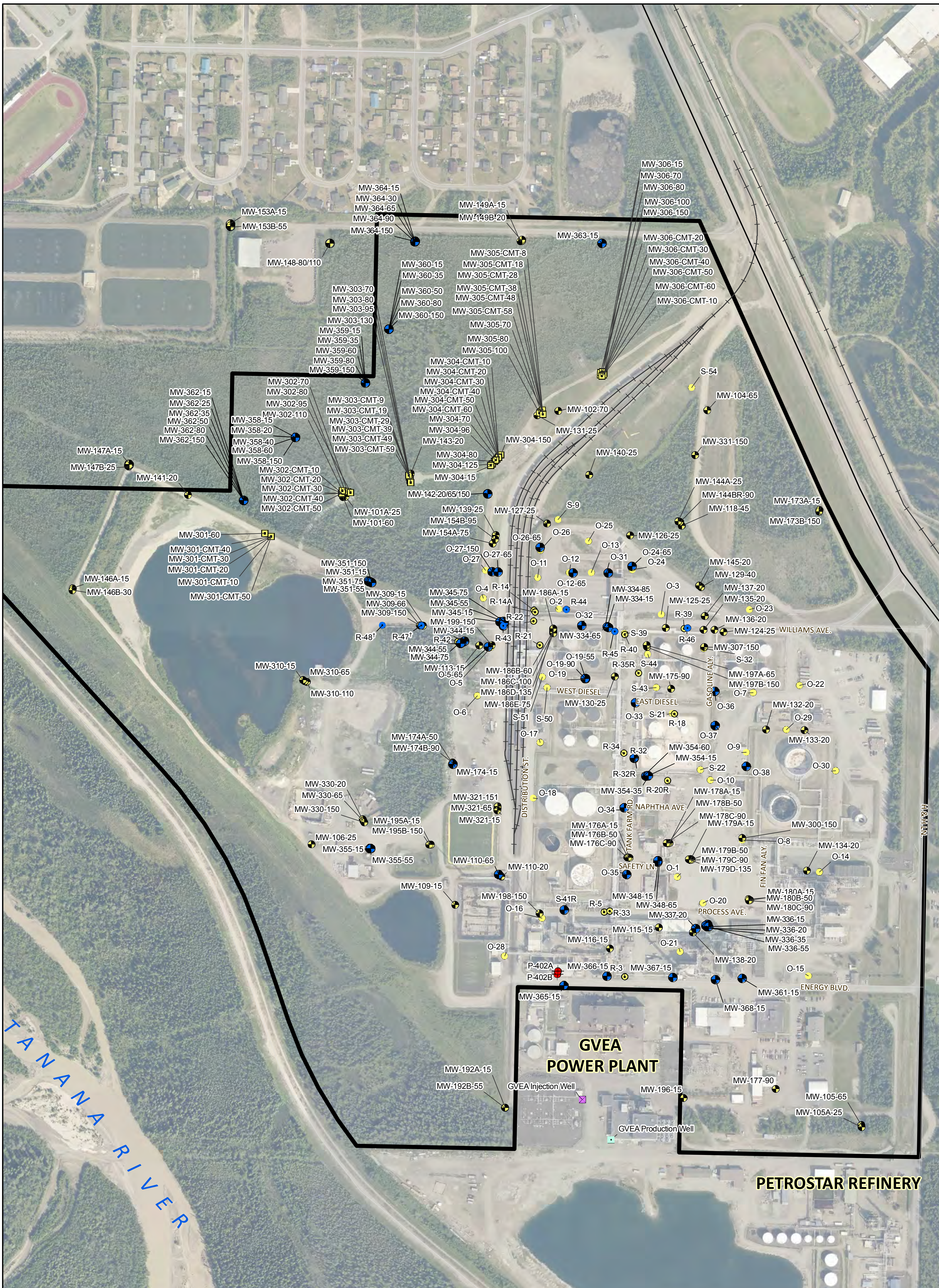
FLINT HILLS RESOURCES ALASKA, LLC
NORTH POLE REFINERY, NORTH POLE, ALASKA

OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

SITE FEATURES

ARCADIS

FIGURE
2-2



Legend

- Monitoring Well
- Observation Well
- Vertical Profile Transect Well
- Recovery Well
- Phase 8 Wells
- 2013 Recovery Wells
- GVEA Injection Well (Approximate)
- GVEA Production Well (Approximate)
- Production Wells (Approximate)
- FHRA Property Boundary

Notes:
-Phase 8 well locations are approximate
-†R-47 and R-48 were installed as part of EGWRT forecasting
-EGWRT = Expanded Groundwater Recovery and Treatment
-GVEA = Golden Valley Electrical Authority
-Image provided courtesy of Pictometry International 2012

0 400 800
SCALE IN FEET

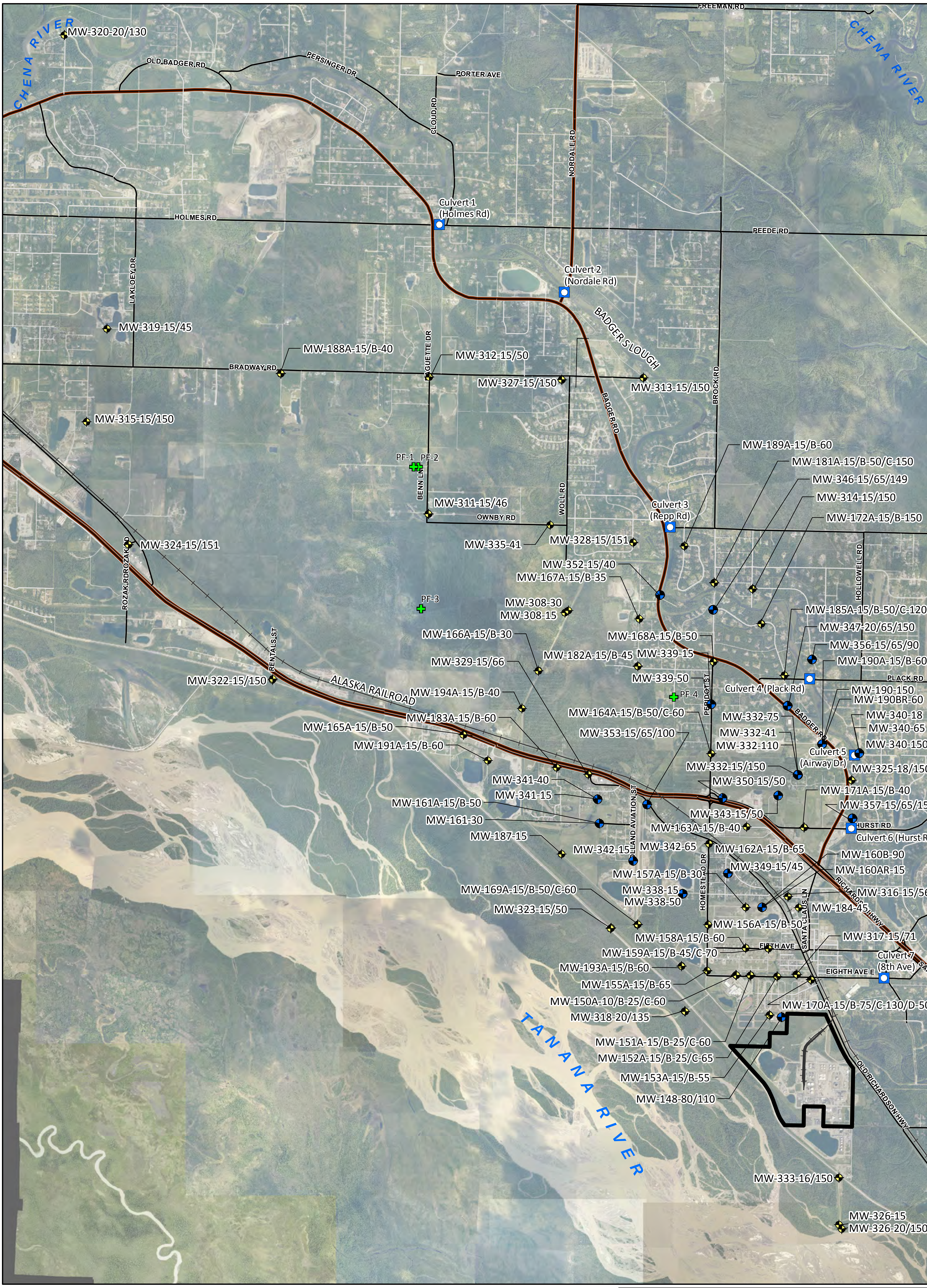
FLINT HILLS RESOURCES ALASKA, LLC
NORTH POLE REFINERY, NORTH POLE, ALASKA
OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

SITE PLAN - ONSITE

ARCADIS

FIGURE
2-3

CITY: HIGHLANDS RANCH, CO DIV/GROUP: ENV/IM DB: BGriffith LD: G FRANCE
Path: W:\GISPrj\GISPROJECTS_ENV\FHR_AK\NorthPoleRefinery\SiteCharacterization2013\2013 Addendum\OFFSITE\Fig 2-4 SitePlan_Offsite.mxd Date: 12/20/2013 Time: 12:18:35 PM



Legend:

- Monitoring Well
- Phase 8 Wells
- Permafrost Boring
- Culvert
- FHRA Property Boundary
- Highway
- Major Road
- Local Road
- Rail Line

0 3,000 6,000 Feet

GRAPHIC SCALE

Note:
Phase 8 well locations are approximate
Image provided courtesy of Pictometry International 2012

FLINT HILLS RESOURCES ALASKA, LLC
NORTH POLE REFINERY, NORTH POLE, ALASKA
OFFSITE SITE CHARACTERIZATION REPORT – 2013 ADDENDUM

SITE PLAN - OFFSITE

ARCADIS

FIGURE
2-4

CITY: HIGHLANDS RANCH, CO DIV/GROUP: ENV/IM DB: BGriffith LD: G FRANCE
Path: W:\GISPrj\GISPROJECTS_ENV\FHR_AK\NorthPoleRefinery\SiteCharacterization2013\2013 Addendum\OFFSITE\Fig 3-1 OffsitePhase8MW.mxd Date: 12/16/2013 Time: 5:38:55 PM

Legend:

- Phase 8 Wells
- Proposed Phase 8 Monitoring Wells
- FHRA Property Boundary
- Highway
- Major Road
- Local Road
- Rail Line

0 1,800 3,600 Feet

GRAPHIC SCALE

Note:
-Phase 8 well locations are approximate
-Proposed monitoring well locations 8-U and 8-P were not installed due to access restrictions and shallow permafrost, respectively
-Image provided courtesy of Pictometry International 2012

FLINT HILLS RESOURCES ALASKA, LLC
NORTH POLE REFINERY, NORTH POLE, ALASKA
OFFSITE SITE CHARACTERIZATION REPORT – 2013 ADDENDUM

OFFSITE PHASE 8 MONITORING WELLS

ARCADIS

FIGURE
3-1

MW-352-40

Depth	TOC
15-16.5	0.0599
42.5-44	0.0825

MW-347-65

Depth	TOC
35.5-36.5	0.0648
62-63	0.0594

MW-347-150

Depth	TOC
90.7-91.0	0.0301J
148.4-148.7	0.0624

MW-350-50

Depth	TOC
20-21.5	0.0542J
50-51.1	0.0783

MW-353-65

Depth	TOC
35-36.5	0.0522J
62-63.5	0.118

MW-353-100

Depth	TOC
50.0-51.5	0.0708
110-111.5	0.0386J

Legend

Monitoring Well

Note:
1. TOC = total organic carbon in %
2. J = Estimated concentration, detected above the detection limit (DL) and below the limit of quantification (LOQ).
3. Sampling depth is provided as feet below ground surface.

Image provided courtesy of Pictometry International 2012

0 1,000 2,000
SCALE IN FEET

FLINT HILLS RESOURCES ALASKA, LLC
NORTH POLE REFINERY, NORTH POLE, ALASKA
OFFSITE SITE CHARACTERIZATION REPORT – 2013 ADDENDUM

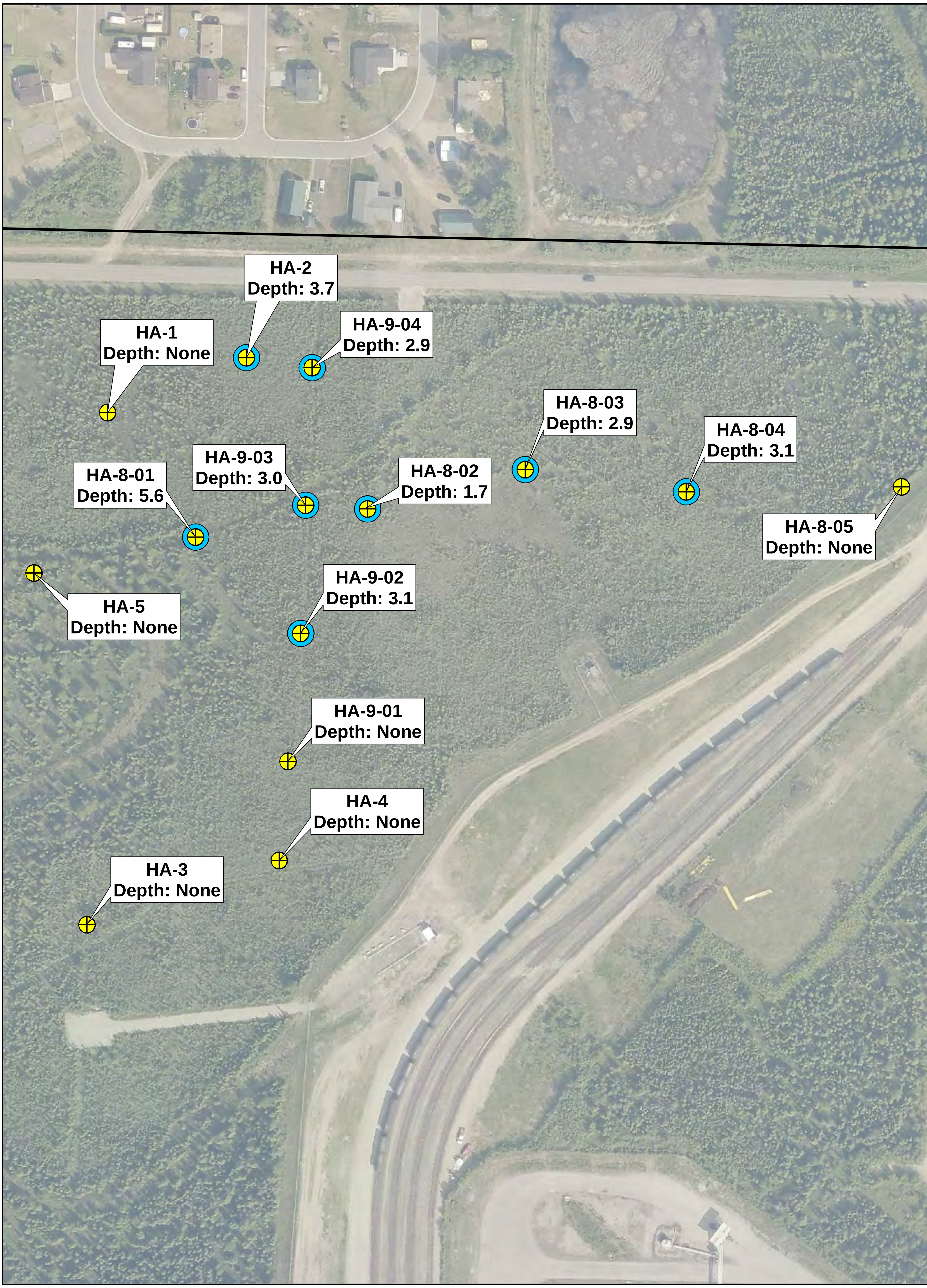
TOTAL ORGANIC CARBON IN SOIL

ARCADIS

FIGURE
3-2

CITY:Highlands Ranch, CO DIV/GROUP:(ENV/GIS) DB: BGriffith
Path: W:\GIS\PJ\GIS\PROJECTS_ENV\FHR_AK\NorthPoleRefinery\SiteCharacterization\2013\2013 Addendum\mxd\OFFSITE\Fig 3-2 TotalOrganicCarbon_Soil.mxd Date: 12/12/2013 Time: 7:32:08 PM

CITY: HIGHLANDS RANCH, CO DIV/GROUP: ENV/IM DB: L DRUM LD: G FRANCE
PATH: W:\GISPRJ\GISPROJECTS_ENV\FHR_AK\NORTHPOLEREFINERY\SITECHARACTERIZATION2013\2013 ADDENDUM\ONSITE\FIG 5-1 SHALLOWPERMAFROST_HANDAUGERLOCATIONS.MXD DATE: 12/16/2013 TIME: 7:16:18 AM



Legend
- No Permafrost Encountered
- Permafrost Encountered
- FHRA Property Boundary

0 130 260
SCALE IN FEET

Notes:
Image provided courtesy of Pictometry International 2012

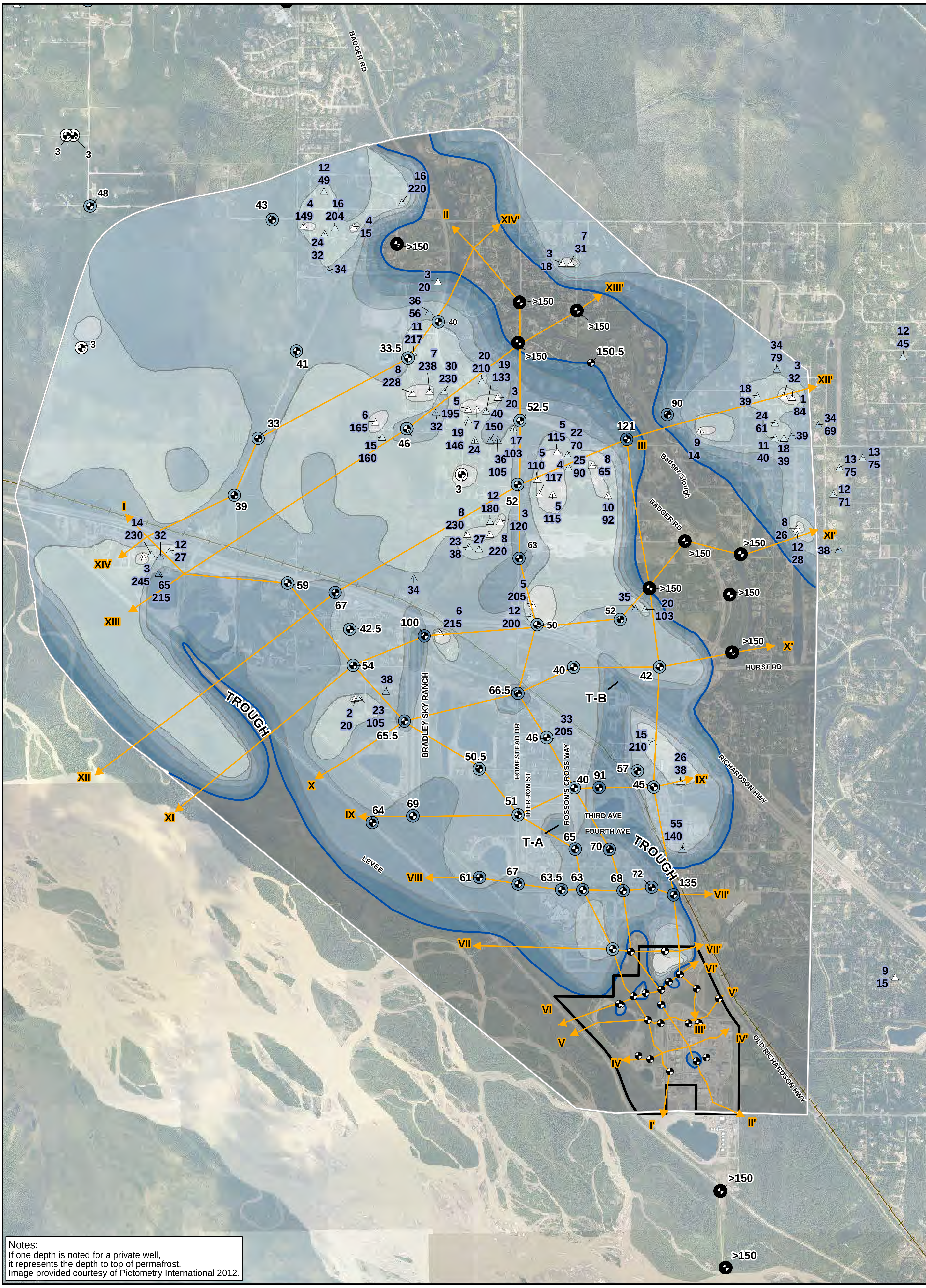
FLINT HILLS RESOURCES ALASKA, LLC
NORTH POLE REFINERY, NORTH POLE, ALASKA
OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

SHALLOW PERMAFROST HAND AUGER LOCATIONS

ARCADIS

FIGURE
4-1

CITY: SF DIV/GROUP: ENV/IM DB: ARM2 LD: PIC: PM: TM: TR:
PROJECT: (PROJECT #)
PATH: I:\Client\FlintHills\Alaska\ReportMaps\NPR\Site_Characterization_Report_2013_Addendum\Geo_PF\ARCADIS Figure 4-2 DepthToPermafrost.mxd 12/19/2013 2:43:32 PM



Notes:
If one depth is noted for a private well,
it represents the depth to top of permafrost.
Image provided courtesy of Pictometry International 2012.

Legend

- Monitoring Well with Depth to Top of Permafrost in Feet bgs
- Private Well with Depth to Top and Bottom of Permafrost in Feet bgs
- Cross-Section Locations
- Area of Interpretation
- FHRA Property Boundary
- T : Talik inferred from geophysical survey

Depth to Top of Permafrost in feet

- < 10
- 10 - 30
- 30 - 60
- 60 - 90
- 90 - 120
- 120 - 150
- > 150

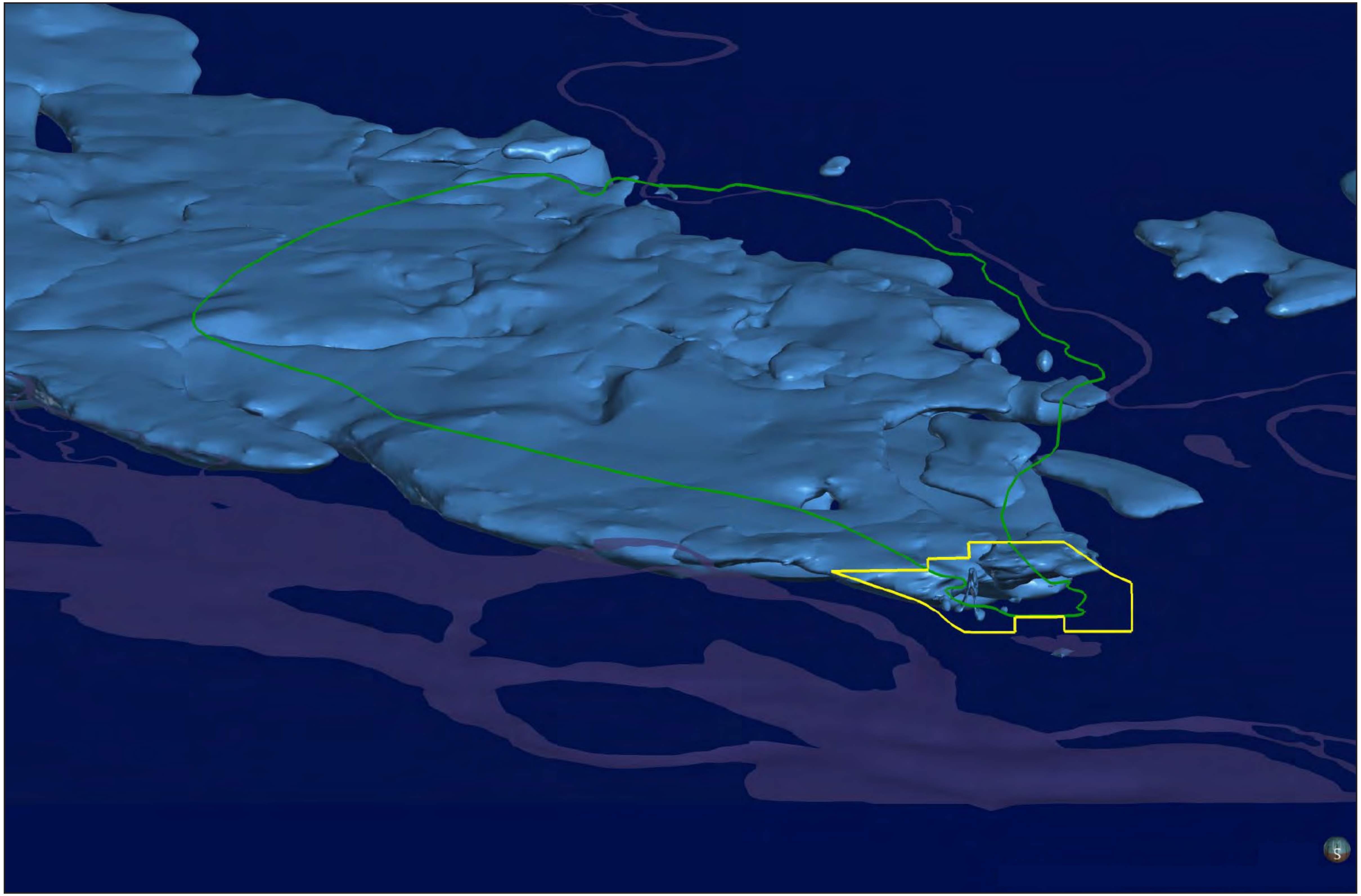
0 2,200 4,400
SCALE IN FEET

FLINT HILLS RESOURCES ALASKA, LLC
NORTH POLE REFINERY, NORTH POLE, ALASKA
OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

DEPTH TO PERMAFROST

ARCADIS

FIGURE
4-2

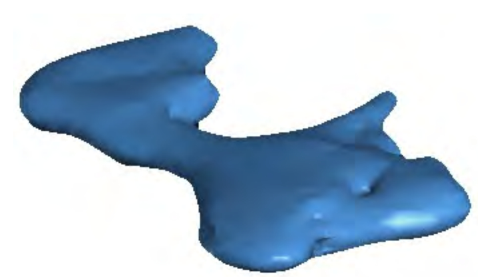


Property boundary

Non-detect boundary

0 500 1,000 1,500

Plunge +20
Looking North



Permafrost

* All data (borelogs, geophysics, etc.) available to view in the viewerfile included as a data CD

FLINT HILLS RESOURCES ALASKA, LLC
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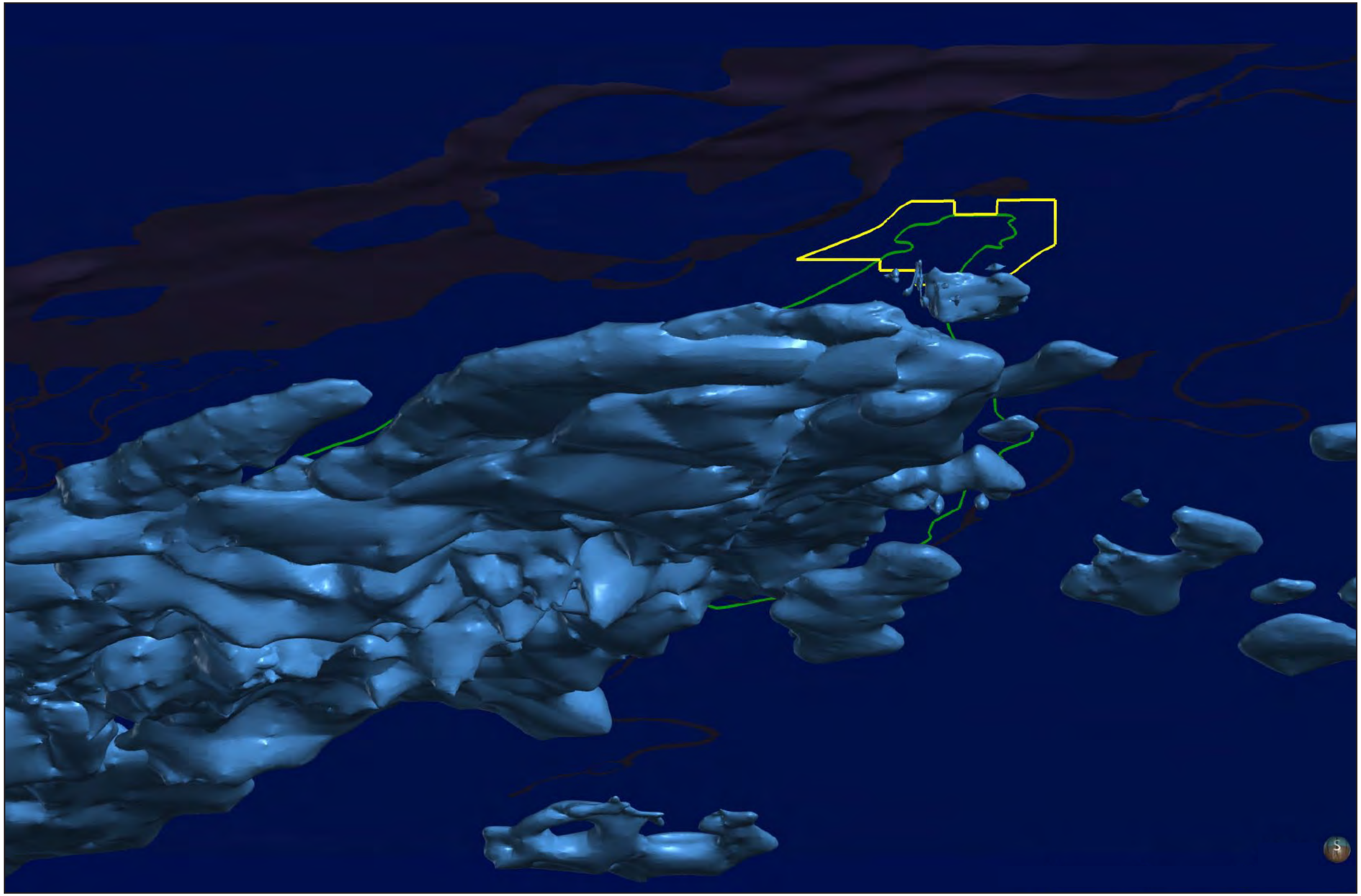
OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

THREE-DIMENSIONAL PERMAFROST MODEL OBLIQUE OVERHEAD VIEW TO THE NORTH

ARCADIS

FIGURE **4-3**

12/19/2013 SYRACUSE, NY-ENV/CAD-DJHOWES
B0081981/0048/00001/OSCR/CDR/81981g15.cdr

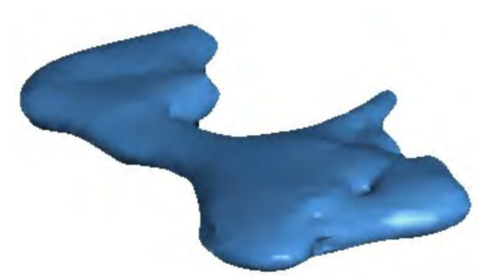


Property boundary

Non-detect boundary

0 500 1,000 1,500

Plunge -20
Looking North



Permafrost

* All data (borelogs, geophysics, etc.) available to view in the viewerfile included as a data CD

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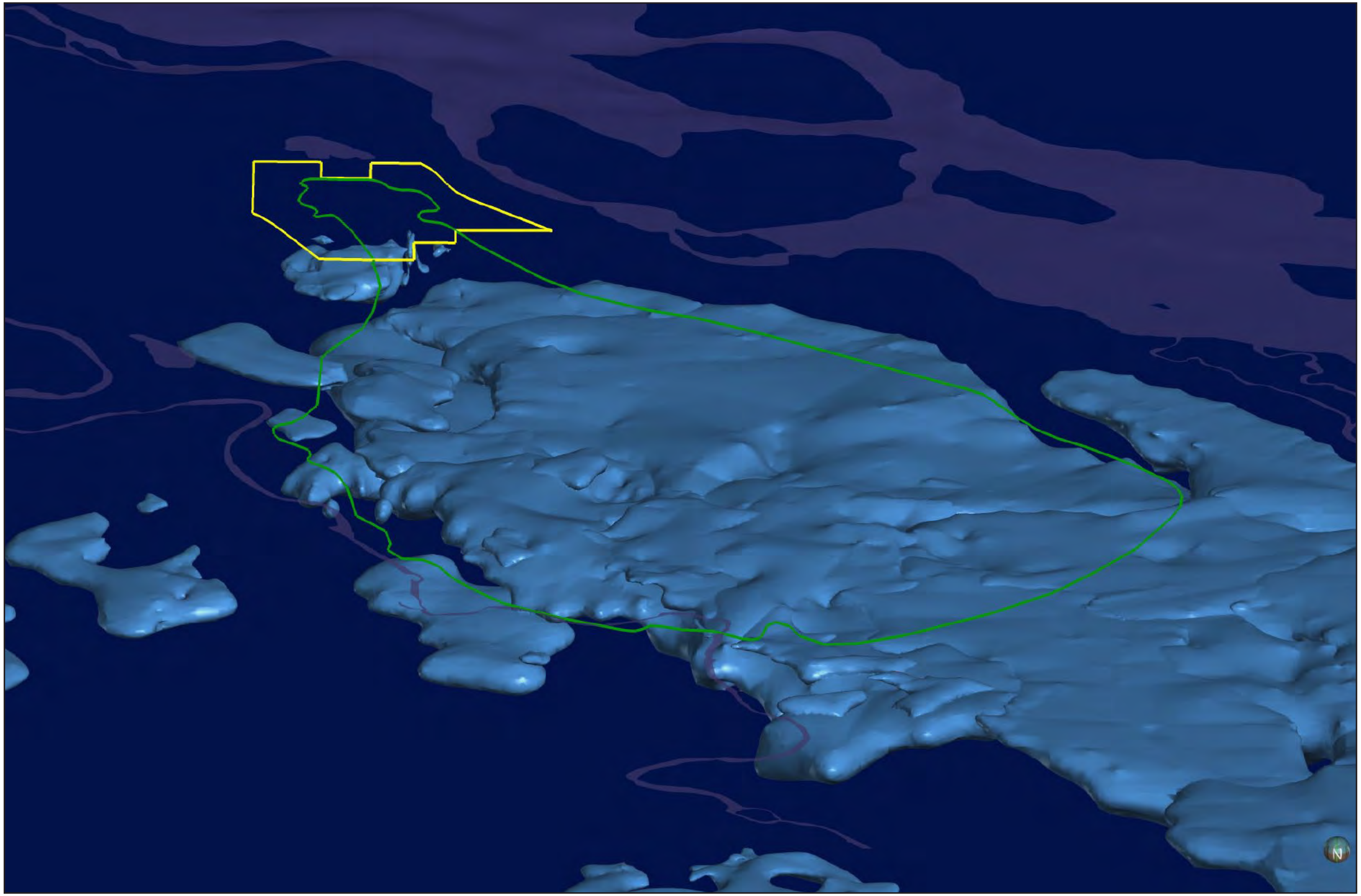
THREE-DIMENSIONAL PERMAFROST MODEL OBLIQUE UNDERSIDE VIEW TO THE NORTH

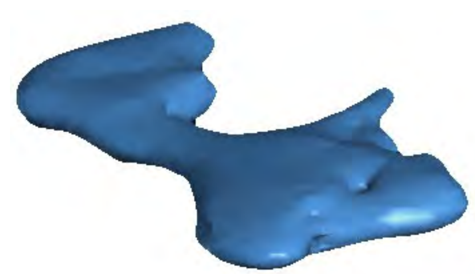
ARCADIS

FIGURE
4-4

12/19/2013 SYRACUSE, NY-ENV/CAD-DJHOWES
B0081981/0048/00001/OSCR/CDR/81981g16.cdr



Property boundary
Non-detect boundary



Permafrost

0 500 1,000 1,500

Plunge +20
Looking South

* All data (borelogs, geophysics, etc.) available to view in the viewerfile included as a data CD

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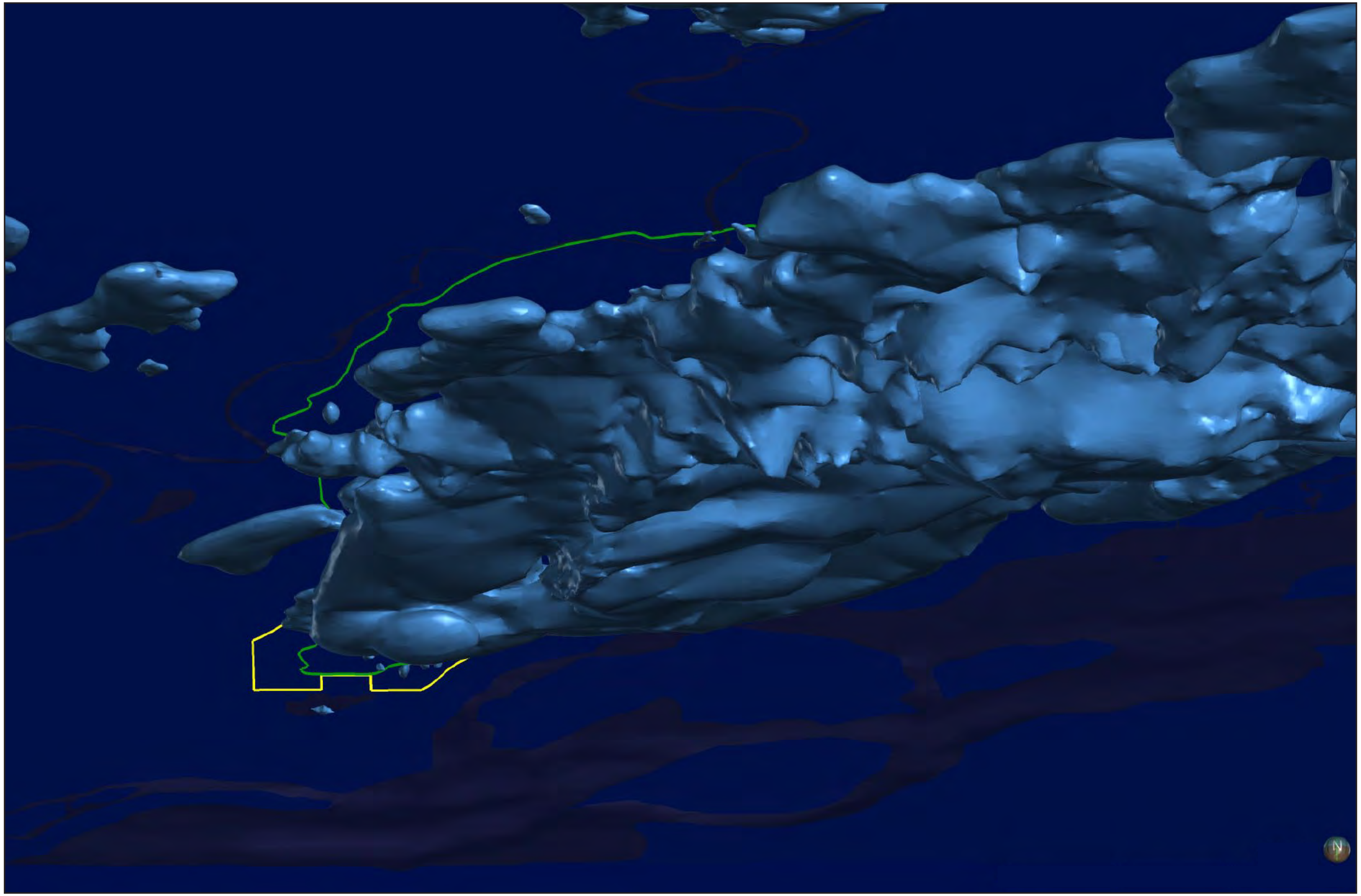
THREE-DIMENSIONAL PERMAFROST MODEL OBLIQUE OVERHEAD VIEW TO THE SOUTH

ARCADIS

FIGURE
4-5

12/19/2013 SYRACUSE, NY-ENV/CAD-DJHOWES
B0081981/0048/00001/OSCR/CDR/81981g17.cdr

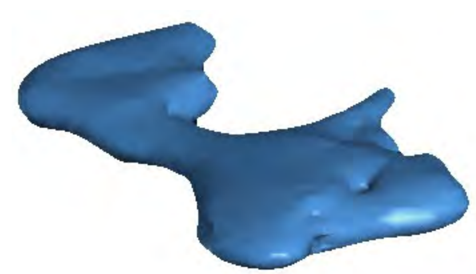


Property boundary

Non-detect boundary

0 500 1,000 1,500

Plunge -20
Looking South



Permafrost

* All data (borelogs, geophysics, etc.) available to view in the viewerfile included as a data CD

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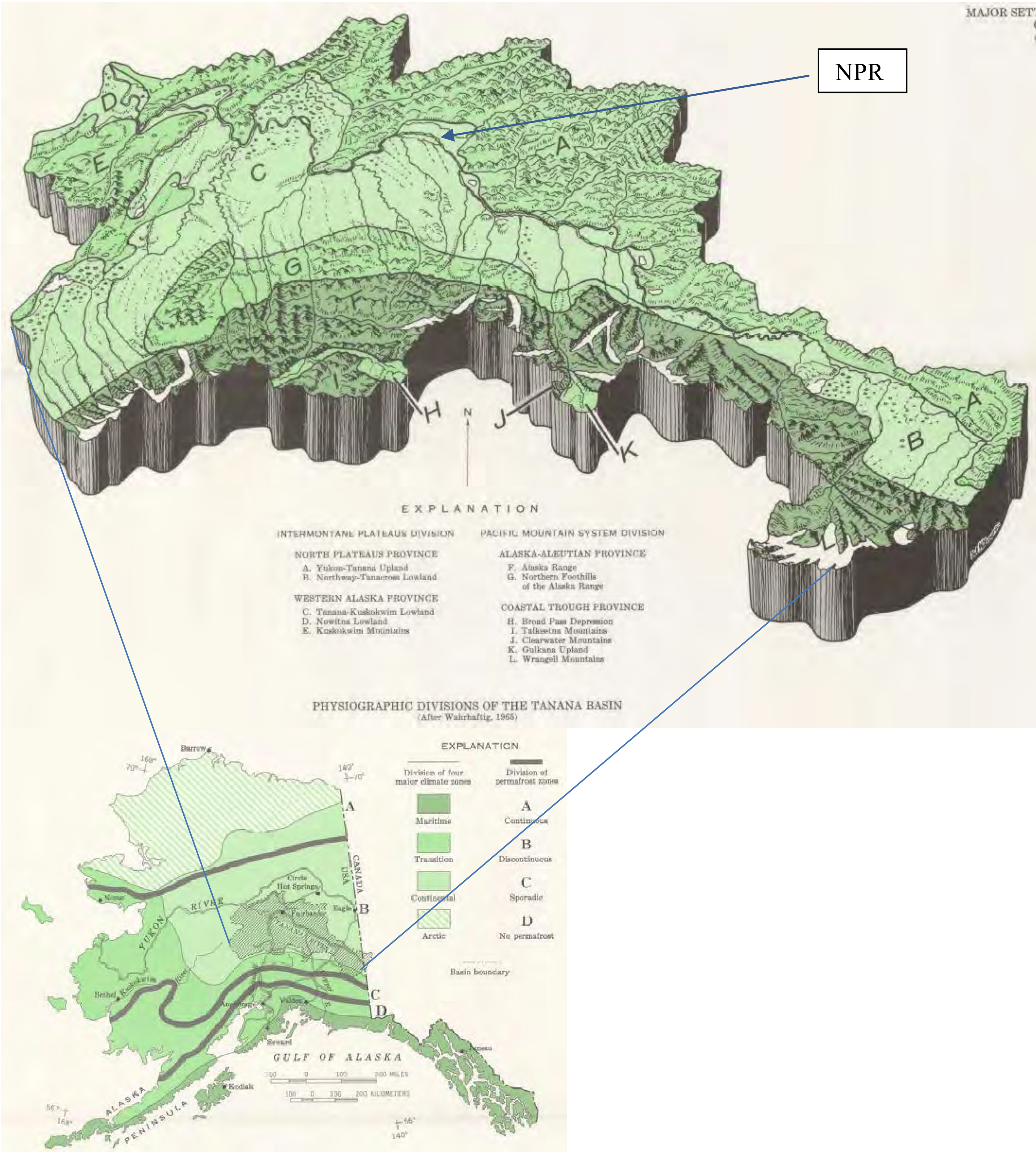
THREE-DIMENSIONAL PERMAFROST MODEL OBLIQUE UNDERSIDE VIEW TO THE SOUTH

ARCADIS

FIGURE
4-6

12/19/2013 SYRACUSE, NY-ENV/CAD-DJHOWES
B0081981/0048/00001/OSCR/CDR/81981g18.cdr



Reference: Anderson, 1970

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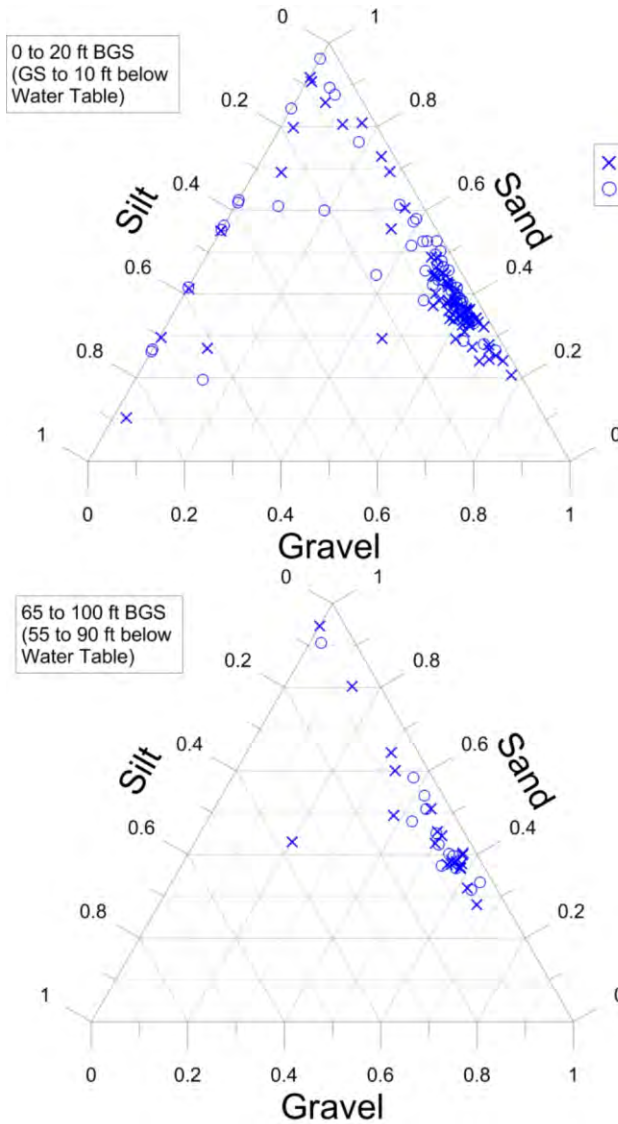
OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

LOCATION OF THE SITE WITH RESPECT TO THE PHYSIOGRAPHIC DIVISIONS OF THE TANANA BASIN

ARCADIS

FIGURE
5-1

12/10/2013 SYRACUSE, NY-ENV/CAD-DJHOWES
B0081981/0048/00001/OSCR/CDR/81981g08.cdr (FIGS A - E)



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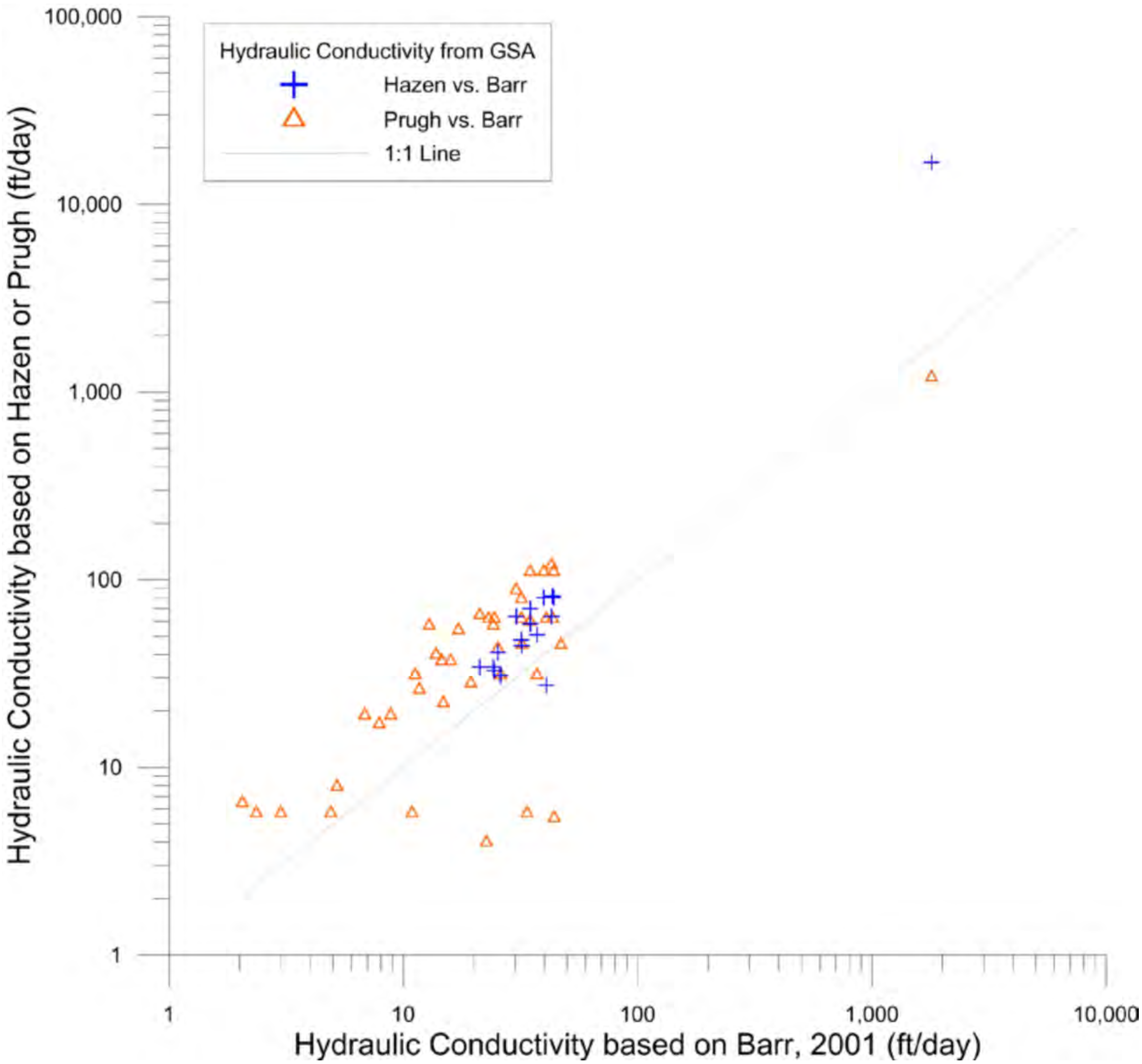
OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

TERNARY PLOTS OF THE GRAIN SIZE ANALYSES. SUBPLOTS ARE BASED ON THE DEPTH OF THE SAMPLE

ARCADIS

FIGURE
5-2

12/10/2013 SYRACUSE, NY-ENV/CAD-DJHOWES
B0081981/0048/00001/OSCR/CDR/81981g08.cdr (FIGS A - E)



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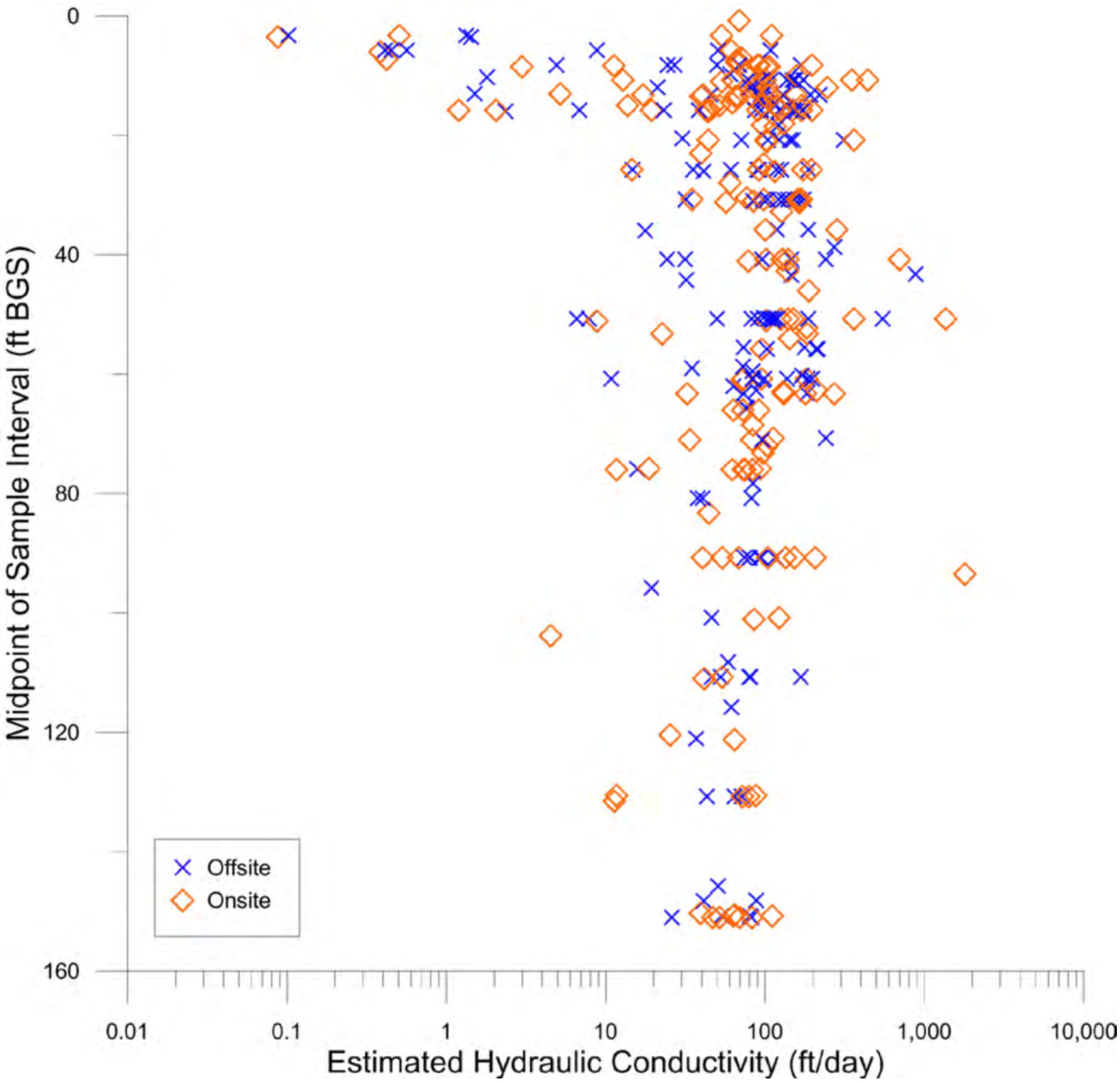
OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

SCATTER PLOT OF HYDRAULIC CONDUCTIVITY ESTIMATES BASED ON GRAIN SIZE ANALYSIS USING THE BARR, HAZEN, AND PRUGH METHODS

ARCADIS

FIGURE
5-3

12/10/2013 SYRACUSE, NY-ENV/CAD-DJHOWES
B0081981/0048/00001/OSCR/CDR/81981g08.cdr (FIGS A - E)



Reference: Anderson, 1970

ft BGS = feet below ground surface
ft/day = feet per day

FLINT HILLS RESOURCES ALASKA, LLC
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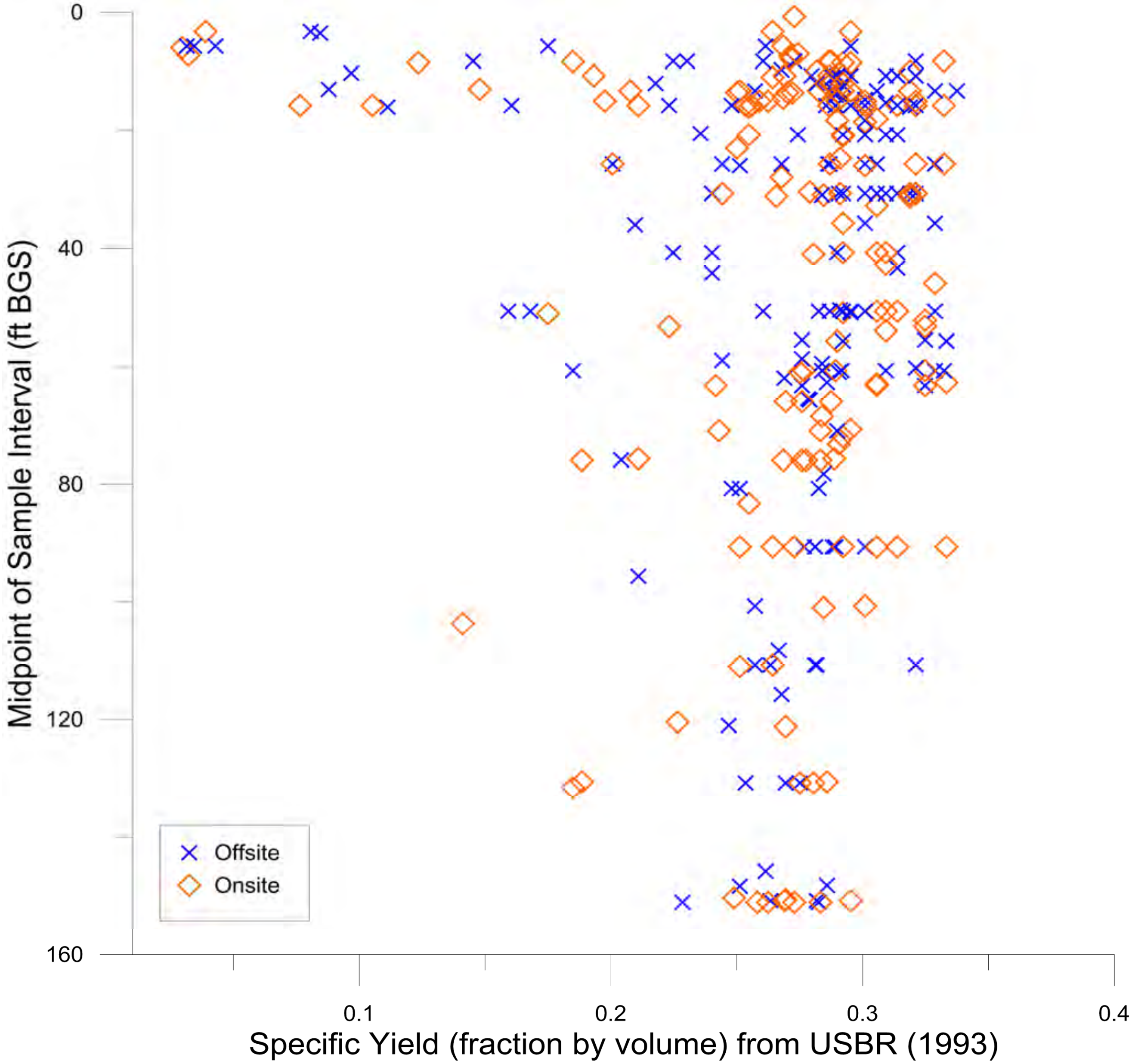
CLASSIFIED SCATTER PLOT OF ESTIMATED HYDRAULIC CONDUCTIVITY BASED ON GRAIN SIZE DISTRIBUTIONS VERSUS DEPTH OF SAMPLE

ARCADIS

FIGURE
5-4A

12/10/2013 SYRACUSE, NY-ENV/CAD-DJHOWES
B0081981/0048/00001/OSCR/CDR/81981g08.cdr (FIGS A - E)



ft bgs = feet below ground surface

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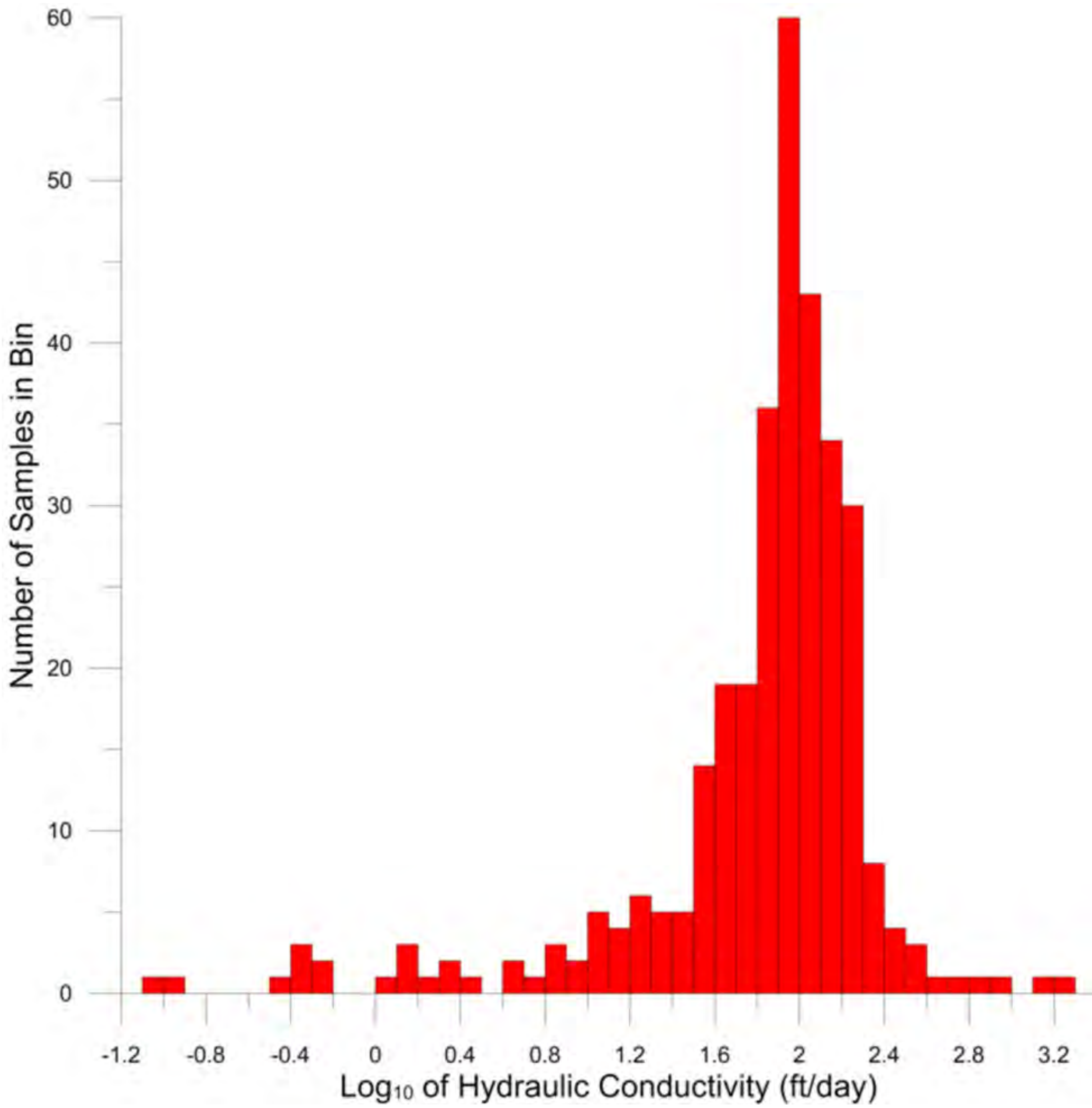
OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

Classified Scatter Plot of Estimated Specific Yield Based on the USBR (1993) Method Versus Depth of Sample

ARCADIS

FIGURE
5-4B



ft/day = feet per day

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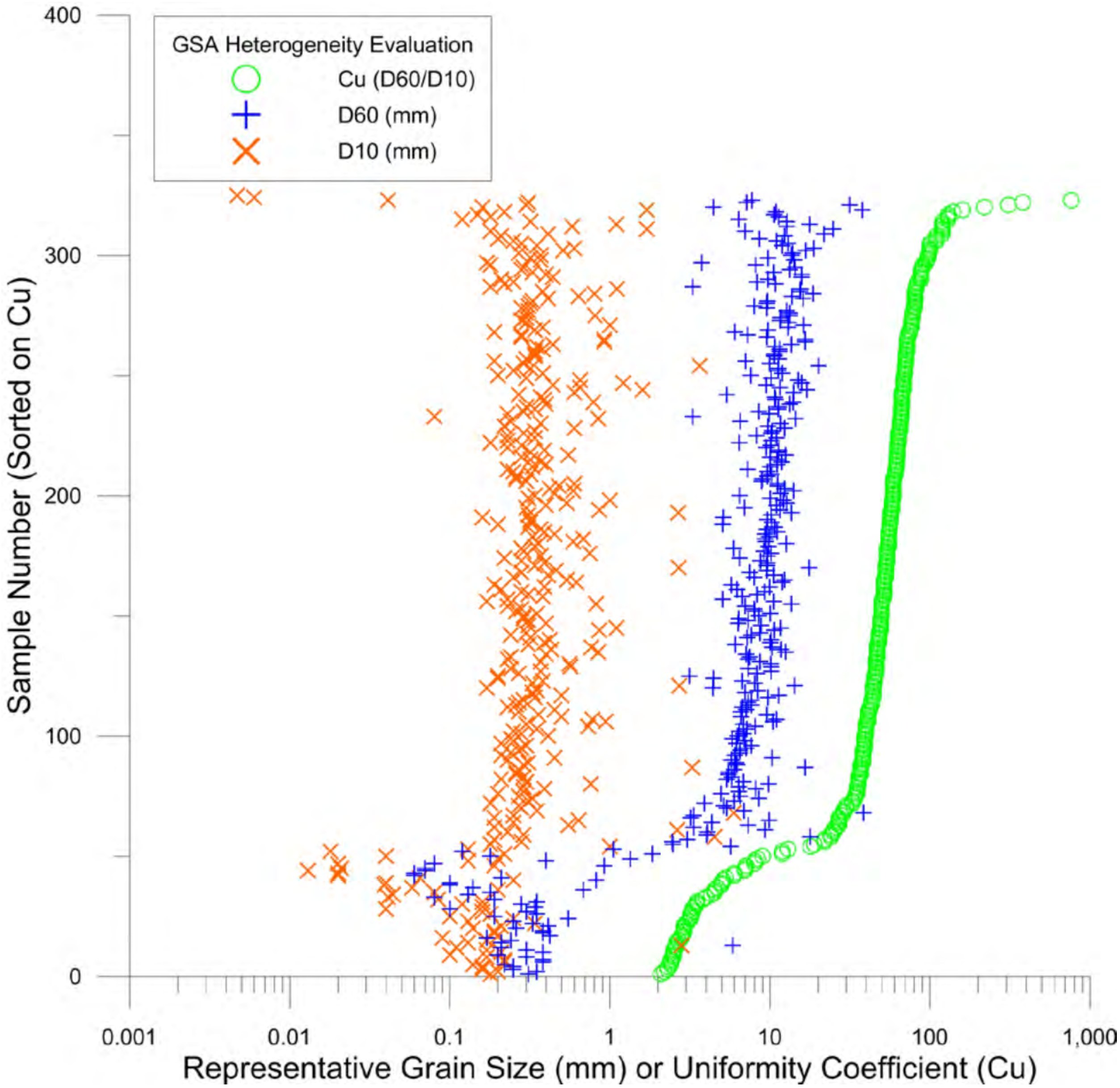
OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

HISTOGRAM OF ESTIMATED HYDRAULIC CONDUCTIVITY BASED ON GRAIN SIZE DISTRIBUTIONS USING THE BARR (2001) METHOD

ARCADIS

FIGURE
5-5

12/10/2013 SYRACUSE, NY-ENV/CAD-DJHOWES
B0081981/0048/00001/OSCR/CDR/81981g08.cdr (FIGS A - E)



Samples were sorted on uniformity coefficient

mm = millimeters

GSA = Grain size analysis

D10 = 10% passing grain size

D60 = 60% passing grain size

Cu = Uniformity Coefficient

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OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

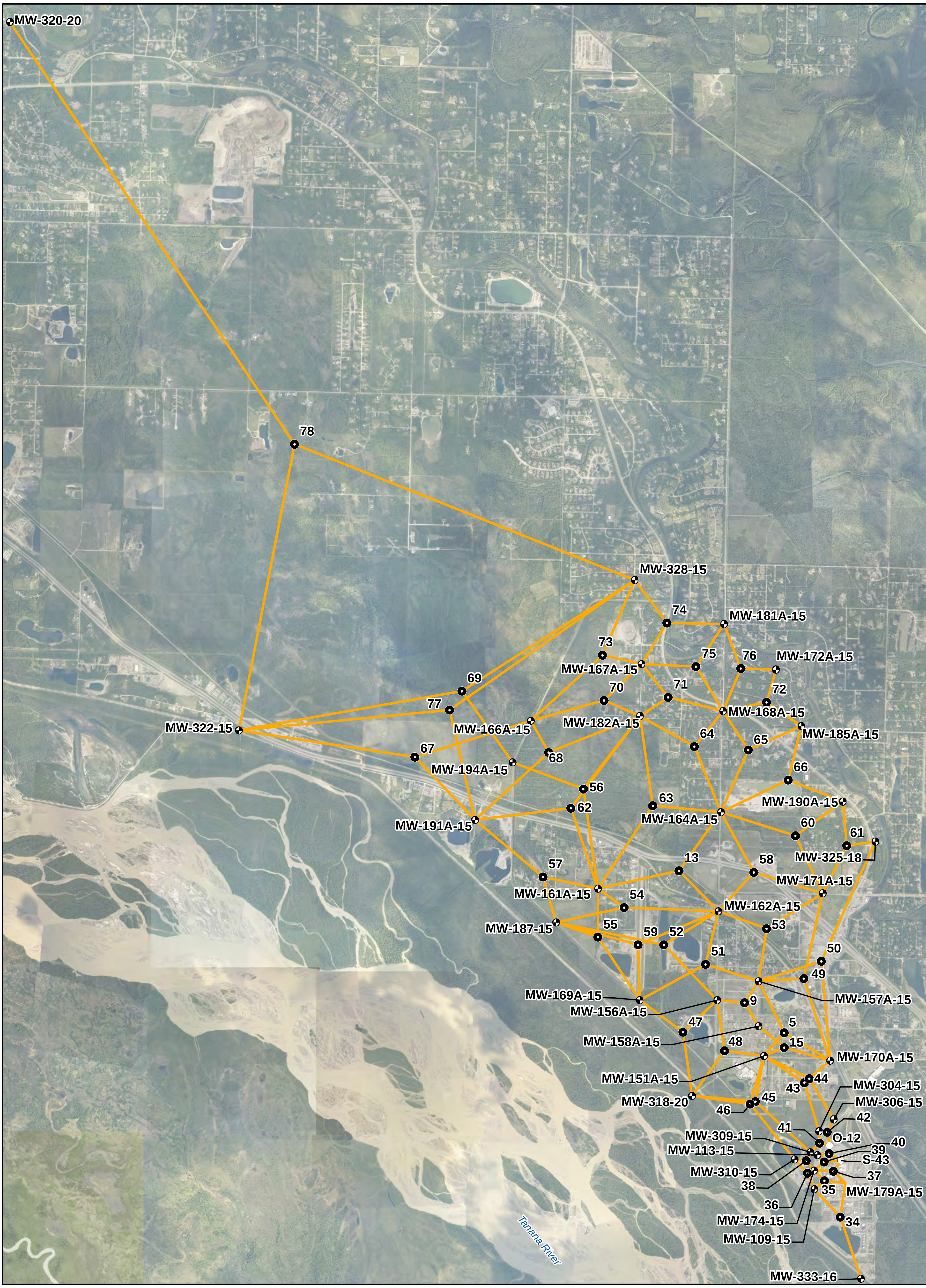
SCATTER PLOTS THE 10% FINER GRAIN SIZE (D10), 60% FINER GRAIN SIZE (D60) AND UNIFORMITY COEFFICIENT VALUES FOR GRAIN SIZE ANALYSIS DATA

ARCADIS

FIGURE
5-6

12/10/2013 SYRACUSE, NY-ENV/CAD-DJHOWES
B0081981/0048/00001/OSCR/CDR/81981g09.cdr (FIGS F - J)

CITY: SF DIV/GROUP: ENV/IM DB: BGRIFFITH LD: PIC: PM: TM: TR:
PROJECT: (PROJECT #)
PATH: W:\GISPrj\GISPROJECTS_ENV\FHR_AK\NorthPoleRefinery\SiteCharacterization2013\2013 Addendum\OFFSITE\Fig 5-7 WellsNearWT_HorizGradEstimates.mxd 12/16/2013 4:28:16 PM



Legend
- Monitoring Well
- Observation Well
- Well Group Centroids
- Connector Between Centroid of Group and Each Well
- FHRA Property Boundary

0 3,000 6,000
SCALE IN FEET

Notes:
Image provided courtesy of Pictometry International 2012

FLINT HILLS RESOURCES ALASKA, LLC
NORTH POLE REFINERY, NORTH POLE, ALASKA

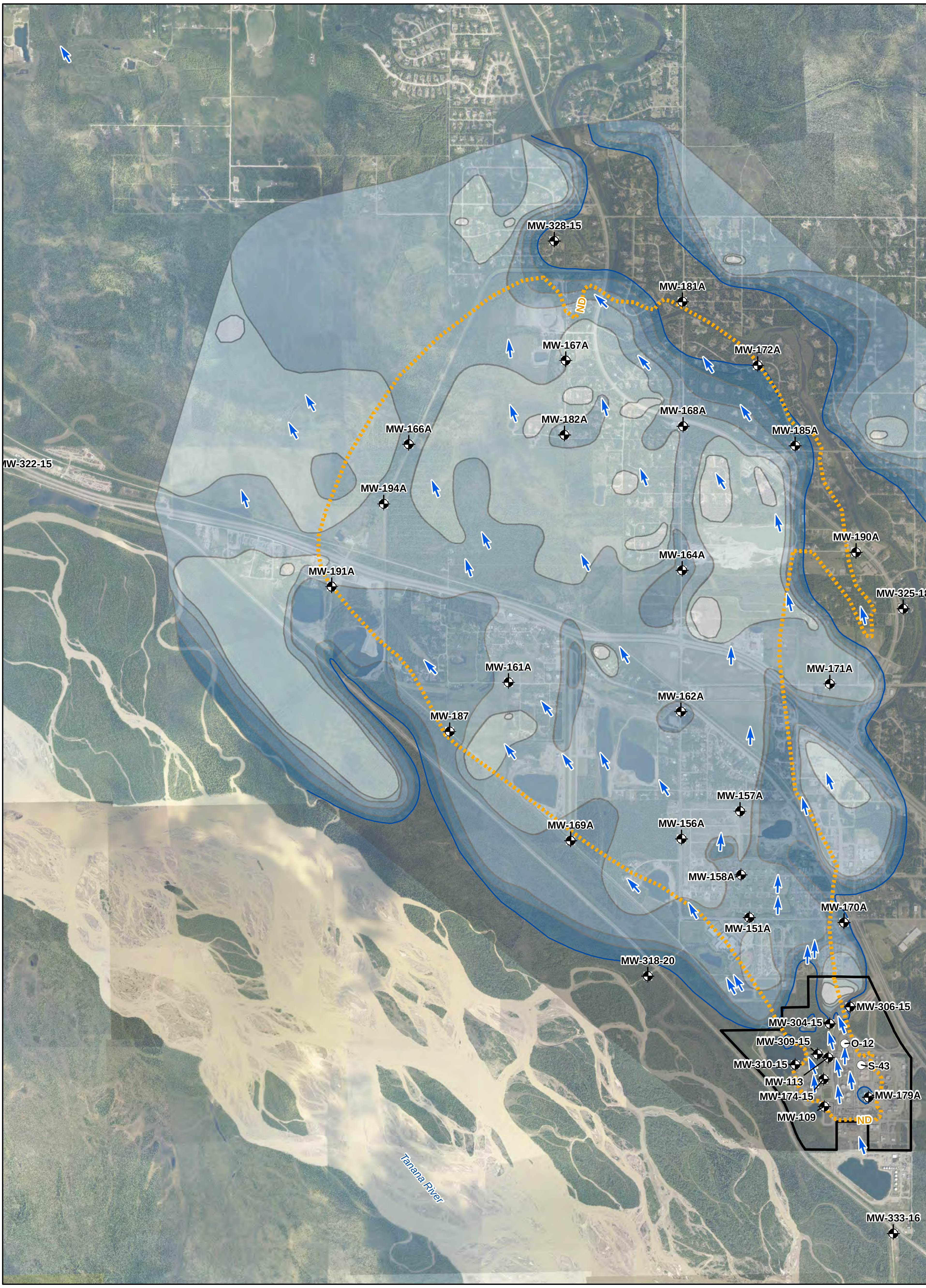
OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

GROUPS OF WELLS NEAR THE WATER TABLE USED IN HORIZONTAL GRADIENT ESTIMATES

ARCADIS

FIGURE
5-7

CITY: SF DIV/GROUP: ENV/IM DB: BGRIFFITH LD: PIC: PM: TM: TR:
PROJECT: (PROJECT #)
PATH: W:\GISPrj\GISPROJECTS_ENV\FHR_AK\NorthPoleRefinery\SiteCharacterization2013\2013 Addendum\OFFSITE\Fig 5-8 AverageGWFlowDirections.mxd 12/19/2013 5:37:43 PM



Legend

- Monitoring Well
- Observation Well
- Groundwater Flow Direction
- Suprapermafrost Sulfolane Plume Isopleths in µg/L
- FHRA Property Boundary

Depth to Top of Permafrost in feet

- < 10
- 10 - 30
- 30 - 60
- 60 - 90
- 90 - 120
- 120 - 150
- > 150

0 2,100 4,200

SCALE IN FEET

Notes:

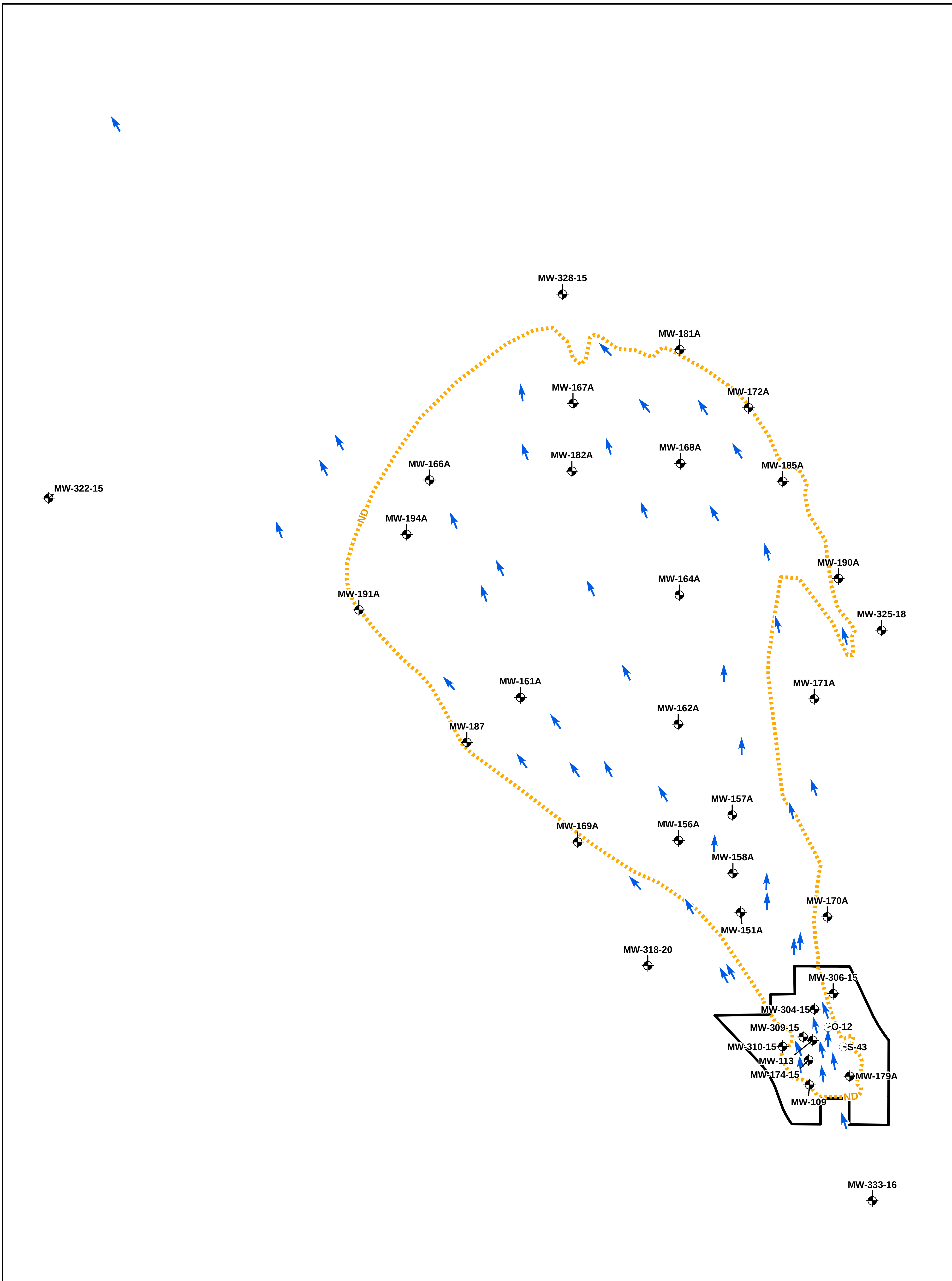
Image provided courtesy of Pictometry International 2012

FLINT HILLS RESOURCES ALASKA, LLC
NORTH POLE REFINERY, NORTH POLE, ALASKA
OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

AVERAGE GROUNDWATER FLOW DIRECTIONS

ARCADIS

FIGURE
5-8



Monitoring Well

Observation Well

Groundwater Flow Direction

Suprapermafrost Sulfolane Plume Isopleths in µg/L

FHRA Property Boundary

Note: MW-320-20 intentionally excluded from view. See text for discussion.

0 1,000 2,000 3,000 4,000

SCALE IN FEET

FLINT HILLS RESOURCES ALASKA, LLC
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OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

COMPARISON OF AVERAGE GROUNDWATER FLOW DIRECTIONS FROM THE DATA LOGGER PROGRAM NEAR THE WATER TABLE WITH THE SULFOLANE PLUME AT WATER TABLE WITHOUT THE TOP OF PERMAFROST MAP

ARCADIS

FIGURE
5-9a

Legend:

Wells with data loggers used in vertical gradient estimates at or near the water table

Monitoring Well

FHRA Property Boundary

0 3,000 6,000 Feet
GRAPHIC SCALE

Note:
Image provided courtesy of Pictometry International 2012

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OFFSITE SITE CHARACTERIZATION REPORT – 2013 ADDENDUM

LOCATIONS OF WELL NESTS WITH MULTIPLE DATA LOGGERS USED FOR VERTICAL HYDRAULIC GRADIENT CALCULATIONS

ARCADIS

FIGURE
5-9b

CITY: HIGHLANDS RANCH, CO DIV/GROUP: ENV/IM DB: L DRUM LD: G FRANCE
PATH: W:\GISPRJ\GISPROJECTS_ENV\FHR_AK\NORTHPOLEREFINERY\SITECHARACTERIZATION2013\2013 ADDENDUM\ONSITE\FIG 6-10 OFFSITEMW_WATERLEVELS_TOCSURVEY.MXD DATE: 12/16/2013 TIME: 8:00:12 AM

Notes:
Image provided courtesy of Pictometry International 2012

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OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

LOCATIONS OF OFFSITE MONITORING WELLS IN WHICH WATER LEVELS HAVE BEEN MEASURED WITH CONCURRENT TOP OF CASING SURVEY SINCE MARCH 2013

ARCADIS

FIGURE
5-10

CITY: HIGHLANDS RANCH, CO DIV/GROUP: ENV/IM DB: L DRUM LD: G FRANCE
PATH: W:\GISPRJ\GISPROJECTS_ENV\FHR_AK\NORTHPOLEREFINERY\SITECHARACTERIZATION2013\2013 ADDENDUM\ONSITE\FIG 6-11 ONSITEMW_WATERLEVELS_TOCSURVEY.MXD DATE: 12/16/2013 TIME: 7:58:08 AM

Legend
- Monitoring Well
- Vertical Profile Transect Well

0 90 180
SCALE IN FEET

Notes:
Image provided courtesy of Pictometry International 2012

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OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

LOCATIONS OF ONSITE MONITORING WELLS IN WHICH WATER LEVELS HAVE BEEN MEASURED WITH CONCURRENT TOP OF CASING SURVEY SINCE MARCH 2013

ARCADIS

FIGURE
5-11

CITY: SF DIV/GROUP: ENV/IM DB: BGRIFFITH LD: PIC: PM: TM: TR:
PROJECT: (PROJECT #)
PATH: W:\GISPrj\GISPROJECTS_ENV\FHR_AK\NorthPoleRefinery\SiteCharacterization2013\2013 Addendum\OFFSITE\Fig 5-12 WellsNearWTUsedHorGradEst.mxd 12/19/2013 5:53:06 PM

Legend

- Monitoring Well
- Observation Well
- T: Tanana River Signature
- O: Other Signature
- 166/194: Signature Unique to Wells MW-166A-15 and MW-194A-15
- 320: See Section 5.1.8 for details
- Groundwater Flow Directions
- Suprapermafrost Sulfolane Plume Isopleths in µg/L
- FHRA Property Boundary

Depth to Top of Permafrost in feet

- < 10
- 10 - 30
- 30 - 60
- 60 - 90
- 90 - 120
- 120 - 150
- > 150

0 2,100 4,200

SCALE IN FEET

FLINT HILLS RESOURCES ALASKA, LLC
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OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

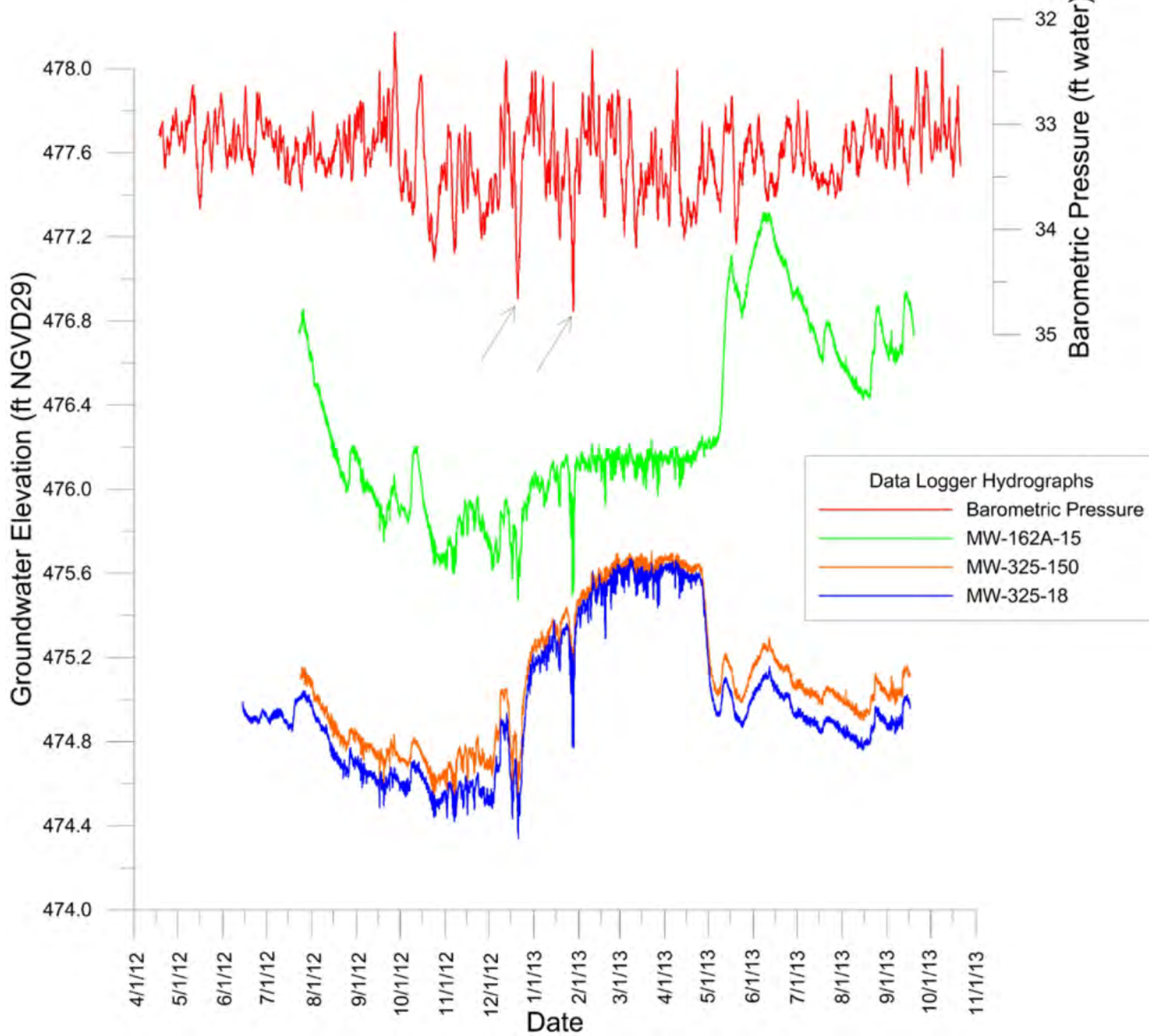
GROUPS OF WELLS NEAR THE WATER TABLE USED IN HORIZONTAL GRADIENT ESTIMATES

ARCADIS

FIGURE

5-12

Notes:
Image provided courtesy of Pictometry International 2012



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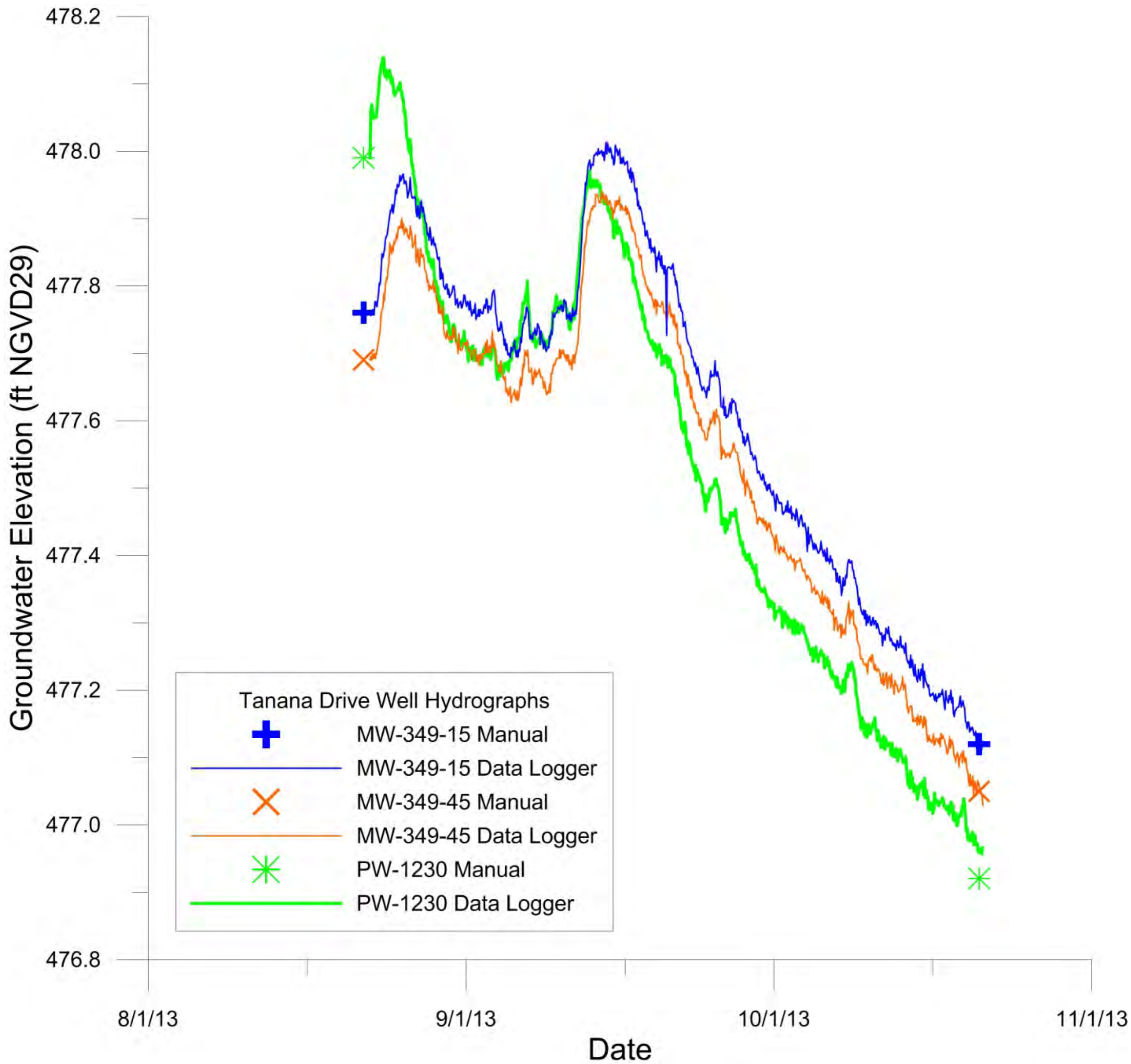
OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

COMPARISON OF BAROMETRIC PRESSURE TREND WITH HYDROGRAPHS FROM WELLS MW-162A-15, MW-325-18, AND MW-325-150

ARCADIS

FIGURE
5-13

12/10/2013 SYRACUSE, NY-ENV/CAD-DJHOWES
B0081981/0048/00001/OSCR/CDR/81981g10.cdr (FIGS K - O)



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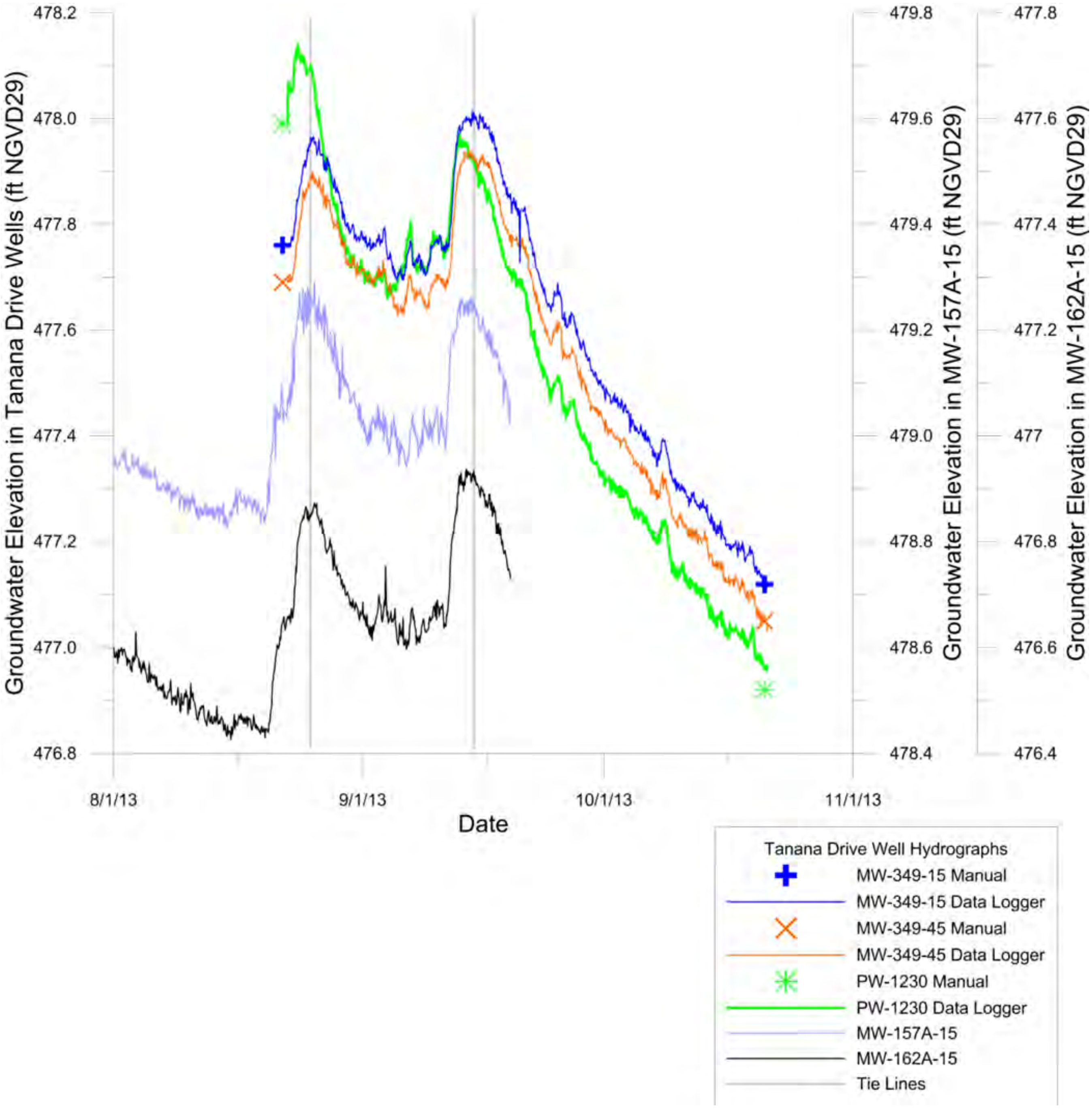
OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

HYDROGRAPHS OF MANUAL AND DATA LOGGER-BASED GROUNDWATER ELEVATIONS FOR THE WELLS AT 2440 TANANA DRIVE

ARCADIS

FIGURE
5-14



Notes:
Hydrographs are from adjacent monitoring wells
Vertical tie lines are for reference and occur on 8/25/13 and 9/14/13.

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OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

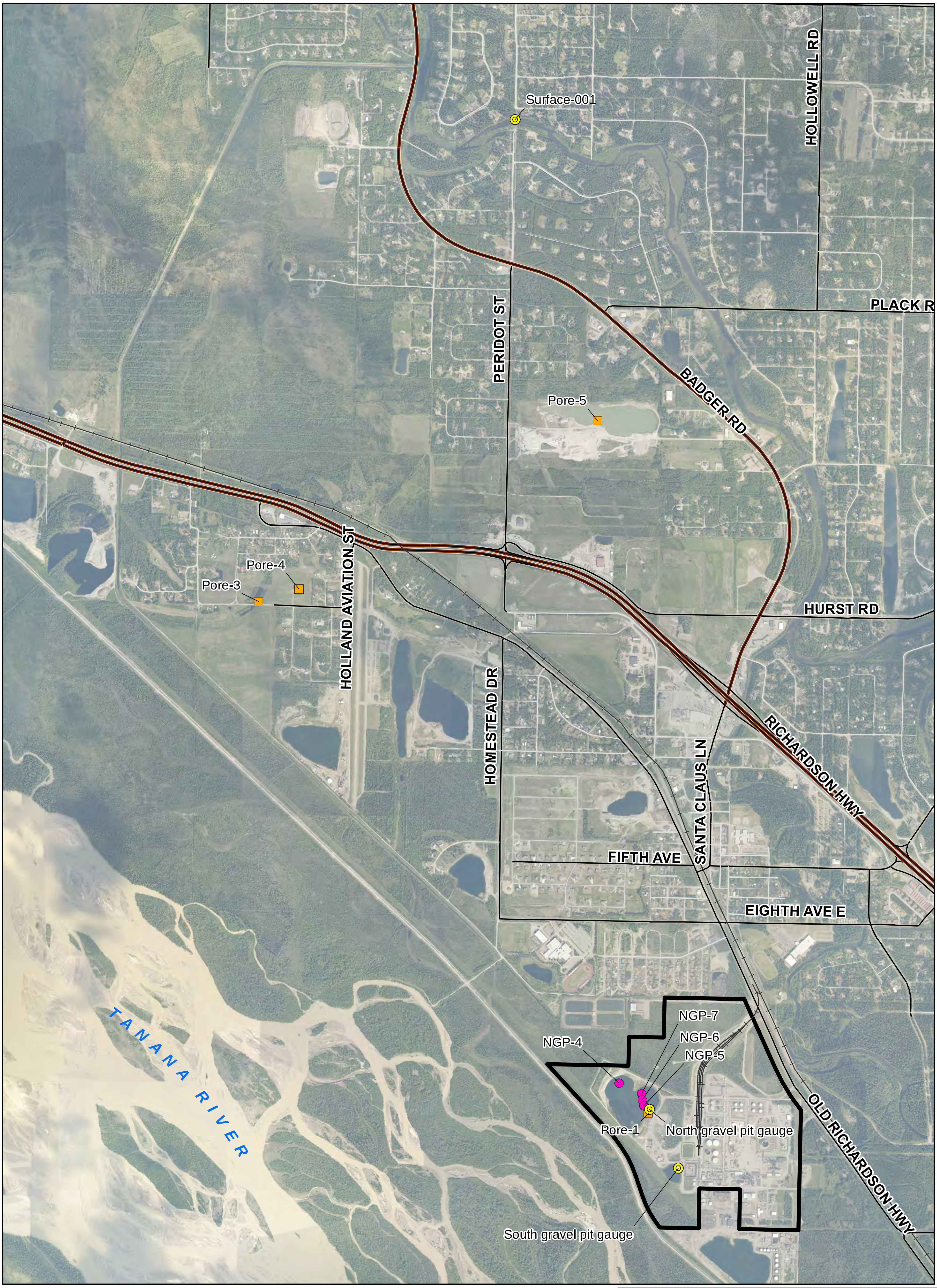
HYDROGRAPHS OF MANUAL AND DATA LOGGER-BASED GROUNDWATER ELEVATIONS FOR THE WELLS AT 2440 TANANA DRIVE

ARCADIS

FIGURE
5-15

12/10/2013 SYRACUSE, NY-ENV/CAD-DJHOWES
B0081981/0048/00001/OSCR/CDR/81981g10.cdr (FIGS K - O)

CITY: HIGHLANDS RANCH, CO DIV/GROUP: ENV/IM DB: BGriffith LD: G FRANCE
Path: W:\GISPrj\GISPROJECTS_ENV\FHR_AK\NorthPoleRefinery\SiteCharacterization2013\2013 Addendum\OFFSITE\Fig 6-1 SurfaceWaterPoreWaterSamplingLocations.mxd Date: 12/12/2013 Time: 7:11:22 PM



Legend:

- Pore Water Sample
- Surface Water Sample
- Proposed Surface Water and Sediment Sampling Location
- FHRA Property Boundary
- Highway
- Major Road
- Local Road
- Rail Line

0 1,600 3,200 Feet
GRAPHIC SCALE

Note:
Image provided courtesy of Pictometry International 2012

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OFFSITE SITE CHARACTERIZATION REPORT – 2013 ADDENDUM

SURFACE WATER AND PORE WATER SAMPLING LOCATIONS

ARCADIS

FIGURE **6-1**

Legend

Private Well Sulfolane Results

- Not Detected
- 3.2 - 362 µg/L
- > 362 µg/L
- FHRA Property Boundary

104 Sulfolane Concentration (µg/L)
J Estimated concentration, detected above the detection limit (DL) and below the limit of quantitation (LOQ)
< Not detected: detection limit listed
1458 Private Well Location ID

Notes:
-Wells shown on this map are included in the quarterly Deep Residential Monitoring Plan
-Sulfolane was analyzed by EPA Method 1625B with iso-dilution
NS = Not Sampled
Image provided courtesy of Pictometry International 2012

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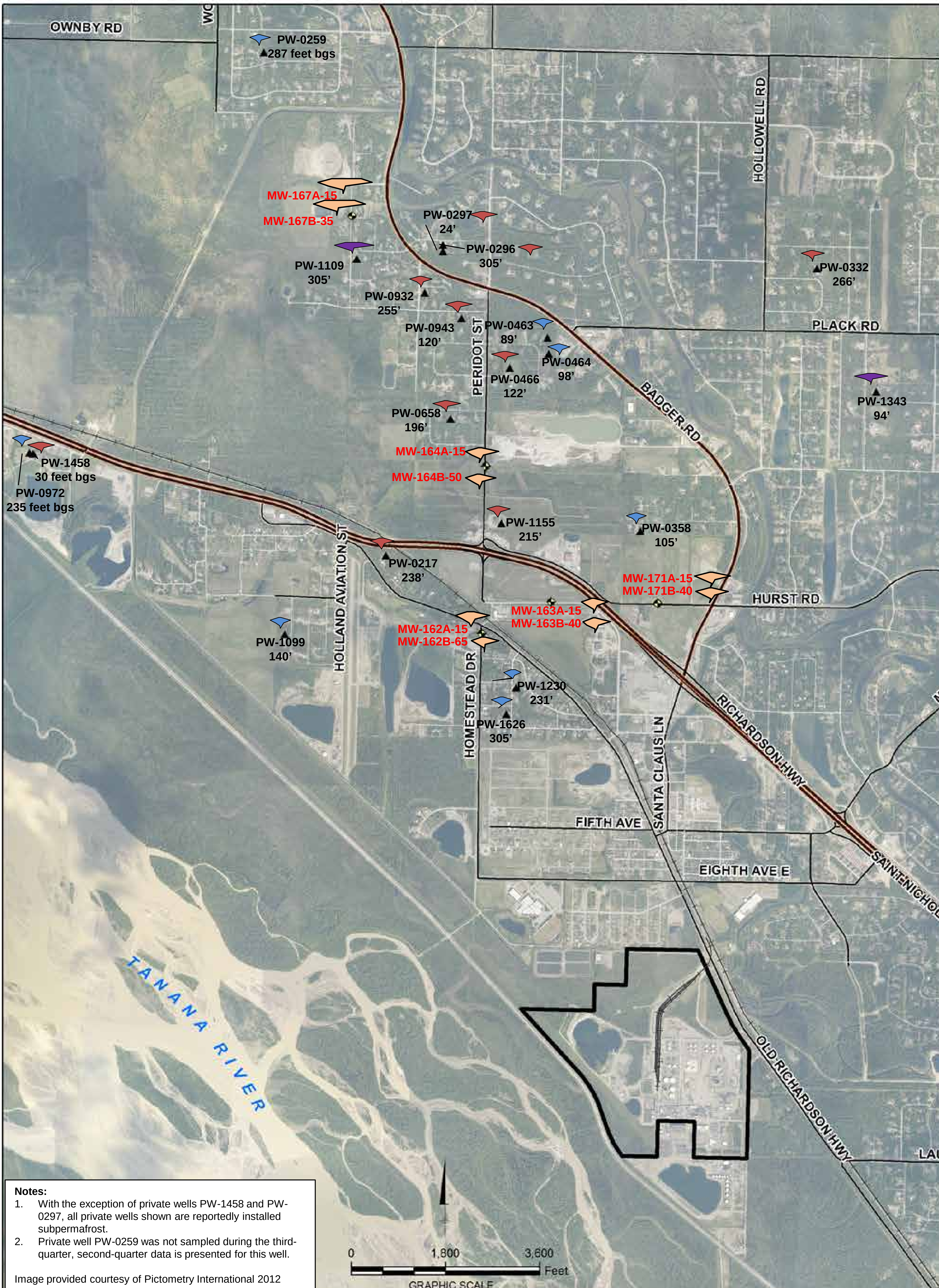
OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

DEEP PRIVATE WELL ANALYTICAL RESULTS - THIRD QUARTER 2013

ARCADIS

FIGURE
7-1

CITY: HIGHLANDS RANCH, CO DIV/GROUP: ENV/IM DB: BGriffith LD: G FRANCE
Path: W:\GISPrj\GISPROJECTS_ENV\FHR_AK\NorthPoleRefinery\SiteCharacterization2013\2013 Addendum\OFFSITE\Fig X ThirdQuarterStiffDiagrams_GWTypes.mxd Date: 12/11/2013 Time: 1:15:27 PM



Notes:

1. With the exception of private wells PW-1458 and PW-0297, all private wells shown are reportedly installed subpermafrost.
2. Private well PW-0259 was not sampled during the third-quarter, second-quarter data is presented for this well.

Image provided courtesy of Pictometry International 2012

Legend:

- Monitoring Well
- Private Well
- FHRA Property Boundary
- Highway
- Major Road
- Local Road
- Rail Line

Stiff Diagram Type Designations::

- Monitoring well – geochemical data originally presented in SCR-2011 (Barr 2012)
- Type A – Relatively older groundwater
- Type B – Relatively younger groundwater
- Type C – Mixed Type A and Type B groundwater

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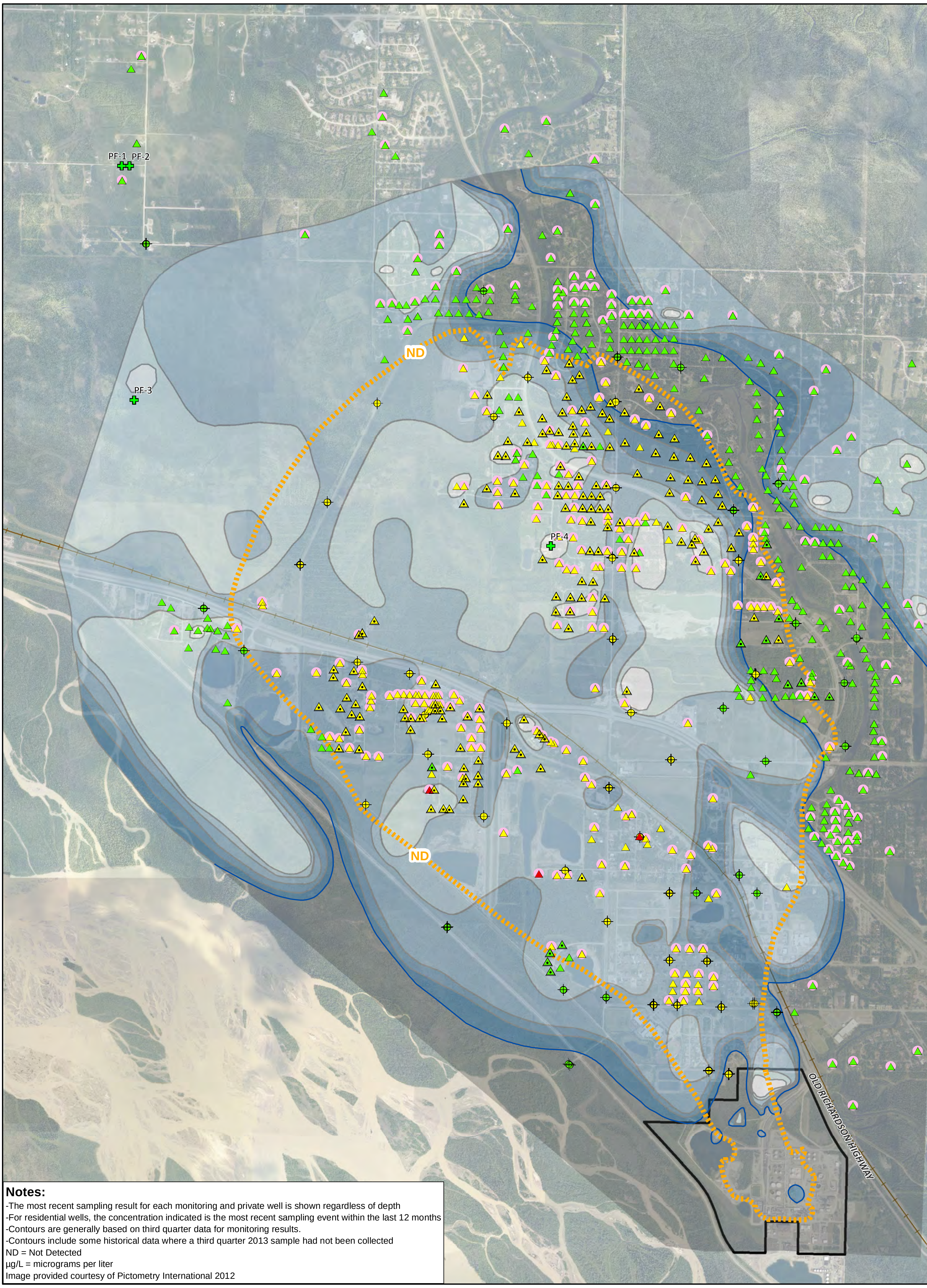
OFFSITE SITE CHARACTERIZATION
REPORT – 2013 ADDENDUM

THIRD-QUARTER 2013 STIFF DIAGRAMS SHOWING INTERPRETED GROUNDWATER TYPES

ARCADIS

FIGURE
7-2

CITY: HIGHLANDS RANCH, CO DIV/GROUP: ENV/IM DB: BGRIFFITH LD: G FRANCE
PATH: W:\GISPRJ\GISPROJECTS_ENV\FHR_AK\NORTHPOLEREFINERY\SITECHARACTERIZATION2013\2013 ADDENDUM\OFFSITE\FIG 7-3 OFFSITEGWANALYTICALRESULTS.MXD DATE: 12/19/2013 TIME: 5:55:18 PM



Notes:

- The most recent sampling result for each monitoring and private well is shown regardless of depth
- For residential wells, the concentration indicated is the most recent sampling event within the last 12 months
- Contours are generally based on third quarter data for monitoring results.
- Contours include some historical data where a third quarter 2013 sample had not been collected

ND = Not Detected
µg/L = micrograms per liter
Image provided courtesy of Pictometry International 2012

Legend

- Monitoring Well
- Point-of-entry treatment system sample collected
- The most recent sample was collected prior to October 2012
- Approximate Sulfolane Isopleth Regardless of Depth in µg/L
- Permafrost Boring
- FHRA Property Boundary

Private Well Sulfolane Results

- Not Detected
- 3.1 - 362 µg/L
- >362 µg/L

Monitoring Well Sulfolane Results

- Not Detected
- 3.1 - 362 µg/L
- >362 µg/L

Depth to Top of Permafrost in feet

- < 10
- 10 - 30
- 30 - 60
- 60 - 90
- 90 - 120
- 120 - 150
- > 150

0 2,000 4,000
SCALE IN FEET

FLINT HILLS RESOURCES ALASKA, LLC
NORTH POLE REFINERY, NORTH POLE, ALASKA

OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

GROUNDWATER ANALYTICAL RESULTS FROM OFFSITE MONITORING WELLS AND PRIVATE WELLS IN SUPRAPERMAFROST AND SUBPERMAFROST AQUIFERS

ARCADIS

FIGURE
7-3

CITY: HIGHLANDS RANCH, CO DIV/GROUP: ENV/IM DB: BGRIFFITH LD: G FRANCE
PATH: W:\GISPRJ\GISPROJECTS_ENV\FHR_AK\NORTHPOLEREFINERY\SITECHARACTERIZATION2013\2013 ADDENDUM\OFFSITE\FIG 7-4 OFFSITEGWANALYTICALRESULTS_SUPRAPERMAFROST.MXD DATE: 12/16/2013 TIME: 2:35:14 PM

Notes:

- Monitoring wells installed to all depths and private wells installed to a depth of 40 feet bgs or shallower are shown on this figure
- The most recent sampling result for each monitoring and private well is shown
- Contours are generally based on third quarter 2013 results. Contours include some historical data where a third quarter 2013 sample had not been collected

ND = Not Detected

J = Estimated concentration, detected above the detection limit (DL) and below the limit of quantitation (LOQ)

Image provided courtesy of Pictometry International 2012

Legend

- Monitoring Well

Monitoring Well Sulfolane Results

- Not Detected
- 3.1 - 362 µg/L
- >362 µg/L

Private Well Sulfolane Results

- Not Detected
- 3.1 - 362 µg/L
- >362 µg/L

- Approximate Sulfolane Isopleth in µg/L
- Permafrost at Surface (no shallow groundwater present)
- The most recent sample was collected prior to October 2012
- FHRA Property Boundary

0 2,000 4,000

SCALE IN FEET

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OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

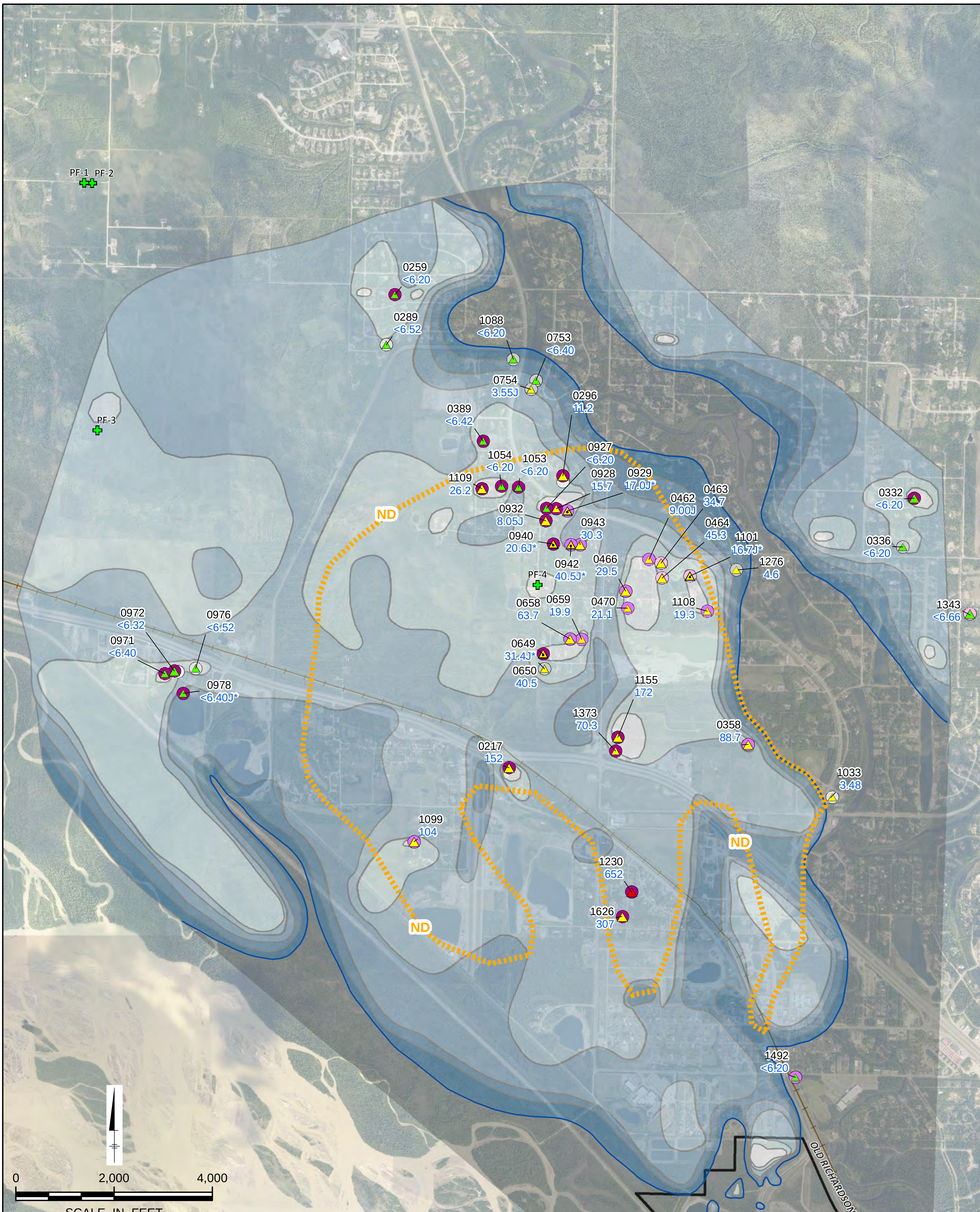
GROUNDWATER ANALYTICAL RESULTS FROM OFFSITE MONITORING WELLS AND PRIVATE WELLS SCREENED IN THE SUPRAPERMAFROST AQUIFER

ARCADIS

FIGURE

7-4

CITY: HIGHLANDS RANCH, CO DIV/GROUP: ENV/IM DB: BGRIFFITH LD: G FRANCE
PATH: W:\GISPRJ\GISPROJECTS_ENV\FHR_AK\NORTHPOLEREFINERY\SITECHARACTERIZATION2013\2013 ADDENDUM\OFFSITE\FIG 7-5 OFFSITEGWANALYTICALRESULTS_SUBPERMAFROST.MXD DATE: 12/19/2013 TIME: 5:52:41 PM



Notes:

- -Only wells with reported construction details are shown on this map
- -The most recent sampling result for each monitoring and private well is shown
- -For residential wells, the concentration indicated is the most recent sampling event within the last 12 months
- -Contours are generally based on third quarter data for monitoring results.
- -Contours include some historical data where a third quarter 2013 sample had not been collected

ND = Not Detected
J = Estimated concentration, detected above the detection limit (DL) and below the limit of quantitation (LOQ)
J* = Result is considered estimated; analyte was detected below the limit of quatitation (LOQ)
Image provided courtesy of Pictometry International 2012

Legend

- Point-of-entry treatment system sample collected
- Permafrost at Surface (no shallow groundwater present)
- Approximate Sulfolane Isopleth in µg/L
- FHRA Property Boundary

Private Well Sulfolane Results

- Not Detected
- 3.1 - 362 µg/L
- >362 µg/L

Private Well Depths

- 0 - 40 feet
- 40 - 70 feet
- 70 - 100 feet
- 100- - 200 feet
- 200 - 400 feet

Depth to Top of Permafrost in feet

- < 10
- 10 - 30
- 30 - 60
- 60 - 90
- 90 - 120
- 120 - 150
- > 150

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OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

GROUNDWATER ANALYTICAL RESULTS FROM PRIVATE WELLS SCREENED IN THE SUBPERMAFROST AQUIFER

ARCADIS

FIGURE
7-5

CITY: SF DIV/GROUP: ENV/IM DB: BGRIFFITH LD: PIC: PM: TM: TR:
PROJECT: (PROJECT #)
PATH: W:\GISPrj\GISPROJECTS_ENV\FHR_AK\NorthPoleRefinery\SiteCharacterization2013\2013 Addendum\OFFSITE\Fig 7-6 LocsOffsiteMWSulfolaneConcEvalTempTrends.mxd 12/17/2013 2:24:26 PM

Legend
- Monitoring Well
- Suprapermafrost Sulfolane Plume Isopleths in µg/L
- FHRA Property Boundary

0 1,500 3,000
SCALE IN FEET

Notes:
Image provided courtesy of Pictometry International 2012

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OFFSITE SITE CHARACTERIZATION REPORT – 2013 ADDENDUM

LOCATIONS OF OFFSITE MONITORING WELLS WITH SULFOLANE CONCENTRATION DATA THAT WERE EVALUATED FOR TEMPORAL TRENDS

ARCADIS

FIGURE
7-6

Legend

Seasonal Trend

- Y: Yes
- P: Possible
- N: No
- I: Inconclusive

Suprapermafrost Sulfolane Plume Isopleths in µg/L

FHRA Property Boundary

0 1,500 3,000

SCALE IN FEET

Notes:
Image provided courtesy of Pictometry International 2012

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OFFSITE SITE CHARACTERIZATION REPORT – 2013 ADDENDUM

SUMMARY OF SEASONAL TREND EVALUATION FOR SULFOLANE CONCENTRATIONS IN OFFSITE MONITORING WELLS

ARCADIS

FIGURE
7-7

CITY: SF DIV/GROUP: ENV/IM DB: BGRIFFITH LD: PIC: PM: TM: TR:
PROJECT: (PROJECT #)
PATH: W:\GISPrj\GISPROJECTS_ENV\FHR_AK\NorthPoleRefinery\SiteCharacterization2013\2013 Addendum\OFFSITE\Fig 7-8 OffsiteMWOverallTempSulfConcTrends.mxd 12/17/2013 3:20:34 PM

Legend

Overall Trend

- D: Steadily Decreasing Trend
- Dm: More recent data show decreasing trend
- Ds: Seasonal max value decreasing over time
- Di: Trend, if initial low value ignored
- I: Steadily Increasing Trend
- Is: Seasonal max value increasing over time

Suprapermafrost Sulfolane Plume Isopleths in µg/L

FHRA Property Boundary

0 1,500 3,000

SCALE IN FEET

Notes:
Image provided courtesy of Pictometry International 2012

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OFFSITE MONITORING WELLS EXHIBITING DISCERNABLE OVERALL TEMPORAL SULFOLANE CONCENTRATION TRENDS

ARCADIS

FIGURE
7-8

Legend

Monitoring Well

Private Wells

- Deep Residential
- POE Accelerated Pilot
- POE In-Home Pilot
- Additional Monitoring Locations
- FHRA Property Boundary

0 1,800 3,600

SCALE IN FEET

Notes:

Image provided courtesy of Pictometry International 2012

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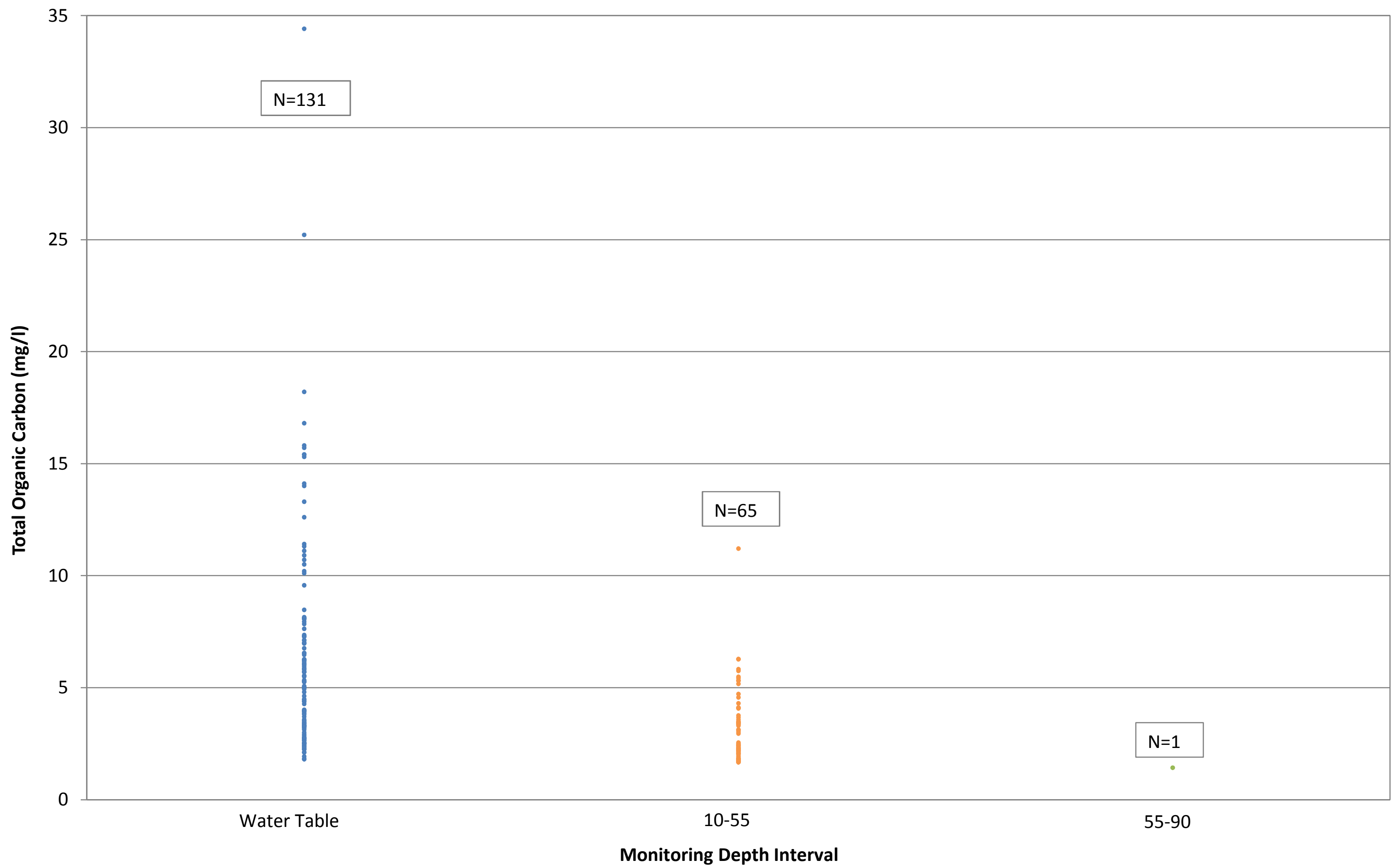
OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

OFFSITE TOTAL ORGANIC CARBON MONITORING LOCATIONS

ARCADIS

FIGURE

7-9



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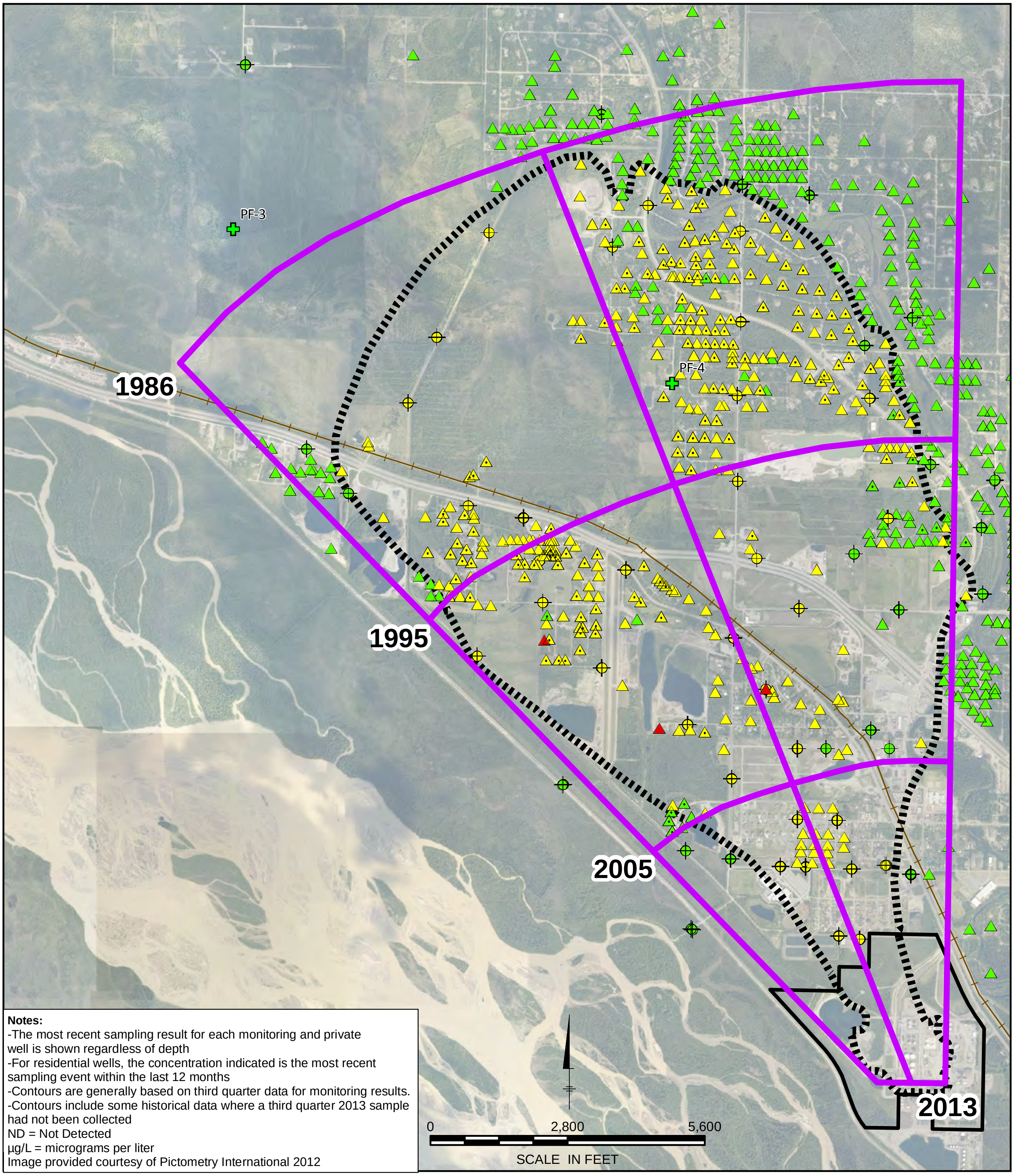
OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

TOTAL ORGANIC CARBON DATA SUMMARY BY MONITORING DEPTH INTERVAL

ARCADIS

FIGURE 7-10



Notes:
-The most recent sampling result for each monitoring and private well is shown regardless of depth
-For residential wells, the concentration indicated is the most recent sampling event within the last 12 months
-Contours are generally based on third quarter data for monitoring results.
-Contours include some historical data where a third quarter 2013 sample had not been collected
ND = Not Detected
µg/L = micrograms per liter
Image provided courtesy of Pictometry International 2012

Legend

- Monitoring Well
- Point-of-entry treatment system sample collected
- Permafrost Boring
- Approximate Sulfolane Isopleth Regardless of Depth in µg/L
- Velocity Arcs (calculated using a plume transport velocity of 2 feet per day)
- FHRA Property Boundary

Private Well Sulfolane Results
- Not Detected
- 3.1 - 362 µg/L
- >362 µg/L

Monitoring Well Sulfolane Results
- Not Detected
- 3.1 - 362 µg/L
- >362 µg/L

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OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

SULFOLANE PLUME EXTENT AND APPROXIMATE RELEASE DATE

ARCADIS

FIGURE **8-1**

CITY: HIGHLANDS RANCH, CO DIV/GROUP: ENV/IM DB: BGriffith LD: G FRANCE
Path: W:\GISPrj\GISPROJECTS_ENV\FHR_AK\NorthPoleRefinery\CSM\November2013\MXD\Fig 3-2 SulfolanePlumeExtent_ReleaseDate_rev1.mxd Date: 12/19/2013 Time: 2:09:43 PM

Legend
- Recovery Well
- Proposed Recovery Well
- Proposed Remediation System Piping
- Remediation System Piping
- FHRA Property Boundary

Notes:
Image provided courtesy of Pictometry International 2012

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OFFSITE SITE CHARACTERIZATION REPORT - 2013 ADDENDUM

GROUNDWATER RECOVERY AND TREATMENT SYSTEM

ARCADIS

FIGURE
9-1