Flint Hills Resources Alaska, LLC

Annual 2022 Onsite Groundwater Monitoring and Five-Year Periodic Review Report

North Pole Terminal
North Pole, Alaska
ADEC File Number: 100.38.090

January 24, 2023

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Acronyms and Abbreviations

2017 LTM Plan	Long-Term Monitoring Plan – 2017 Update
µg/L	microgram per liter
AAC	Alaska Administrative Code
AC	assimilative capacity
ADEC	Alaska Department of Environmental Conservation
Arcadis	Arcadis U.S., Inc.
BTEX	benzene, toluene, ethylbenzene, and xylenes
C_d	average groundwater concentration
CF	conversion factor
COC	constituent of concern
DO	dissolved oxygen
DRO	diesel-range organics
FHRA	Flint Hills Resources Alaska, LLC
GRO	gasoline-range organics
GRTS	groundwater remediation and treatment system
h	thickness of submerged source zone
ITRC	Interstate Technology & Regulatory Council
kg	kilogram
LNAPL	light nonaqueous phase liquid
LTM	long-term monitoring
m^3 $H_2O/m^2/sec$	cubic meter of water per square meter per second
mg/L	milligram per liter
NSZD	natural source zone depletion
Onsite RSAP	Revised Onsite Sampling and Analysis Plan
Onsite SCR – 2013	Onsite Site Characterization Report – 2013 Addendum
POC	point of compliance
q_d	groundwater-specific discharge
R_{BioSat}	rate of light nonaqueous phase liquid biodegradation in the submerged source zone
R_{Dis}	rate of source zone mass loss by dissolution to groundwater
report	Annual 2022 Onsite Groundwater Monitoring and Five-Year Periodic Review Report

reporting period	first and third quarters of 2022
ROCP	Revised Onsite Cleanup Plan
site	North Pole Terminal, located on H and H Lane in North Pole, Alaska
TPH	total petroleum hydrocarbons
VPT	vertical profile transect
w	width of submerged source zone

1 Introduction

Arcadis U.S., Inc. (Arcadis) prepared this Annual 2022 Onsite Groundwater Monitoring and Five-Year Periodic Review Report (report) for the North Pole Terminal, located on H and H Lane in North Pole, Alaska (site). This report summarizes onsite field activities completed during the first and third quarters of 2022 (reporting period), as described in Section 3 and presented in Table 1-1.

The data, analyses, and conclusions presented in this report are the product of a collaborative effort by a consulting team engaged by Flint Hills Resources Alaska, LLC (FHRA) to undertake the work discussed in this report. The team includes qualified professionals in a variety of technical disciplines from three environmental consulting firms: Arcadis, Shannon & Wilson, Inc., and Barr Engineering Co. FHRA engaged these consulting firms to perform various tasks for the project. Pursuant to 18 Alaska Administrative Code (AAC) 75.335(c)(1), this report was prepared and submitted by Qualified Environmental Professionals. Samples were collected and analyzed in accordance with 18 AAC 75.355(a). Sample locations are defined in the Long-Term Monitoring Plan – 2017 Update (2017 LTM Plan), provided as Appendix A to the Revised Onsite Cleanup Plan (ROCP; Arcadis 2017b) and the 2022 Updates to the 2017 LTM Plan (Arcadis 2022). During the reporting period, sampling and analyses were completed in accordance with the following documents, which were also prepared by Qualified Environmental Professionals and approved by the Alaska Department of Environmental Conservation (ADEC):

- ROCP (Arcadis 2017b)
- 2017 LTM Plan (Arcadis 2017b)
- Revised Onsite Sampling and Analysis Plan (Onsite RSAP; provided as Appendix A to the Second Semiannual 2016 Onsite Groundwater Monitoring Report [Arcadis 2017a])
- 2022 Updates to the 2017 LTM Plan (approved in an email from ADEC dated May 5, 2022 [Arcadis 2022]).

The site, offsite area, and the site's physical setting are described in the conceptual site model, which was provided in Appendix A of the Onsite Site Characterization Report – 2013 Addendum (Onsite SCR – 2013; Arcadis 2013). The site location, current site features, and an onsite site plan are shown on Figures 1-1, 1-2, and 1-3, respectively. The former treatment systems (GAC West and GAC East) are shown on Figure 1-2. GAC West was shut down in third quarter 2016. GAC East (also referred to in this report as the groundwater remediation and treatment system [GRTS]) was shut down in third quarter 2017 (see Section 2). Responses to shutdown of the treatment system are discussed in Section 5. The former recovery well locations are shown on Figure 1-3.

2 Current Groundwater Monitoring Program and Methods

The following monitoring and sampling activities were conducted in accordance with the 2017 LTM Plan and the 2022 Updates to the LTM Plan (Arcadis 2017b, 2022):

- Groundwater elevation measurements
- Light nonaqueous phase liquid (LNAPL) migration monitoring
- Groundwater sampling and analysis of sulfolane

- Groundwater sampling and analysis of other constituents of concern (COCs), including benzene, toluene, ethylbenzene, and xylenes (BTEX); gasoline-range organics (GRO); and diesel-range organics (DRO)
- Groundwater sampling and analysis of natural attenuation parameters (iron, manganese, sulfate, methane, and dissolved oxygen [DO]).

The ROCP (Arcadis 2017b) was submitted to and approved by ADEC in February 2017. In accordance with the ROCP, in third quarter 2017 the GRTS was shut down and the updated sampling program defined under the ROCP was implemented. This report includes a five-year periodic review of post-shut down conditions at the site.

Table 1-1 summarizes the field activities completed during the reporting period. Monitoring methods and well construction details are described in the Onsite RSAP (Arcadis 2017a). One deviation from the 2017 LTM Plan and the 2022 Updates to the 2017 LTM Plan (Arcadis 2017b, 2022) was noted during the reporting period. Monitoring well MW-198-150 was frozen during the planned groundwater elevation monitoring event; therefore, a depth to water measurement was not collected from this well during the first semiannual monitoring event.

In accordance with the 2022 Updates to the 2017 LTM Plan (Arcadis 2017b, 2022) dated May 5, 2022, several wells in the sulfolane network that were sampled in first quarter were subsequently reduced to an annual sampling frequency. Because the wells were already sampled once during the reporting period, these wells were not sampled again during the third quarter as part of the usual annual sampling network. These wells are listed below:

- MW-148A-15
- MW-149B-30
- MW-148C-55
- MW-148-80
- MW-176A-15
- MW-304-CMT-20
- MW-330-20
- MW-334-15
- MW-336-20
- MW-354-35
- MW-372-15
- O-1
- O-24
- O-34.

Similarly, the sulfolane sampling frequency increased for three wells (MW-154B-95, MW-303-CMT-39, and MW-359-35) from annual to semiannual. This change was made in May 2022 in accordance with the 2022 Updates to the 2017 LTM Plan (Arcadis 2017b), after the first semiannual event was completed; therefore, the wells were only sampled during the second semiannual event.

3 Groundwater Monitoring Results

Groundwater impacts have been characterized and continue to be monitored through the analysis of water-level gauging data and groundwater samples collected from onsite monitoring wells. This section presents the results of water-level gauging and groundwater analyses of onsite well samples. Data are presented in Tables 3-1 through 3-7.

Historical groundwater elevation and LNAPL thickness measurements, and BTEX, GRO, DRO, and sulfolane analytical results are provided in Appendix A. Analytical laboratory reports are provided in Appendix B. A data quality evaluation, including ADEC quality assurance/quality control checklists, is provided in Appendix C. Field data sheets are provided in Appendix D.

3.1 Groundwater Elevation

Depth to water measurements were collected from monitoring wells on March 25 and September 22, 2022. Potentiometric maps are included for each monitoring zone: water table, 10 to 55, 55 to 90, and 90 to 160 feet below the water table for each monitoring event (Figures 3-1 through 3-8). During the reporting period, the general direction of the horizontal hydraulic gradient was interpreted to be to the north-northwest, which is consistent with historical groundwater data. Groundwater elevations and horizontal hydraulic gradients were within the range of historical groundwater data.

Groundwater well field parameters for the reporting period are presented in Table 3-1. Groundwater elevations for the reporting period, as well as surface water elevations and depth to LNAPL, are presented in Tables 3-2a and 3-2b. Measurements were recorded from gauging points located at the North Gravel Pit on March 25 and September 22, 2022. Data are presented in Tables 3-2a and 3-2b and shown on Figures 3-1 through 3-8. Historical gauging data are provided in Appendix A.

3.2 Light Nonaqueous Phase Liquid Monitoring Results

LNAPL migration observations were collected from a network of monitoring, observation, and recovery wells screened across the water table according to the 2017 LTM Plan and the 2022 Updates to the 2017 LTM Plan (Arcadis 2017b, 2022). Additionally, LNAPL was gauged throughout the reporting period during monitoring events at wells outside of the LNAPL migration network. Comprehensive LNAPL gauging data are provided in Appendix E.

A qualitative evaluation of the chemical composition of groundwater to determine LNAPL depletion rates is included in Section 4.

3.2.1 Light Nonaqueous Phase Liquid Extent

Per the 2017 LTM Plan and the 2022 Updates to the 2017 LTM Plan (Arcadis 2017b, 2022), LNAPL migration observations were made from wells along the perimeter of the LNAPL plume. During the annual LNAPL migration monitoring event, LNAPL was observed in LNAPL migration wells O-11 and O-27. Results are presented in Table 3-3. Figure 3-9 shows thickness data from the LNAPL migration monitoring event, as well as maximum thickness data measured during the reporting period in other gauging events. LNAPL was gauged during the following monitoring events throughout the reporting period: groundwater elevation monitoring, and groundwater sampling and field parameter collection. Gauging data from each monitoring event conducted at the site during the reporting period are provided in Appendix E.

LNAPL thickness measurements during the reporting period were similar to historical results. LNAPL was not detected in any new wells during the reporting period (that is, in wells that have not previously had a detection).

3.2.2 Natural Source Zone Depletion Assessment Results

Fifteen monitoring wells were sampled for natural source zone depletion (NSZD) parameters to evaluate the potential for NSZD to occur at the site. Sample locations are defined in the 2017 LTM Plan and the 2022 Updates to the 2017 LTM Plan (Arcadis 2017b, 2022). LNAPL was present in NSZD monitoring wells MW-138-20 and MW-348-15. In accordance with the 2017 LTM Plan and the 2022 Updates to the 2017 LTM Plan (Arcadis 2017b, 2022), LNAPL was removed from the wells prior to collection of the NSZD samples. Field parameters were collected from 15 monitoring wells and are presented in Table 3-1. Natural attenuation parameters (iron, manganese, sulfate, and methane), GRO, and DRO are presented in Table 3-4 and shown on Figure 3-10.

The NSZD assessment methodology is discussed and results are provided in Section 4.

3.3 Monitoring Well Sampling

Petroleum analyte sample locations are defined in the 2017 LTM Plan and the 2022 Updates to the 2017 LTM Plan (Arcadis 2017b, 2022). Monitoring wells included in these plans were sampled for BTEX, GRO, and DRO. Results are presented in Tables 3-5a and 3-5b. Figures 3-11 and 3-12 show analytical results for benzene.

Analyses for sulfolane were completed on groundwater samples collected from the wells identified in the 2017 LTM Plan and the 2022 Updates to the 2017 LTM Plan (Arcadis 2017b, 2022). Sulfolane analytical results are presented in Tables 3-6a and 3-6b and shown on Figures 3-13 through 3-19.

Groundwater samples were collected from the point of compliance (POC) wells to evaluate the vertical distribution of sulfolane concentrations. Sulfolane concentrations for the POC, which includes well nests MW-358, MW-359, MW-360, MW-362, and MW-364, and well MW-149A-15, are presented in Table 3-7. Groundwater samples were also collected from wells along the vertical profile transect (VPT), which is located between 250 and 950 feet upgradient of the POC wells.

Sulfolane trends (post-GRTS shutdown) are further discussed in Section 5.

3.4 Statistical Analyses of Benzene and Sulfolane Data

A statistical evaluation of benzene and sulfolane concentration trends using Mann-Kendall trend analyses is conducted annually using analytical data for samples collected through the third quarter to evaluate plume migration, stability, and remedial action effectiveness. A graphical analysis of analytical and gauging data is also completed to identify relationships between concentrations, groundwater elevations, and flow directions. Use of the Monitoring and Remediation Optimization System for Mann-Kendall trend analysis was applied to groundwater monitoring data collected since 2006 from monitoring and observation wells. Only wells that were sampled during the reporting period were included in the analyses. Wells with LNAPL present were excluded from evaluation of the benzene statistical trend; results for samples collected since LNAPL was last detected were used for the analyses.

The analysis trends are expressed as probably increasing, increasing, probably decreasing, decreasing, stable, or no trend. Results of the Mann-Kendall trend analyses for wells sampled during the reporting period are provided in Appendix F (Tables F-1 and F-2; Figures F-1, F-2, F-3, F-4, F-5, and F-6) and presented in the table below.

Parameter Trend	Third Quarter	
	Benzene	Sulfolane
Number of wells	26	57
All results nondetect[1]	6	1
Insufficient data points[1]	3	0
Probably decreasing	0	0
Decreasing	4	24
Probably increasing	0	0
Increasing	4	9
Stable	2	8
No trend	7	15

Note:
[1]Wells with insufficient data points for the statistical analysis (less than four points), but with all results less than detection limits, are listed under "all results nondetect."

Results of the Mann-Kendall trend analyses were evaluated and compared visually to the trend charts; this evaluation is discussed below.

3.4.1 Benzene Statistical Evaluation

The Mann-Kendall trend analyses indicated an increasing benzene concentration trend in wells MW-130-25, MW-154B-95, O-4, and O-24, as seen on the benzene time-series plots provided in Appendix F, Attachment F-1.

Monitoring well MW-130-25 is within the detectable benzene plume at the site, near the downgradient extent. Although the Mann-Kendall analysis indicates a trend that is increasing in this well, concentrations consistently decreased from 2015 to 2018 with a partial rebound starting in 2019. Concentrations decreased in 2021 and 2022 and are less than historical levels observed in this well. MW-154B-95 is also within the detectable benzene plume at the site. The analysis indicates an increasing trend in this well; however, recent concentrations have fluctuated between detectable and nondetectable. The results in 2022 indicated a low-level detection (3.0 micrograms per liter [µg/L]), which is less than the maximum concentration observed in this well.

Wells O-4 and O-24 are within the detectable benzene plume at the site, near the downgradient extent. Concentrations in O-4 have decreased since the maximum detected concentration of 86.0 µg/L in July 2018 and were nondetectable in 2022. Benzene concentrations increased in the sample collected from O-24 in 2022. Benzene trend charts for O-24 as well as nearby upgradient wells (O-3, MW-125-25, MW 130-25, and MW-136-20) and the nearest downgradient well (O-25) were evaluated. No trend is apparent at the nearest upgradient well (O-3). However, since shutdown of the GRTS in 2017, upgradient wells MW-130-25, MW 125 25, and MW-137-20 show increasing trends in benzene concentrations that peaked in 2019 or 2020 and have subsequently plateaued or started to decrease. It is possible that the increased benzene concentration observed in O-24 in August 2022 also represents rebounding after the GRTS was shut down. Future monitoring at O-24 is recommended to determine if benzene concentrations plateau or begin decreasing, similar to the patterns observed in upgradient monitoring wells.

Benzene concentration trends are further discussed in Section 5.1.

3.4.2 Sulfolane Statistical Evaluation

As noted in Section 3.3 of the ROCP (Arcadis 2017b), the cleanup objective for sulfolane in groundwater is 400 µg/L at the POC. As discussed below, none of the POC wells or wells along the VPT had sulfolane concentrations exceeding 400 µg/L during the reporting period. The only wells with concentrations exceeding 400 µg/L during the reporting period are water table wells near the former source areas, which is consistent with results observed since the 2017 shut down of the GRTS. Current trends support the cleanup objective and do not suggest that sulfolane will exceed 400 µg/L at the POC.

Sulfolane time-series plots for all wells sampled during the reporting period are provided in Appendix F, Attachment F-1. These time-series plots are presented with both linear and logarithmic concentration scales to facilitate the evaluation of concentration trends since shutdown of the GRTS. The time since GRTS shutdown is relatively short compared to the periods of record for most of the monitoring wells; therefore, stabilization of sulfolane concentrations in many wells is apparent in charts with the logarithmic concentration scale, whereas stabilization may not be as apparent in the charts with linear concentration scales.

The Mann-Kendall trend analyses for the site sample results indicate that the majority of onsite wells exhibit decreasing trends. In particular, concentrations in well S-51, located along the main plume axis upgradient of the former recovery wells, have decreased to less than 400 µg/L and continue to decrease, supporting the goal of meeting the cleanup objective for sulfolane. Wells with current concentrations exceeding 400 µg/L (MW-176A-15, MW-336-20, MW-372-15, and O-1) are source area wells located more than 1,500 feet upgradient of the POC. Monitoring wells MW-336-20, MW-176A-15, and O-1 have overall decreasing concentration trends, and monitoring well MW-372-15 exhibits a stable trend. A review of trend graphs for MW-372-15 shows that concentrations have decreased from the historical high concentration observed in 2017.

Most of the onsite wells exhibiting an increasing sulfolane concentration trend are located adjacent to or downgradient from the recovery wells associated with the former treatment systems (MW-345-15, MW-345-55, MW-345-75, MW-371-15, O-26-65, O-27, and O-27-65). Monitoring wells MW-304-80 and MW-359-80 also exhibited increasing trends but are further downgradient from the former treatment systems. These results are as expected, as discussed below, and do not suggest that sulfolane will exceed 400 µg/L at the POC. There are no probably increasing or increasing trends in the 90- to 160-foot zone wells.

In addition to these Mann-Kendall trend analyses results, other wells located within and downgradient from the former recovery wells exhibit increases in concentration following GRTS shutdown, but not an overall increasing or probably increasing trend based on all data from a given well. As with the Mann-Kendall results described above, these are expected outcomes and do not suggest that sulfolane will exceed 400 µg/L at the POC. The observed sulfolane trends that have developed in response to the GRTS shutdown are discussed in Section 5.

3.5 Nonroutine Activities

No nonroutine activities were conducted during the reporting period. However, during routine well inspections conducted the reporting period, it was noted that three site monitoring wells (MW-143-20, O-12-65, and O-21) have been damaged beyond repair. Monitoring wells O-12-65 and O-21 are not part of the current long-term monitoring (LTM) network and will be properly decommissioned; no replacement wells are proposed. Monitoring well MW-143-20 is currently one of the wells sampled annually for COCs. Based on current and historical data collected from this well and the proximity of other upgradient wells currently in the network, this well will also be decommissioned, and no replacement well is proposed. Other minor well maintenance activities that do not impact the integrity of the wells will be scheduled for 2023.

4 Natural Source Zone Depletion Assessment and Assimilative Capacity Evaluation

The potential efficacy of NSZD as a means of reducing LNAPL mass, which through time will further reduce LNAPL mobility, was evaluated following protocols outlined in the Interstate Technology & Regulatory Council (ITRC) guidance for LNAPL site characterization and management (ITRC 2009, 2018). As a component of this evaluation, assimilative capacity (AC) was estimated, and sensitivity testing of this estimate was conducted. AC is the mass of hydrocarbon constituents that may be biodegraded based on the available concentrations of other biodegradation reaction components in groundwater.

4.1 Methodology

NSZD is a combination of natural processes that reduce the mass of LNAPL in the subsurface through time. NSZD occurs when processes act to physically redistribute LNAPL components to the aqueous phase via dissolution, or to the gaseous phase via volatilization. NSZD preferentially depletes the most soluble and volatile constituents of the LNAPL. As LNAPL constituents migrate away from the source zone in vapor and groundwater, these constituents are biologically degraded (ITRC 2018). Biodegradation rates of LNAPL constituents dissolved in groundwater depends, in part, on the type and availability of electron acceptors. Hydrocarbon constituents may be degraded by aerobic and anaerobic oxidation. Aerobic oxidation occurs under oxygen-rich conditions, and anaerobic biodegradation occurs under oxygen-poor conditions. The use of available electron acceptors during biodegradation typically occurs in the following order, from greater energy availability to lesser energy availability: oxygen, nitrate, manganese oxides, ferric iron hydroxides, sulfate, and fermentation of organics/carbon dioxide reduction to methane (methanogenesis). Aerobic degradation and nitrate reduction result in decreased concentrations of DO and nitrate (respectively) in groundwater, relative to background concentrations. Reduction of iron and manganese hydroxides and oxides results in increased concentrations of dissolved iron and manganese in groundwater. Sulfate reduction results in decreased sulfate concentrations in groundwater, relative to background. Methanogenesis results in increased concentrations of methane in groundwater.

The rate of depletion of LNAPL constituents dissolved and biodegraded in groundwater can be determined through inspection of upgradient and downgradient hydrocarbon and electron acceptor concentrations and understanding the volumetric flow rate of groundwater through the LNAPL source zone. An observation of increased dissolved-phase petroleum hydrocarbon constituent concentrations between upgradient and downgradient groundwater monitoring locations provides evidence that LNAPL dissolution is occurring. Depletion of electron acceptors (oxygen, nitrate, and sulfate), production of biodegradation reaction products (ferrous iron, manganese, and methane), and generation of hydrocarbon fermentation byproducts (acetate and methane) demonstrate that microbial metabolism of hydrocarbons is ongoing. Differences in concentrations of electron acceptors and biodegradation reaction products upgradient and downgradient of LNAPL can be used to estimate the magnitude of biodegradation.

4.1.1 Source Zone Mass Depletion by Dissolution to Groundwater in the Saturated Zone

As groundwater moves through the subsurface it will contact LNAPL-impacted soil within the saturated zone, and infiltrating precipitation may contact LNAPL-impacted soil within the vadose zone. In both cases, petroleum hydrocarbons will partition into the water and result in a loss of mass from the LNAPL body. When infiltration of precipitation is insignificant and clean groundwater enters the LNAPL source zone, the rate of LNAPL source mass loss by dissolution can be simplified to consider only dissolved hydrocarbons exiting the submerged portion of the source zone. The rate of source zone mass loss by dissolution to groundwater (R_{Dis}) can be determined using Equation 1 (ITRC 2009):

Equation 1:

$$R_{Dis}=q_d*h*w*(C_d*CF)$$

Where:

q_d = groundwater-specific discharge (cubic meter of water per square meter per second [m^3 $H_2O/m^2/sec$])

h = thickness of submerged source zone (meters)

w = width of submerged source zone (meters)

C_d = average groundwater concentration (milligram per liter [mg/L])

CF = conversion factor (1,000 mg/L per kilogram per cubic meter of water).

4.1.2 Source Zone Mass Depletion by Biodegradation in the Saturated Zone

Biodegradation of LNAPL in the saturated zone results in decreasing concentrations of dissolved electron acceptors (oxygen, nitrate, and sulfate) from influent groundwater and precipitation recharge, and increasing concentrations of biodegradation transformation products (dissolved manganese, iron, and methane). Comparison of the loss of electron acceptors and formation of transformation products supports estimation of the rate of LNAPL biodegradation in the submerged source zone (R_{BioSat}). An estimate of the biodegradation rate was completed using Equation 2 (ITRC 2009).

Equation 2:

$$R_{BioSat}=q_d* h* w* AC$$

Where:

q_d = groundwater-specific discharge (m^3 $H_2O/m^2/sec$)

h = thickness of submerged source zone (meters)

w = width of submerged source zone (meters)

AC = assimilative capacity, the difference between upgradient and downgradient concentrations of each natural attenuation indicator species multiplied by a representative stoichiometric coefficient.

4.2 Data Evaluation

Data presented in the following sections were used to evaluate NSZD processes and to calculate rates of LNAPL mass reduction at the site.

4.2.1 Data for Dissolution Rate in Saturated Zone

A significant portion of the LNAPL-impacted area of the site is covered with low-permeability surfaces. Based on that observation, infiltration of precipitation was not considered a significant contribution of DO to the subsurface. This assumption simplifies the dissolution rate equation used in the NSZD evaluation. Another assumption in the dissolution calculations is that groundwater entering the LNAPL source zone is unimpacted by upgradient contaminant sources. Monitoring wells MW-192A-15 and O-15 were selected as the representative background wells for the NSZD evaluation. Both wells are outside of and upgradient from the LNAPL and dissolved-phase plumes. Appendix G, Table G-1 presents dissolved-phase petroleum hydrocarbon constituent concentrations in groundwater samples collected from wells MW-192A-15 and O-15 in August 2022. In each of these samples, GRO and DRO were nondetect (MW-192A-15), or present only at qualified concentrations near or less than the duplicate sample level of detection (O-15), indicating that influent groundwater contains (at most) only trace amounts of petroleum hydrocarbons. Therefore, the LNAPL mass loss rate by dissolution can be simplified to consider only dissolved hydrocarbons exiting the submerged portion of the source zone.

A change in dissolved-phase petroleum hydrocarbon constituent concentrations between groundwater monitoring locations upgradient and within or downgradient from the LNAPL source zone provides evidence that LNAPL dissolution is occurring. Source zone monitoring wells MW-125-25, MW-130-25, MW-138-20, MW-348-15, and MW-336-20 were selected to represent groundwater quality within the LNAPL-influenced dissolved-phase plume because the wells are distributed throughout an area of the site where the majority of LNAPL has been observed. Average dissolved-phase GRO and DRO concentrations of 20.1 and 4.8 mg/L, respectively, were calculated based on concentrations in groundwater samples collected in August 2022 (Appendix G, Tables G-1 and G-2).

The overall concentration of dissolved-phase total petroleum hydrocarbons (TPH), interpreted as the sum of the GRO and DRO values, is 24.9 mg/L. This concentration is comparable to that calculated in 2018, although a subset of the wells sampled for the evaluation is different between the two events.

4.2.2 Data for Biodegradation Rate in Saturated Zone

Quantification of biodegradation in the saturated zone uses biogeochemical parameters (oxygen, nitrate, sulfate, dissolved iron and manganese, and methane). Monitoring wells MW-125-25, MW-130-25, MW-138-20, MW-348-15, and MW-336-20 were selected to represent the source zone and downgradient conditions for the NSZD evaluation. Monitoring wells MW-192A-15 and O-15 were used as background monitoring wells. Biogeochemical data for the reporting period at these wells are provided in Appendix G, Table G-1. In addition, sensitivity testing was conducted to determine the estimated value for AC used to calculate the rate of LNAPL biodegradation in the submerged source zone. For this sensitivity testing, the AC was estimated using data collected during August 2022 for three separate groups of downgradient monitoring wells relative to upgradient monitoring well MW-192A-15. Background monitoring well O-15 was excluded from sensitivity testing because of the outsized influence of sulfate concentrations that were inconsistent between the primary and duplicate samples and with earlier measurements that were more consistent with the concentrations measured at MW-192A-15. AC was estimated in Downgradient Area A using data from monitoring wells MW-138-20, MW-336-20, and MW-348-15; in Downgradient Area B using data from monitoring wells MW-130-25 and MW-125-25; and in Downgradient Area C using data from monitoring wells MW-139-25, MW-142-20, and MW-154B-95. Additionally, for sensitivity testing, stoichiometric coefficients were used for decane (ITRC 2009) and BTEX. Appropriate stoichiometric coefficients for BTEX were determined by Wiedemeier et al. (1994) and Suarez and Rifai (2004) and were based on derivation using the methods described by Wiedemeier et al. (1994) in cases where the stoichiometric coefficients were not available (manganese reduction and methanogenesis).

4.3 Natural Source Zone Depletion Assessment

4.3.1 Qualitative Assessment of Natural Source Zone Depletion

Biodegradation and dissolution of the submerged portion of the LNAPL can be assessed by comparing the chemical composition of groundwater upgradient from the source zone with groundwater immediately downgradient. Biodegradation of petroleum hydrocarbons results in a decrease in electron acceptor concentrations and a corresponding increase in biodegradation transformation products between upgradient and within and/or downgradient from the LNAPL plume. The relevant biogeochemical data (DO, sulfate, dissolved iron, dissolved manganese, and methane) are provided in Appendix G, Table G-1. The upgradient (MW-192A-15 and O-15) and source zone/downgradient (MW-125-25, MW-130-25, MW-138-20, MW-348-15, and MW-336-20) data are compared below:[1]

- Oxygen decreased from 0.51 mg/L at the upgradient monitoring locations to an average of 0.1 mg/L in the source zone/downgradient monitoring locations, indicating oxygen reduction from anaerobic degradation.
- Sulfate decreased from 29 mg/L at the upgradient monitoring locations to an average of 5.8 mg/L in the source zone/downgradient monitoring locations, indicating sulfate reduction from anaerobic degradation. While this average sulfate concentration is based on the primary sample from background well O-15 (18.1 mg/L J*) and the sample from background well MW-192A-15 (39.3 mg/L), it may not be a reliable estimate based on the difference in sulfate concentrations in the primary (18.1 mg/L J*) and duplicate (42.7 mg/L J*) samples from O-15. These results were flagged (J*) to indicate a quality control failure.
- Dissolved iron increased from nondetect at the upgradient monitoring locations to an average of 16 mg/L in the source zone/downgradient monitoring locations, indicating iron reduction from anaerobic degradation.
- Dissolved manganese increased from 0.17 mg/L at the upgradient monitoring locations to 4.9 mg/L in the source zone/downgradient monitoring locations, indicating manganese reduction from anaerobic degradation.
- The methane concentration increased from 0.01 mg/L at the upgradient locations to 3.7 mg/L in the source zone monitoring locations, indicating carbon dioxide reduction or organic acid fermentation from anaerobic degradation.

[1] Note that all concentrations referenced are average concentrations across the set of upgradient and downgradient wells, and nondetect concentrations were excluded from averages.

- Nitrate monitoring was not conducted in 2022 as a result of the observation from earlier sampling that naturally occurring nitrate levels in the aquifer are low; therefore, nitrate is not readily available as an electron acceptor at the site.

This comparison of upgradient and source zone/downgradient natural attenuation parameters shows a clear decrease in electron acceptor concentrations and an increase in biodegradation transformation product concentrations, which demonstrates that biodegradation of LNAPL constituents is occurring.

4.3.2 Estimate of Source Zone Mass Depletion by Dissolution to Groundwater in the Saturated Zone

LNAPL mass loss occurs via dissolution of hydrocarbons into water as groundwater moves through the subsurface and contacts LNAPL-impacted soil within the saturated zone. The flux of groundwater exiting the LNAPL source area and the concentrations of hydrocarbons that dissolve into groundwater dictate the mass loss. Based on the average hydraulic conductivity, site groundwater gradient, and cross-sectional area of the impacted groundwater, approximately 280 cubic meters of groundwater exit the source area every day. The average 2022 dissolved-phase concentration of petroleum compounds in the wells immediately downgradient from the source areas (but upgradient from the groundwater recovery system) is 24.9 mg/L.

Using Equation 1 and the plume parameters provided in Appendix G, Table G-2, the LNAPL mass depletion rate as a result of dissolution is estimated to be between 800 and 4,400 kilograms (kg) TPH per year based on the range of water hydraulic conductivities presented in the Onsite SCR – 2013 (Arcadis 2013). This equates to between 300 and 1,400 gallons of LNAPL depleted per year. LNAPL mass depletion rates as a result of dissolution are provided in Appendix G, Table G-2.

4.3.3 Estimate of Source Zone Mass Depletion Rate by Biodegradation in the Saturated Zone

Mass loss of LNAPL via biodegradation of hydrocarbons is controlled by groundwater flux into the LNAPL source zone, as discussed above, and the AC of the aquifer. AC is a measure of the extent to which hydrocarbon constituents may be biodegraded in a specified volume of water based on the availability of electron acceptors to couple with their oxidation. For the sensitivity testing, six estimates of AC were made. AC was estimated based on three datasets using two sets of stoichiometric coefficients, for decane and for BTEX. The three datasets include:

- Concentrations measured during August 2022 between upgradient monitoring well MW-192A-15 and downgradient monitoring wells MW-138-20, MW-336-20, and MW-348-15 (Downgradient Area A).
- Concentrations measured during August 2022 between upgradient monitoring well MW-192A-15 and downgradient monitoring wells MW-130-25 and MW-125-25 (Downgradient Area B).
- Concentrations measured during August 2022 between upgradient monitoring well MW-192A-15 and downgradient monitoring wells MW-139-25, MW-142-20, and MW-154B-95 (Downgradient Area C).

Background monitoring well O-15 was not used with MW-192A-15 because of the anomalous sulfate results noted in Section 4.3.1. Calculations of AC are provided in Appendix G, Table G-3 and are between 9.88×10^{-3} kg TPH per cubic meter of groundwater (between upgradient monitoring well MW-192A-15 and Downgradient Area C using the stoichiometric coefficients for decane) and 1.40×10^{-2} kg TPH per cubic meter of groundwater (between upgradient monitoring well MW-192A-15 and Downgradient Area A using the stoichiometric coefficients for BTEX).

The AC calculations indicate that approximately 1 percent is attributed to aerobic biodegradation, approximately 1 to 6 percent are attributed to manganese reduction, approximately 4 to 7 percent are attributed to iron reduction, approximately 54 to 58 percent are attributed to sulfate reduction, and approximately 28 to 39 percent are attributed to methanogenesis (Appendix G, Table G-3).

Substantial biodegradation of petroleum hydrocarbon constituents is interpreted to occur in Downgradient Areas A, B, and C based on elevated concentrations of dissolved iron and manganese, depleted concentrations of sulfate, and elevated concentrations of methane. Concentrations of electron acceptors further downgradient at monitoring wells MW-101A-25, MW-303-CMT-39, MW-304-CMT-40, MW-359-35, and MW-360-50 reflect a return to background conditions, with:

- Dissolved iron and manganese concentrations that are greater than upgradient monitoring well MW-192A-15, but less than those at wells in Downgradient Areas A, B, and C
- Sulfate concentrations that are comparable to upgradient monitoring well MW-192A-15, but greater than those at wells in Downgradient Areas A, B, and C
- Methane concentrations that are slightly elevated relative to upgradient monitoring well MW-192A-15, but less than those at wells in Downgradient Areas A, B, and C.

The apparent recovery to near background conditions at the furthest downgradient monitoring wells in the NSZD area suggests that electron acceptors are generally available in the aquifer and support AC on a long-term basis.

Using Equation 2 and the plume parameters provided in Appendix G, Tables G-4, G-5, and G-6, the LNAPL mass depletion rate due to biodegradation in the saturated zone is estimated to be between 300 and 2,500 kg TPH per year based on the range of water hydraulic conductivities presented in the Onsite SCR – 2013 (Arcadis 2013) and the range in AC estimates provided in Appendix G, Table G-3. This equates to between 100 and 800 gallons of LNAPL depleted per year.

4.4 Natural Source Zone Depletion Evaluation Summary

A qualitative evaluation of the chemical composition of groundwater indicates that LNAPL is being depleted through natural processes, including dissolution and biodegradation in the saturated zones. NSZD rates were quantified and the estimated total mass loss rate in the saturated zone by dissolution is 300 to 1,400 gallons per year, while the mass loss rate by biodegradation in the saturated zone is 100 to 800 gallons per year. These rates are comparable to those presented in the Onsite SCR – 2013 (Arcadis 2013; 100 to 300 and 200 to 900 gallons per year, respectively) and in the Annual 2018 Onsite Groundwater Monitoring Report (Arcadis 2018; 300 to 1,500 and 100 to 1,300 gallons per year) and are within the expected range. The depletion rates may be biased high due to seasonal changes in soil diffusivity and biological activity. However, at a minimum, the natural LNAPL depletion rate in the saturated zone at the site is on the order of hundreds to thousands of gallons per year. LNAPL depletion rates have remained robust following GRTS shutdown and support the assumptions of the ROCP (Arcadis 2017b).

5 Concentration Trends in Response to Groundwater Remediation and Treatment System Shutdown

The monitoring results presented in this section are based on sulfolane and benzene data gathered in accordance with the 2017 LTM Plan and the 2022 Updates to the 2017 LTM Plan (Arcadis 2017b, 2022). The objectives of the monitoring are to:

- Monitor the nature and extent of COCs onsite
- Evaluate the potential exposure to COCs
- Evaluate contaminant trends and groundwater modelling predictions.

In addition, this section evaluates short-term monitoring results following shutdown of the groundwater remediation system in 2017 in accordance with the ROCP (Arcadis 2017b). Objectives of the short-term monitoring evaluation, in addition to those listed above, include evaluations of:

- Contaminant rebound (discussed below)
- Updated benzene and sulfolane trends (Sections 3.4,5.1, and 5.2)
- BTEX AC (Section 4).

This section reviews the short-term monitoring program and discusses contaminant rebound, horizontal and vertical gradients, and updated analysis of benzene and sulfolane trends.

5.1 Benzene and Diesel-Range Organics

As part of the five-year review process required by the ROCP (Arcadis 2017b), this section discusses contaminant trends for benzene and DRO. The BTEX AC, also required by the ROCP, is discussed in Section 4. The ROCP states that COCs, including benzene and DRO, will not exceed 18 AAC 75.345 Table C cleanup objectives at the POC; the Table C cleanup objectives for benzene and DRO are 4.6 and 1,500 µg/L, respectively.

As shown on Figure 3-12, the plume axis is well-defined, and the plume orientation downgradient of the former treatment systems is consistent with the north to northwest groundwater flow discussed in Section 3.1. Maximum benzene concentrations in the plume in this area decrease in the downgradient direction and do not exceed 4.6 µg/L in POC wells or at the VPT. Benzene concentrations and trends within the plume in the area influenced by the GRTS shutdown do not suggest that benzene will exceed 4.6 µg/L at the POC.

Benzene concentrations during the reporting period, and concentration trends since GRTS shutdown for all wells sampled during the reporting period in areas where increases were expected and subsequently observed following GRTS shutdown, are summarized below:

- *Wells adjacent to the former recovery wells*. The greatest benzene concentration in any well in this area during the reporting period was 762 µg/L (MW-137-20; Table 3-5b), which is similar to the greatest concentration measured in 2021 (Appendix A). A potential increase in benzene concentrations (i.e., rebound) was expected following GRTS shutdown and was observed at MW-137-20, O-3, and O-4. However, following the rebound, all wells now exhibit stabilized or decreasing concentrations (MW-125-25, MW-137-20, O-3, and O-4).

- *Wells between the former recovery wells and the VPT*. Benzene concentrations increased at three wells following GRTS shutdown (MW-139-25, MW-154B-95, and O-24) and the greatest benzene concentration in any well in this area during the reporting period was 130 µg/L (O-24; Table 3-5b), which is more than the greatest concentration measured in 2021. An increase at O-24 is not unexpected because an increase was previously observed at MW-125-25, MW-137-20, and O-3, which are directly upgradient. The concentration measured at O-24 (130 µg/L) is less than the maximum rebound concentration measured at MW-137-20 in 2019 (1,010 µg/L), which indicates that continued biodegradation is occurring. Decreasing concentrations in the upgradient wells discussed above are an indication that concentrations should also decrease at O-24. The benzene concentration at MW-139-25 peaked in 2019 and has since fluctuated. Results at this location will continue to be monitored. The benzene concentrations at MW-154B-95 peaked in 2018, but subsequent concentrations have been low and intermittent (nondetect to 3 µg/L). Four wells in this area (MW-140-25, MW-142-20, O-25, and S-9) that were sampled multiple times since GRTS shutdown either have nondetect or low-level concentrations and currently exhibit stable or decreasing concentrations.
- *Wells in the VPT*. Benzene was detected in one well at the VPT (2.60 µg/L in MW-304-CMT-40), similar to the concentration detected in this well in 2021 (1.83 µg/L). This well is downgradient of wells that rebounded following GRTS shutdown, so low-level detections are not unexpected. Results at this location will continue to be closely monitored. All other wells in this group that were sampled multiple times since GRTS shutdown exhibit stabilized or decreasing concentrations since GRTS shutdown. Benzene has remained at nondetect concentrations for at least the past 3 years (or longer in some locations) in wells MW-101A-25, MW-131-25, MW-143-20, MW-303-CMT-19, and MW-303-CMT-39.
- *Wells in and downgradient of the POC*. Benzene was not detected in any wells in this area (Table 3-5b), which was also the case in 2021 (Appendix A).

For the wells listed above, initial benzene increases were observed in most wells following GRTS shutdown, as was expected. In most cases, this has been followed by stabilization and decreases in concentration. The detected benzene concentrations decrease with distance downgradient of the GRTS recovery wells, which is indicative of continued natural attenuation. Figure 5-1 shows the interpreted extent of the detectable benzene plume when the GRTS system was shut down (third quarter 2017), two years after shutdown of the GRTS system (third quarter 2019), and at the five-year review (third quarter 2022).

As noted in Section 3.3 of the ROCP (Arcadis 2017b), the cleanup objective for benzene is 4.6 µg/L at the POC. Since GRTS shutdown, benzene has not been detected in any of the POC wells. The distal end of the benzene plume and furthest downgradient detection is at MW-304-CMT-40, and the concentrations detected in 2021 and 2022 are less than the cleanup objective. These concentration trends continue to support that benzene will not exceed 4.6 µg/L at the POC.

DRO has been detected intermittently at low concentrations in groundwater samples collected from POC/property boundary wells such as MW-358-15, MW-358-20, MW-359-15, MW-359-35, MW-360-15, MW-360-50, and MW-149-15. All concentrations reported are less than the DRO groundwater cleanup objective for the POC of 1,500 µg/L. Concentrations appear to be stable or decreasing, although trends may not be obvious due to the intermittent nature of the detections. Concentrations in upgradient wells are mostly stable or decreasing, with several starting to decrease following the GRTS shutdown-related rebound (e.g., MW-125-25, MW-139-25, MW-142-20, MW-143-20, MW-303-CMT-39, and O-4). Concentrations appear to be increasing at wells MW-371-15 and O-24; however, these wells are located upgradient of the VPT and the reported concentrations are less than the target groundwater concentration for the POC wells (1,500 µg/L). The high amount of organic matter present in the aquifer may also result in false positive detections.

5.2 Sulfolane

As part of the five-year review process required by the ROCP (Arcadis 2017b), this section discusses contaminant trends for sulfolane and compares actual results with modeling predictions. The ROCP (Arcadis 2017b) states that sulfolane will not exceed 400 µg/L at the POC. As shown on Figures 3-16, 3-17, and 3-18, the plume axis is well-defined and the plume orientation downgradient of the former treatment systems is consistent with the north to northwest groundwater flow discussed in Section 3.1. Maximum concentrations in the plume in this area decrease in the downgradient direction and do not exceed 400 µg/L in POC wells or at the VPT. Sulfolane concentrations and trends within the plume in the area influenced by the GRTS shutdown do not suggest that sulfolane will exceed 400 µg/L at the POC.

Sulfolane concentrations during the reporting period, and concentration trends since GRTS shutdown for all wells sampled during the reporting period in areas where increases were predicted by the groundwater model and subsequently observed following GRTS shutdown, are summarized below:

- *Wells adjacent to the former recovery wells*. The greatest sulfolane concentration in any well in this area during the reporting period was 219 µg/L (MW-345-15; Table 3-6a), which is less than the greatest concentration measured in 2021 (Appendix H). All wells now exhibit stabilized or decreasing concentrations since GRTS shutdown (MW-186A-15, MW-186B-60, MW-309-15, MW-334-15, MW-345-15, MW-345-55, MW-345-75, and O-2). Observed concentrations in wells MW-186A-15, MW345-55, and O-2 were compared to simulated concentrations from the groundwater fate and transport model built for the site. While the simulated data are often noisy with potential seasonal variations, the model predicts wells will rebound in concentration after GRTS shutdown, followed by a period of decreasing concentrations. Observed concentrations in these three wells also showed an initial rebound followed by decreasing concentrations (Appendix A).
- *Wells between the former recovery wells and the VPT*. The greatest sulfolane concentration in any well in this area during the reporting period was 203 µg/L (O-27; Table 3-6b), which is less than the greatest concentration measured in 2021. All wells in this area that were sampled multiple times since GRTS shutdown exhibit stabilized or decreasing concentrations following the shutdown (MW-127-25, MW-139-25, MW-142-20, MW-154B-95, MW-371-15, MW-371-55, O-24, O-26, O-26-65, O-27, and O-27-65). Observed concentrations in wells MW-154B-95, MW-371-15, O-26, O-27, and O-27-65 were compared to simulated concentrations from the groundwater model. The simulated data from this area are also often noisy with potential seasonal variations; however, the model predicts that all wells except MW-371-15 will have a rebound in concentrations after GRTS shutdown, followed by a period of decreasing concentrations. Observed concentrations in all five of these wells show an initial rebound followed by decreasing concentrations (Appendix A). Monitoring well MW-371-15 is slightly offset from the axis of the plume as interpreted in the model. The rebound in concentrations is consistent with other nearby wells and is not considered anomalous.
- *Wells in the VPT*. The greatest sulfolane concentration in any well in this area during the reporting period was 191 µg/L (MW-303-CMT-19; Table 3-6b), which is less than the greatest concentration measured in 2021. All wells in this group that were sampled multiple times since GRTS shutdown exhibit stabilized or decreasing concentrations since GRTS shutdown (MW-301-CMT-20, MW-301-60, MW-302-CMT-20, MW-302-CMT-50, MW-302-CMT-80, MW-303-CMT-19, MW-303-CMT-29, MW-303-CMT-39, MW-303-CMT-49, MW 303-CMT-59, MW-303-80, MW-304-CMT-20, MW-304-CMT-40, MW-304-CMT-60, MW-304-80, MW-304-96, MW-305-CMT-28, and MW-305-CMT-48). Observed concentrations in wells MW-303-CMT-19, MW-303-CMT-39, MW-

303-CMT-59, MW-303-95, and MW-304-CMT-20 were compared to simulated concentrations from the groundwater model. The simulated data for all five wells show a rebound in concentrations after GRTS shutdown, followed by a period of decreasing concentrations. Observed concentrations in all five of these wells show an initial rebound followed by decreasing or stabilizing concentrations (Appendix A).

- *Wells in and downgradient of the POC*. The greatest sulfolane concentration in any well in this area during the reporting period was 185 µg/L (MW-359-35; Table 3-6b), which is less than the greatest concentration measured in 2021. All 16 wells in this group sampled during the reporting period exhibit decreasing, stabilized, or stabilizing concentrations since GRTS shutdown. Observed concentrations in POC wells MW-358-20, MW-359-15, MW-359-35, and MW-359-80 were compared to simulated concentrations from the groundwater model. The simulated data for all four wells show a rebound in concentrations after GRTS shutdown, followed by a period of decreasing concentrations. Observed concentrations in all four of these wells also show an initial rebound followed by decreasing concentrations (Appendix A).

Model results were also compared with observed concentrations of sulfolane for 24 monitoring well locations (Appendix H). These locations were selected based on location relative to the sulfolane plume and concentration trends observed since the GRTS system was shut down in 2017.

For the wells listed above, initial increases were observed in most wells following GRTS shutdown, followed by stabilization and (in most cases) decreases in concentration. General trends in rebounding concentrations and subsequent decreases were also indicated in the sulfolane concentrations simulated by the groundwater model. Graphs for select locations to allow for comparison of model-simulated versus actual sulfolane concentrations are provided in Appendix H.

As noted in Section 3.3 of the ROCP (Arcadis 2017b), the cleanup objective for sulfolane is 400 µg/L at the POC. None of the samples collected from wells in any of the areas influenced by the GRTS shutdown had sulfolane concentrations exceeding 400 µg/L during the reporting period or since GRTS shutdown. In addition, the concentration trends do not suggest that sulfolane will exceed 400 µg/L at the POC. Figure 5-2 shows the interpreted extents of detectable suflolane as well as sulfolane concentrations greater than 400 µg/L when the GRTS system was shut down (third quarter 2017), two years after shutdown of the GRTS system (third quarter 2019) and at the five-year review (third quarter 2022).

6 Conclusions

Groundwater monitoring and sampling events were conducted during the reporting period in accordance with the Onsite RSAP, 2017 LTM Plan, and the 2022 Updates to the 2017 LTM Plan (Arcadis 2017a, 2017b, 2022).

The cleanup objectives for groundwater established in the ROCP (Arcadis 2017b) are that sulfolane concentrations will not exceed 400 µg/L at the POC and cleanup objectives for other COCs listed at 18 AAC 75.345 Table C will be met at the POC.

Conclusions based on results of the onsite field activities conducted during the reporting period are summarized below:

- Groundwater monitoring data collected during the reporting period and for the five years following shutdown of the GRTS system are within expected ranges and support the cleanup objective presented in the ROCP (Arcadis 2017b). There have been no exceedances of the cleanup objectives and no indication that an exceedance will occur.

- Sulfolane concentrations in the source areas are decreasing in most cases. Increases in sulfolane and benzene concentrations were noted in only a limited number of wells downgradient of the former treatment systems. These concentration increases were expected, and the results of trend analysis support the cleanup objectives presented in the ROCP (Arcadis 2017b).
- The statistical analyses provided in Appendix F show that sulfolane concentrations in 23 wells and benzene concentrations in four wells across the plume are decreasing, while sulfolane concentrations in nine wells and benzene concentrations in four wells across the plume are increasing. Sulfolane concentrations in seven wells and benzene concentrations in two wells across the plume are stable.
- As expected, and as described in previous reports, a sulfolane concentration rebound occurred in many wells near and downgradient from the former treatment systems; in most cases, concentrations have subsequently stabilized and are decreasing. Sulfolane trends at the VPT generally peaked by 2021 (four years following shutdown of the GRTS system) and the groundwater plume has reached steady state.
- The only wells with sulfolane concentrations greater than 400 µg/L are located in the historical source areas, more than 1,500 feet upgradient of the POC, and concentrations in these wells are trending downward. The extent of the sulfolane plume exceeding 400 µg/L has contracted considerably since GRTS system shutdown, and no new wells have exceeded 400 µg/L during the five-year period following shut down.

The five-year periodic review of data and comparison of modelled groundwater results to observed concentrations further support that the plume is behaving as predicted following the 2017 shutdown of the GRTS, and that the cleanup objectives presented in the ROCP (Arcadis 2017b) are appropriate.

The current nature and extent of site COCs is supportive of the cleanup objectives. The five-year review confirms that the CSM and the dynamics of the plume are well understood, and the plume has responded to system shutdown as predicted. Therefore, there is no need for further evaluation of the hydrogeological system. Ongoing groundwater monitoring should focus on continuing confirmation that cleanup objectives are being met at the POC wells. Accordingly, the LTM networks have been updated for ongoing monitoring beginning in 2023. The revised networks are provided in Appendix I.

7 References

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Tables

Table 1-1
Field Activities

Annual 2022 Onsite Groundwater Monitoring Report
North Pole Terminal, North Pole, Alaska

Activity	Frequency during 2022
Groundwater Elevation Monitoring	Semiannual (March and September)
LNAPL Migration Monitoring	Annual (October)
Sulfolane Network Sampling	Throughout Q1 and Q3
Constituents of Concern (BTEX, GRO, and DRO) Monitoring Network Sampling	Throughout Q1 and Q3
Natural Source Zone Depletion Monitoring Network Sampling	Throughout Q3
Monitoring Well Repair and Maintenance	No major well repairs in 2022.

General Notes:

Q1 represents field activities associated with the sample results received January 1, 2022 through March 31, 2022.

Q3 represents field activities associated with the sample results received July 1, 2022 through September 30, 2022.

Acronyms and Abbreviations:
BTEX = Benzene, Toluene, Ethylbenzene, and Xylenes
DRO = Diesel Range Organics
GRO = Gasoline Range Organics
LNAPL = Light Non-Aqueous Phase Liquid

Table 3-1
Groundwater Well Field Parameters

Annual 2022 Onsite Groundwater Monitoring Report
North Pole Terminal, North Pole, Alaska

Well ID	Sample Name	Date	Analysis	Depth to Water (feet)	Depth to LNAPL (feet)	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	ORP (mV)	Water Clarity	Purge Criteria	Sample Collection Notes
MW-101A-25	MW-101A-25	7/28/2022	COC, NSZD	9.98	—	5.6	0.07	242.1	7.42	-18.6	Clear	3WV	
MW-125-25	MW-125-25	8/3/2022	NSZD	11.39	—	4.5	0.02	313.8	7.19	-107.1	Clear	SP	
MW-127-25	MW-127-25	8/2/2022	S	11.48	—	4.5	0.07	248.3	7.38	-95.8	Clear	3WV	
MW-130-25	MW-130-25	8/9/2022	COC, NSZD	10.89	—	5.0	0.16	274.9	6.93	-80.4	Clear	SP	
MW-131-25	MW-131-25	7/28/2022	COC	10.71	—	4.2	0.10	274.6	7.14	42.0	Clear	3WV	
MW-137-20	MW-137-20	8/3/2022	COC	11.48	—	5.0	0.06	482.6	6.29	-40.6	Clear	SP	
MW-138-20	MW-138-20	8/8/2022	NSZD	8.90	8.82	—	—	—	—	—	—	1WV	Product present; parameters not recorded.
MW-139-25	MW-139-25	2/18/2022	COC	12.91	—	2.9	0.44	270.9	7.04	-64.6	Clear	SP	
MW-139-25	MW-139-25	8/4/2022	S, COC, NSZD	11.88	—	3.4	0.05	266.9	7.18	-105.4	Clear	SP	
MW-140-25	MW-140-25	2/22/2022	COC	10.65	—	2.3	0.79	280.9	7.09	87.9	Clear	SP	
MW-142-20	MW-142-20	2/18/2022	COC	11.72	—	3.4	0.44	275.8	7.22	-63.8	Clear	3WV	
MW-142-20	MW-142-20	8/4/2022	S, NSZD	10.44	—	5.1	0.02	287.1	7.45	-129.9	Clear	SP	
MW-143-20	MW-143-20	8/10/2022	COC	9.89	—	8.8	0.80	316.0	7.20	-16.5	Clear	SP	
MW-148-80	MW-148-80	2/16/2022	S	10.25	—	3.6	0.44	205.7	7.19	-12.3	Clear	SP	
MW-148A-15	MW-148A-15	2/16/2022	S	10.15	—	2.6	1.07	152.0	6.50	53.6	Opaque	3WV	Water became turbid with the last sample jar.
MW-148B-30	MW-148B-30	2/16/2022	S	10.10	—	2.4	0.36	260.4	7.09	-15.4	Clear	SP	
MW-148C-55	MW-148C-55	2/16/2022	S	10.25	—	2.8	0.43	230.3	7.17	-14.5	Clear	SP	
MW-154B-95	MW-154B-95	8/4/2022	S, COC, NSZD	12.56	—	4.9	0.15	202.5	7.41	-98.6	Clear	SP	
MW-176A-15	MW-176A-15	2/23/2022	S	12.38	Sheen	—	—	—	—	—	—	1WV	Product present; parameters not recorded.
MW-186A-15	MW-186A-15	2/23/2022	S	11.55	Sheen	—	—	—	—	—	—	1WV	Product present; parameters not recorded.
MW-186A-15	MW-186A-15	8/8/2022	S	10.17	Sheen	—	—	—	—	—	—	1WV	Product present; parameters not recorded.
MW-186B-60	MW-186B-60	8/4/2022	S	10.22	—	5.3	0.05	211.4	7.45	72.5	Clear	SP	
MW-192A-15	MW-192A-15	8/5/2022	NSZD	8.39	—	6.4	0.54	251.4	7.04	119.6	Translucent	SP	Water has black particulates, odor, black-brown color.
MW-301-60	MW-301-60	7/29/2022	S	7.62	—	6.3	0.06	228.1	7.46	89.2	Clear	3WV	
MW-301-CMT-20	MW-301-CMT-20	8/9/2022	S	7.58	—	7.9	0.13	245.2	7.38	-42.5	Clear	SP	
MW-302-CMT-20	MW-302-CMT-20	7/26/2022	S	8.90	—	5.3	0.12	239.5	7.46	-32.4	Clear	SP	
MW-303-CMT-19	MW-303-CMT-19	2/22/2022	S	11.94	—	2.4	0.31	268.5	7.12	31.2	Clear	3WV	
MW-303-CMT-19	MW-303-CMT-19	7/27/2022	S	10.99	—	8.0	0.23	305.6	7.07	81.2	Clear	SP	Potential hydrocarbon odor.
MW-303-CMT-19	MW-303-CMT-19	8/10/2022	COC	10.67	—	6.3	0.14	290.8	7.22	-49.8	Clear	SP	
MW-303-CMT-29	MW-303-CMT-29	7/27/2022	S	10.49	—	5.7	0.16	286.8	7.33	-37.6	Clear	3WV	
MW-303-CMT-39	MW-303-CMT-39	7/27/2022	S	10.70	—	5.2	0.10	269.2	7.45	-71.0	Clear	SP	
MW-303-CMT-39	MW-303-CMT-39	8/10/2022	COC, NSZD	10.68	—	6.4	0.10	251.1	7.36	-59.1	Clear	SP	
MW-303-CMT-49	MW-303-CMT-49	7/27/2022	S	10.70	—	6.1	0.10	250.6	7.43	-66.8	Clear	SP	Potential hydrocarbon odor.
MW-303-CMT-59	MW-303-CMT-59	8/10/2022	S	10.68	—	6.7	0.08	237.0	7.36	-59.8	Clear	SP	
MW-303-80	MW-303-80	7/28/2022	S	6.52	—	15.7	0.45	278.6	7.36	169.1	murky	SP	
MW-304-CMT-20	MW-304-CMT-20	2/22/2022	S	13.45	—	3.2	0.68	316.4	6.87	26.1	Clear	3WV	
MW-304-CMT-40	MW-304-CMT-40	7/29/2022	S, COC, NSZD	12.46	—	5.8	0.09	272.2	7.41	-48.2	Clear	SP	
MW-304-CMT-60	MW-304-CMT-60	7/29/2022	S	12.43	—	5.9	0.10	239.6	7.43	-47.2	Clear	SP	
MW-304-80	MW-304-80	8/9/2022	S	11.49	—	5.1	0.20	212.5	7.36	86.2	Clear	SP	
MW-305-CMT-28	MW-305-CMT-28	7/29/2022	S	11.30	—	6.5	0.10	299.9	7.37	74.9	Clear	SP	
MW-309-15	MW-309-15	8/1/2022	S	9.12	—	4.5	0.19	255.6	7.13	-40.5	Clear	SP	
MW-310-15	MW-310-15	8/2/2022	S	8.71	—	7.0	0.21	300.1	6.69	11.3	Clear	3WV	
MW-330-20	MW-330-20	2/16/2022	S	14.81	—	5.1	0.38	299.2	6.80	91.9	Clear	3WV	
MW-334-15	MW-334-15	2/24/2022	S	12.56	Sheen	—	—	—	—	—	—	1WV	Product present; parameters not recorded.
MW-336-20	MW-336-20	2/23/2022	S	7.02	—	2.3	0.57	317.0	6.70	15.1	Clear	SP	Hydrocarbon odor; no sheen.
MW-336-20	MW-336-20	8/4/2022	NSZD	5.91	—	8.3	0.06	315.4	6.71	-63.0	Brown/tan	SP	
MW-345-15	MW-345-15	2/18/2022	S	11.07	—	1.3	0.54	301.6	7.15	8.4	Clear	3WV	
MW-345-15	MW-345-15	8/1/2022	S	10.00	—	6.7	0.21	369.8	7.12	-102.6	Clear	SP	
MW-345-55	MW-345-55	8/1/2022	S	10.23	—	5.3	0.10	221.3	7.42	-40.7	Clear	SP	

Table 3-1
Groundwater Well Field Parameters

Annual 2022 Onsite Groundwater Monitoring Report
North Pole Terminal, North Pole, Alaska

Well ID	Sample Name	Date	Analysis	Depth to Water (feet)	Depth to LNAPL (feet)	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	ORP (mV)	Water Clarity	Purge Criteria	Sample Collection Notes
MW-345-75	MW-345-75	8/1/2022	S	9.88	—	5.2	0.08	217.3	7.40	-6.2	Clear	SP	
MW-348-15	MW-348-15	8/8/2022	NSZD	6.88	Sheen	—	—	—	—	—	—	1WV	Product present; parameters not recorded.
MW-354-35	MW-354-35	2/18/2022	S	11.35	—	4.5	0.37	225.2	7.34	-21.9	Clear	SP	
MW-358-20	MW-358-20	7/26/2022	S, COC	10.96	—	5.0	0.09	263.9	7.17	20.0	Clear	SP	
MW-358-40	MW-358-40	7/26/2022	S	10.58	—	4.2	0.09	245.5	7.30	100.7	Clear	SP	
MW-359-15	MW-359-15	7/25/2022	S	10.10	—	7.2	1.79	309.1	6.66	159.5	Clear	3WV	
MW-359-35	MW-359-35	7/26/2022	S, COC, NSZD	10.07	—	3.8	0.14	273.0	7.41	-38.1	Clear	SP	
MW-359-60	MW-359-60	7/25/2022	S	10.12	—	4.9	0.07	225.3	7.46	-18.9	Clear	SP	
MW-359-80	MW-359-80	7/25/2022	S	10.15	—	5.0	0.06	209.6	7.49	24.3	Clear	SP	
MW-360-15	MW-360-15	7/25/2022	S	10.27	—	6.0	0.20	373.3	6.88	-44.9	Clear	3WV	
MW-360-35	MW-360-35	7/25/2022	S	10.39	—	4.1	0.13	271.9	7.29	-59.1	Clear	SP	
MW-360-50	MW-360-50	7/26/2022	S, NSZD	10.11	—	4.0	0.15	274.3	7.11	-26.1	Clear	SP	
MW-360-80	MW-360-80	7/25/2022	S	9.80	—	5.1	0.08	204.0	7.48	-7.9	Clear	SP	
MW-364-30	MW-364-30	7/30/2022	DRO	10.25	—	3.5	0.16	235.6	7.30	119.4	Clear	SP	
MW-364-65	MW-364-65	7/30/2022	S, DRO	9.76	—	4.6	0.13	228.9	7.44	101.2	Clear	SP	
MW-364-90	MW-364-90	7/30/2022	S, DRO	10.12	—	4.7	0.12	229.0	7.42	84.5	Clear	SP	
MW-371-15	MW-371-15	7/28/2022	S	10.54	—	8.5	0.05	253.9	7.31	-96.4	Clear	3WV	
MW-372-15	MW-372-15	2/16/2022	S	15.27	—	2.6	0.51	375.3	6.88	93.4	Clear	3WV	
O-1	O-1	2/18/2022	S	11.12	—	1.7	0.54	227.1	7.36	-13.3	Clear	3WV	
O-2	O-2	2/24/2022	S	12.78	Sheen	—	—	—	—	—	—	1WV	Product present; parameters not recorded.
O-2	O-2	8/8/2022	S	12.65	Sheen	—	—	—	—	—	—	1WV	Product present; parameters not recorded.
O-3	O-3	8/3/2022	COC	12.35	—	8.2	0.25	603.0	6.92	20.8	Clear	3WV	
O-4	O-4	8/5/2022	COC	10.98	—	6.3	0.09	323.9	7.06	-30.7	Clear	SP	
O-15	O-15	8/5/2022	NSZD	10.75	—	6.2	0.48	248.2	6.56	240.7	Clear	SP	
O-24	O-24	2/23/2022	S	12.61	—	2.2	0.55	282.4	6.99	0.1	Clear	3WV	
O-24	O-24	8/3/2022	COC	11.76	—	6.6	0.05	522.1	6.75	-77.0	Clear	SP	Hydrocarbon odor
O-25	O-25	8/9/2022	COC	12.28	—	8.2	0.46	243.6	6.70	40.4	Clear	SP	
O-26	O-26	2/23/2022	S	12.70	—	2.5	0.54	395.5	7.21	6.4	Clear	3WV	
O-26	O-26	8/2/2022	S	12.72	—	6.4	0.34	442.0	7.06	-69.6	Clear	SP	
O-26-65	O-26-65	8/3/2022	S	11.22	—	5.2	0.04	219.1	7.39	38.2	Clear	3WV	
O-27	O-27	2/23/2022	S	12.81	Sheen	—	—	—	—	—	—	1WV	Product present; parameters not recorded.
O-27	O-27	8/2/2022	S	11.48	Sheen	—	—	—	—	—	—	1WV	Product present; parameters not recorded.
O-27-65	O-27-65	8/2/2022	S	11.91	—	5.5	0.05	353.4	7.41	12.8	Clear	3WV	
O-34	O-34	2/23/2022	S	11.10	Sheen	—	—	—	—	—	—	1WV	Product present; parameters not recorded.
S-9	S-9	2/22/2022	COC	10.80	—	3.2	0.68	265.1	7.15	29.8	Clear	3WV	
S-51	S-51	8/8/2022	S	9.87	Sheen	—	—	—	—	—	—	1WV	Product present; parameters not recorded.

General Note:
MW-148 nest is located offsite near the property boundary, but is being monitored and report as part of the onsite groundwater monitoring program.
Acronyms and Abbreviations:
-- = Not applicable
°C = Degrees Celsius
µS/cm = Microsiemens per centimeter
1WV = One well volume
3WV = Three well volumes
CMT = Continuous multichannel tubing
COC = Contaminants of concern (benzene, toluene, ethylbenzene, xylenes [BTEX], gasoline range organics [GRO], and diesel range organics [DRO])
DRO = Diesel range organics
GRO = Gasoline range organics
LNAPL = Light-nonaqueous-phase liquid
mg/L = Milligrams per liter
mV = Millivolt
MW = Monitoring well
NSZD = Natural source zone depletion (BTEX, GRO, DRO, oxygen, sulfate, dissolved iron, dissolved manganese, and methane)
ORP = Oxidation-reduction potential
S = Sulfolane
SP = Stable parameters

Table 3-2a
First Semiannual 2022 Groundwater Elevation, Surface Water Elevations and Depth to LNAPL Monitoring Results

Annual 2022 Onsite Groundwater Monitoring Report
North Pole Terminal, North Pole, Alaska

Well ID	Zone	Date	Riser Elevation (feet MSL)	Survey Date	Depth to LNAPL (feet)	Depth to Water (feet)	LNAPL Thickness (feet)	Corrected Water Table Elevation (feet MSL)	Notes
MW-104-65	10-55	3/25/2022	496.03	9/13/2018	--	12.07	--	483.96	
MW-142-20	Water Table	3/25/2022	495.83	9/13/2018	--	11.93	--	483.90	
MW-144BR-90	55-90	3/25/2022	495.03	9/13/2018	--	10.58	--	484.45	
MW-145-20	Water Table	3/25/2022	495.63	9/14/2018	--	11.02	--	484.61	
MW-149A-15	Water Table	3/25/2022	493.20	9/13/2018	--	10.15	--	483.05	
MW-173B-150	90-150	3/25/2022	496.33	9/13/2018	--	11.87	--	484.46	
MW-174-15	Water Table	3/25/2022	494.43	9/13/2018	--	9.29	--	485.14	
MW-174A-50	10-55	3/25/2022	493.59	9/13/2018	--	9.03	--	484.56	
MW-174B-90	55-90	3/25/2022	493.49	9/13/2018	--	8.62	--	484.87	
MW-176A-15	Water Table	3/25/2022	497.11	9/13/2018	11.10	13.00	1.90	485.66	
MW-176B-50	10-55	3/25/2022	496.93	9/13/2018	--	11.39	--	485.54	
MW-186A-15	Water Table	3/25/2022	495.98	9/13/2018	11.43	11.77	0.34	484.49	
MW-186B-60	10-55	3/25/2022	495.97	9/13/2018	--	11.49	--	484.48	
MW-192A-15	Water Table	3/25/2022	496.28	9/13/2018	--	9.82	--	486.46	
MW-192B-55	10-55	3/25/2022	495.59	9/13/2018	--	9.01	--	486.58	
MW-198-150	90-150	3/25/2022	493.16	9/14/2018	--	frozen	--	—	Depth to ice = 7.09 feet
MW-300-150	90-150	3/25/2022	495.94	9/13/2018	--	10.12	--	485.82	
MW-301-60	10-55	3/25/2022	492.70	9/13/2018	--	8.95	--	483.75	
MW-302-CMT-50	10-55	3/25/2022	494.21	9/13/2018	--	10.44	--	483.77	
MW-302-80	55-90	3/25/2022	493.41	9/13/2018	--	9.61	--	483.80	
MW-303-CMT-59	10-55	3/25/2022	495.73	9/13/2018	--	12.15	--	483.58	
MW-303-80	55-90	3/25/2022	491.56	9/13/2018	--	7.81	--	483.75	
MW-306-80	55-90	3/25/2022	496.47	9/13/2018	--	12.83	--	483.64	
MW-309-15	Water Table	3/25/2022	494.77	9/13/2018	--	10.46	--	484.31	
MW-310-15	Water Table	3/25/2022	494.26	9/13/2018	--	10.02	--	484.24	
MW-310-110	90-150	3/25/2022	493.85	9/13/2018	--	9.56	--	484.29	
MW-321-15	Water Table	3/25/2022	495.59	9/13/2018	--	10.31	--	485.28	
MW-334-15	Water Table	3/25/2022	497.06	9/13/2018	12.68	12.84	0.16	484.35	
MW-336-20	Water Table	3/25/2022	493.26	9/20/2018	--	7.18	--	486.08	
MW-358-20	Water Table	3/25/2022	495.53	9/13/2018	--	12.28	--	483.25	
MW-358-40	10-55	3/25/2022	495.19	9/13/2018	--	11.91	--	483.28	
MW-358-60	10-55	3/25/2022	495.46	9/13/2018	--	11.91	--	483.55	
MW-359-15	Water Table	3/25/2022	495.16	9/13/2018	--	11.52	--	483.64	
MW-359-60	10-55	3/25/2022	495.02	9/13/2018	--	11.57	--	483.45	
MW-359-80	55-90	3/25/2022	495.02	9/13/2018	--	11.54	--	483.48	
MW-360-15	Water Table	3/25/2022	494.96	9/13/2018	--	11.66	--	483.30	
MW-360-50	10-55	3/25/2022	494.86	9/13/2018	--	11.37	--	483.49	
MW-360-80	55-90	3/25/2022	494.46	9/13/2018	--	11.16	--	483.30	
MW-360-150	90-150	3/25/2022	494.57	9/13/2018	--	11.20	--	483.37	
MW-362-15	Water Table	3/25/2022	495.09	9/13/2018	--	11.67	--	483.42	
MW-362-50	10-55	3/25/2022	494.99	9/13/2018	--	11.40	--	483.59	
MW-362-150	90-150	3/25/2022	495.27	9/13/2018	--	11.72	--	483.55	

Table 3-2a
First Semiannual 2022 Groundwater Elevation, Surface Water Elevations and Depth to LNAPL Monitoring Results

Annual 2022 Onsite Groundwater Monitoring Report
North Pole Terminal, North Pole, Alaska

Well ID	Zone	Date	Riser Elevation (feet MSL)	Survey Date	Depth to LNAPL (feet)	Depth to Water (feet)	LNAPL Thickness (feet)	Corrected Water Table Elevation (feet MSL)	Notes
MW-364-15	Water Table	3/25/2022	494.23	9/13/2018	--	11.33	--	482.90	
MW-364-65	10-55	3/25/2022	494.09	9/13/2018	--	11.16	--	482.93	
MW-364-90	55-90	3/25/2022	494.28	9/13/2018	--	11.22	--	483.06	
MW-366-15	Water Table	3/25/2022	493.51	9/13/2018	No LNAPL	7.50	0.00	486.01	
North Gravel Pit	Surface Water	3/25/2022	492.78	9/13/2018	--	8.60	--	484.18	
O-34	Water Table	3/25/2022	496.56	9/13/2018	No LNAPL	11.22	0.00	485.34	

General Notes:
If LNAPL is present, the water table elevation is corrected according to the following formula (riser elevation - depth to water) + (0.8 x LNAPL thickness)

Only monitoring wells scheduled for gauging per Table 3-1 of the 2022 Long-Term Monitoring Plan Updates are shown here (Arcadis 2022)

Acronyms and Abbreviations:
-- = A water sounder was used. The well was not checked with an interface probe for the presence of LNAPL.
btoc = Below top of casing
LNAPL = Light Non-Aqueous Phase Liquid
MSL = Mean sea level
Sheen = LNAPL thickness was less than 0.01 feet and not detected with an interface probe; product was detected visually.

Table 3-2b
Second Semiannual 2022 Groundwater Elevation, Surface Water Elevations and Depth to LNAPL Monitoring Results

Annual 2022 Onsite Groundwater Monitoring Report
North Pole Terminal, North Pole, Alaska

Well ID	Zone	Date	Riser Elevation (feet MSL)	Depth to LNAPL (feet)	Depth to Water (feet)	LNAPL Thickness (feet)	Corrected Water Table Elevation (feet MSL)	Notes
MW-104-65	10-55	9/22/2022	496.03	--	11.53	--	484.50	
MW-142-20	Water Table	9/22/2022	495.83	--	11.32	--	484.51	
MW-144BR-90	55-90	9/22/2022	495.03	--	10.05	--	484.98	
MW-145-20	Water Table	9/22/2022	495.63	--	10.43	--	485.20	
MW-149A-15	Water Table	9/22/2022	493.20	--	9.55	--	483.65	
MW-173B-150	90-150	9/22/2022	496.33	--	11.33	--	485.00	
MW-174-15	Water Table	9/22/2022	494.43	--	8.72	--	485.71	
MW-174A-50	10-55	9/22/2022	493.59	--	8.48	--	485.11	
MW-174B-90	55-90	9/22/2022	493.49	--	8.05	--	485.44	
MW-176A-15	Water Table	9/22/2022	497.11	10.48	12.26	1.78	486.30	
MW-176B-50	10-55	9/22/2022	496.93	--	10.82	--	486.11	
MW-186A-15	Water Table	9/22/2022	495.98	--	10.91	--	485.07	
MW-186B-60	10-55	9/22/2022	495.97	--	10.91	--	485.06	
MW-192A-15	Water Table	9/22/2022	496.28	--	9.26	--	487.02	
MW-192B-55	10-55	9/22/2022	495.59	--	8.47	--	487.12	
MW-198-150	90-150	9/22/2022	493.16	--	6.77	--	486.39	
MW-300-150	90-150	9/22/2022	495.94	--	9.53	--	486.41	
MW-301-60	10-55	9/22/2022	492.70	--	8.40	--	484.30	
MW-302-CMT-50	10-55	9/22/2022	494.21	--	9.87	--	484.34	
MW-302-80	55-90	9/22/2022	493.41	--	9.06	--	484.35	
MW-303-CMT-59	10-55	9/22/2022	495.73	--	11.45	--	484.28	
MW-303-80	55-90	9/22/2022	491.56	--	7.26	--	484.30	
MW-306-80	55-90	9/22/2022	496.47	--	12.23	--	484.24	
MW-309-15	Water Table	9/22/2022	494.77	--	9.76	--	485.01	
MW-310-15	Water Table	9/22/2022	494.26	--	9.46	--	484.80	
MW-310-110	90-150	9/22/2022	493.85	--	8.99	--	484.86	
MW-321-15	Water Table	9/22/2022	495.59	--	9.71	--	485.88	
MW-334-15	Water Table	9/22/2022	497.06	12.08	12.28	0.20	484.94	
MW-336-20	Water Table	9/22/2022	493.26	--	6.61	--	486.65	
MW-358-20	Water Table	9/22/2022	495.53	--	11.49	--	484.04	
MW-358-40	10-55	9/22/2022	495.19	--	11.38	--	483.81	
MW-358-60	10-55	9/22/2022	495.46	--	11.41	--	484.05	
MW-359-15	Water Table	9/22/2022	495.16	--	10.95	--	484.21	
MW-359-60	10-55	9/22/2022	495.02	--	10.94	--	484.08	
MW-359-80	55-90	9/22/2022	495.02	--	11.00	--	484.02	
MW-360-15	Water Table	9/22/2022	494.96	--	11.09	--	483.87	
MW-360-50	10-55	9/22/2022	494.86	--	10.80	--	484.06	
MW-360-80	55-90	9/22/2022	494.46	--	10.61	--	483.85	
MW-360-150	90-150	9/22/2022	494.57	--	10.67	--	483.90	

Table 3-2b
Second Semiannual 2022 Groundwater Elevation, Surface Water Elevations and Depth to LNAPL Monitoring Results

Annual 2022 Onsite Groundwater Monitoring Report
North Pole Terminal, North Pole, Alaska

Well ID	Zone	Date	Riser Elevation (feet MSL)	Depth to LNAPL (feet)	Depth to Water (feet)	LNAPL Thickness (feet)	Corrected Water Table Elevation (feet MSL)	Notes
MW-362-15	Water Table	9/22/2022	495.09	--	11.11	--	483.98	
MW-362-50	10-55	9/22/2022	494.99	--	10.84	--	484.15	
MW-362-150	90-150	9/22/2022	495.27	--	11.17	--	484.10	
MW-364-15	Water Table	9/22/2022	494.23	--	10.78	--	483.45	
MW-364-65	10-55	9/22/2022	494.09	--	10.30	--	483.79	
MW-364-90	55-90	9/22/2022	494.28	--	10.67	--	483.61	
MW-366-15	Water Table	9/22/2022	493.51	Sheen	6.88	Sheen	486.63	
North Gravel Pit	Surface Water	9/22/2022	492.78	--	8.06	--	484.72	
O-34	Water Table	9/22/2022	496.56	--	10.59	--	485.97	

General Notes:

If LNAPL is present, the water table elevation is corrected according to the following formula (riser elevation - depth to water) + (0.8 x LNAPL thickness)

Only monitoring wells scheduled for gauging per Table 3-1 of the 2022 Long-Term Monitoring Plan Updates are shown here (Arcadis 2022)

Acronyms and Abbreviations:

-- = A water sounder was used. The well was not checked with an interface probe for the presence of LNAPL.
btoc = Below top of casing
CMT = Continuous Multichannel Tubing
LNAPL = Light Non-Aqueous Phase Liquid
MSL = Mean sea level
No LNAPL = An air-oil-water interface probe was used. LNAPL was not detected.
Sheen = LNAPL thickness was less than 0.01 feet and not detected with an interface probe; product was detected visually.

Table 3-3

LNAPL Migration Monitoring

Annual 2022 Onsite Groundwater Monitoring Report

North Pole Terminal, North Pole, Alaska

Location	Date	Frequency	Top of Riser Elevation (feet MSL)	Depth to LNAPL (feet)	Depth to Water (feet)	LNAPL Thickness (feet)	Water Table Elevation (feet MSL)
MW-139-25	10/20/2022	Annual	497.24	No LNAPL	13.27	0.00	483.97
MW-142-20	10/20/2022	Annual	495.83	No LNAPL	12.08	0.00	483.75
MW-145-20	10/20/2022	Annual	495.63	No LNAPL	11.15	0.00	484.48
O-4	10/20/2022	Annual	496.58	No LNAPL	12.40	0.00	484.18
O-5	10/20/2022	Annual	495.83	No LNAPL	11.65	0.00	484.18
O-7	10/20/2022	Annual	496.47	Sheen	11.81	Sheen	484.66
O-11	10/20/2022	Annual	497.91	13.69	13.70	0.01	484.22
O-12	10/20/2022	Annual	496.44	No LNAPL	12.34	0.00	484.10
O-24	10/20/2022	Annual	497.15	No LNAPL	13.05	0.00	484.10
O-25	10/20/2022	Annual	497.86	No LNAPL	13.78	0.00	484.08
O-26	10/20/2022	Annual	497.00	No LNAPL	13.01	0.00	483.99
O-27	10/20/2022	Annual	496.91	12.77	12.90	0.13	484.12

General Notes:

If LNAPL is present, the water table elevation is corrected according to the following formula (riser elevation - depth to water) + (0.8 x LNAPL thickness).

Only monitoring wells scheduled for gauging per Table 3-2 of the 2022 Long-Term Monitoring Plan Updates are shown here (Arcadis 2022). A comprehensive LNAPL gauging table is included in Appendix E.

Acronyms and Abbreviations:

LNAPL = Light Non-Aqueous Phase Liquid

MSL = Mean sea level

No LNAPL = An interface probe was used to measure depth to water. LNAPL was not observed

Table 3-4
Natural Source Zone Depletion Monitoring Results

Annual 2022 Onsite Groundwater Monitoring Report
North Pole Terminal, North Pole, Alaska

Well ID	Zone	Sample Name	DUP	Date	Benzene	Toluene	Ethylbenzene	P & M -Xylene	o-Xylene	Total Xylenes	Gasoline Range Organics	Diesel Range Organics	Dissolved Iron	Dissolved Manganese	Sulfate	Methane
					µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
MW-101A-25	10-55	MW-101A-25	—	7/28/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	0.436J	0.731	2.15	36.4	0.0329JL*
MW-125-25	10-55	MW-125-25	—	8/3/2022	308	<5.00B*	151	1800	<5.00B*	1800	12.8	1.94JL*	29.8	15.5	<0.100	3.38
MW-130-25	10-55	MW-130-25	—	8/8/2022	147	17.5J*	67.5	379	111	490	3.13JH*	2.23JL*	11.0	2.75	7.07	2.35
MW-138-20	WT	MW-138-20	—	8/8/2022	1980	2760	76.0J	4160	2790	6950	22.9	4.49JL*	9.07	0.688	2.28	1.67
MW-139-25	10-55	MW-139-25	—	8/4/2022	33.4	<0.500	31.8	309	<25.0	309	1.47JH*	1.75J*	24.0	6.19	7.46	5.98
MW-142-20	WT	MW-142-20	—	8/4/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	0.0673J	<0.283B*	14.0	8.54	4.54	1.65
MW-154B-95	55-90	MW-154B-95	—	8/4/2022	3.00	<0.500	0.726J	2.56	<0.500	2.56J	0.0596J	<0.278B*	4.63	3.30	21.8	1.07
MW-154B-95	55-90	MW-254B-95	DUP	8/4/2022	2.83	<0.500	0.770J	3.20	<0.500	3.20	0.0630J	<0.288B*	4.62	3.28	21.8	1.11
MW-192A-15	WT	MW-192A-15	—	8/5/2022	0.191J	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	<0.288	<0.125	0.109	39.3	0.00810
MW-303-CMT-39	10-55	MW-303-CMT-39	—	8/10/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	<0.577B*	1.08	2.59	31.5	0.235
MW-304-CMT-40	10-55	MW-304-CMT-40	—	7/29/2022	2.60	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	<0.294	0.719	4.51	32.6	0.352
MW-336-20	WT	MW-336-20	—	8/5/2022	12100	2990	1480	12100	1260	13400	61.5	13.1	25.1	3.69	<0.100	10.3
MW-348-15	WT	MW-348-15	—	8/8/2022	5.03	4.97	1.34	22.8	11.3	34.1	0.226	2.18JL*	5.41	2.00	8.08	0.881
MW-359-35	10-55	MW-359-35	—	7/26/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	0.553J	1.02	6.66	17.6	0.136
MW-360-50	10-55	MW-360-50	—	7/26/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	0.222J	3.83	4.96	22.8	0.103
O-15	WT	O-15	—	8/5/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	0.0516J	0.224J	<0.125	0.232	18.1J*	0.0193
O-15	WT	O-115	DUP	8/5/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	<0.288	<0.125	0.221	42.7J*	0.0187

General Notes:

Total xylenes are calculated by Shannon & Wilson, Inc. as the sum of o-, p- and m-xylenes

Only monitoring wells scheduled for sampling per Table 3-6 of the 2022 Long-Term Monitoring Plan Updates are shown here (Arcadis 2022). Additional constituents of concern (COC) sampling data are included on Tables 3-5a and 3-5b.

Acronyms and Abbreviations:
-- = Not applicable
< = Not detected; presented as <LOD (limit of detection). Unless otherwise noted by
µg/L = Micrograms per liter
B* = Result is considered not detected due to quality control failures; see data review checklist for details. Flag applied by Shannon & Wilson, Inc.
DUP = Field-duplicate sample
J = Estimated concentration, detected above the detection limit (DL) and below the limit of quantitation (LOQ). Flag applied by laboratory.
J* = Result is considered estimated (no direction of bias), due to QC failures or sample-handling anomalies. Flag applied by Shannon & Wilson, Inc.
JH* = Estimated concentration, biased high, due to quality control failures. Flag applied by Shannon & Wilson, Inc.
mg/L =Milligrams per liter
NSZD = Natural Source Zone Depletion analytes (GRO, DRO, BTEX, sulfate, dissolved iron, dissovled manganese, and methane)

Table 3-5a
First Semiannual 2022 Constituents of Concern Analytical Results

Annual 2022 Onsite Groundwater Monitoring Report
North Pole Terminal, North Pole, Alaska

Well ID	Zone	Sample Name	DUP	Date	Benzene	Toluene	Ethylbenzene	P & M -Xylenes	O-Xylene	Total Xylenes	Gasoline Range Organics	Diesel Range Organics
					µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L
MW-139-25	10-55	MW-139-25	--	2/18/2022	25.3	<0.500	19.2	345	0.312J	345	1.38JH*	1.99
MW-140-25	10-55	MW-140-25	--	2/18/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	<0.588B*
MW-142-20	WT	MW-142-20	--	2/22/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	0.0733J	0.912
S-9	WT	S-9	--	2/22/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	<0.556B*
S-9	WT	S-109	DUP	2/22/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	<0.588B*

General Notes:
Total xylenes are calculated by Shannon & Wilson, Inc. as the sum of o-, p- and m-xylenes
Only monitoring wells scheduled for sampling per Table 3-4 of the 2022 Long-Term Monitoring Plan Updates are shown here (Arcadis 2022). Additional constituents of concern (COC) data collected as part of the natural source zone depletion (NSZD) sampling are included on Table 3-4.

Acronyms and Abbreviations:
-- = Not applicable
< = Not detected; limit of detection (LOD) listed unless otherwise noted due to quality control failures.
µg/L = Micrograms per liter
B* = Result is considered estimated (no direction of bias), due to method blank detection. Flag applied by Shannon & Wilson, Inc.
DUP = Field-duplicate sample
J = Estimated concentration, detected above the detection limit (DL) and below the limit of quantitation (LOQ). Flag applied by laboratory.
JH* = Result is considered estimated, biased high, due to QC failures. Flag applied by Shannon & Wilson, Inc.
mg/L = Milligrams per liter

Table 3-5b
Second Semiannual 2022 Constituents of Concern Analytical Results

Annual 2022 Onsite Groundwater Monitoring Report
North Pole Terminal, North Pole, Alaska

Well ID	Zone	Sample Name	DUP	Date	Benzene	Toluene	Ethylbenzene	P & M -Xylenes	O-Xylene	Total Xylenes	Gasoline Range Organics	Diesel Range Organics
					µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L
MW-101A-25	10-55	MW-101A-25	—	7/28/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	0.436J
MW-130-25	10-55	MW-130-25	—	8/8/2022	147	67.5	111	379	17.5J*	490	3.13JH*	2.23JL*
MW-130-25	10-55	MW-230-25	DUP	8/9/2022	161	63.6	110	384	9.93J*	495	3.17JH*	2.34
MW-131-25	10-55	MW-131-25	—	7/28/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	0.526J
MW-137-20	WT	MW-137-20	—	8/3/2022	762	1880	3690	7930	5570	11600	45.8	7.39JL*
MW-139-25	10-55	MW-139-25	—	8/4/2022	33.4	31.8	<25.0	309	<0.500	309	1.47JH*	1.75J*
MW-143-20	WT	MW-143-20	—	8/10/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	<0.588B*
MW-154B-95	55-90	MW-154B-95	—	8/4/2022	3.00	0.726J	<0.500	2.56	<0.500	2.56J	0.0596J	<0.278B*
MW-303-CMT-19	WT	MW-303-CMT-19	—	8/10/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	<1.04B*
MW-303-CMT-39	10-55	MW-303-CMT-39	—	8/10/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	<0.577B*
MW-304-CMT-40	10-55	MW-304-CMT-40	—	7/29/2022	2.60	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	<0.294
MW-358-20	WT	MW-358-20	—	7/26/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	0.289J
MW-359-35	10-55	MW-359-35	—	7/26/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	0.553J
MW-364-30	10-55	MW-364-30	—	7/30/2022	—	—	—	—	—	—	—	<0.283
MW-364-65	10-55	MW-364-65	—	7/30/2022	—	—	—	—	—	—	—	<0.288
MW-364-90	55-90	MW-364-90	—	7/30/2022	—	—	—	—	—	—	—	<0.300
O-3	WT	O-3	—	8/3/2022	<0.200	<0.500	<0.500	<1.00	<0.500	<1.50	<0.0500	<0.294J*
O-4	WT	O-4	—	8/5/2022	<0.200	<0.500	<0.500	0.799J	<0.500	<1.50	0.0741J	1.63
O-24	WT	O-24	—	8/3/2022	130	<0.500	<0.500	<1.00	<0.500	<1.50	0.267	0.617JL*
O-25	WT	O-25	—	8/9/2022	14.2	<0.500	0.330J	2.03	<0.500	2.36J	0.0572J	<0.273
O-25	WT	O-125	DUP	8/9/2022	17.4JH*	<0.500J*	<0.500J*	1.72JL*	<0.500J*	1.72JL*	<0.0500	0.394J

General Notes:
Total xylenes are calculated by Shannon & Wilson, Inc. as the sum of o-, p- and m-xylenes
Only monitoring wells scheduled for sampling per Table 3-4 of the 2022 Long-Term Monitoring Plan Updates are shown here (Arcadis 2022). Additional constituents of concern (COC) data collected as part of the natural source zone depletion (NSZD) sampling are included on Table 3-4.

Acronyms and Abbreviations:
-- = Not applicable
< = Not detected; limit of detection (LOD) listed. Unless otherwise noted by quality control failures.
µg/L = micrograms per liter
B* = Result is considered not detected, due to QC failures. Flag applied by Shannon & Wilson, Inc.
DUP = Field-duplicate sample
J = Estimated concentration, detected above the detection limit (DL) and below the limit of quantitation (LOQ). Flag applied by laboratory.
JH* = Result is considered estimated, biased high, due to QC failures. Flag applied by Shannon & Wilson, Inc.
mg/L = Milligrams per liter

Table 3-6a
First Semiannual 2022 Onsite Sulfolane Analytical Results

Annual 2022 Onsite Groundwater Monitoring Report
North Pole Terminal, North Pole, Alaska

Well ID	Zone	Sample Name	DUP	Date	Sulfolane µg/L
MW-148A-15	WT	MW-148A-15	--	2/16/2022	<5.15J*
MW-148B-30	10-55	MW-148B-30	--	2/16/2022	46.1
MW-148C-55	10-55	MW-148C-55	--	2/16/2022	54.8
MW-148C-55	10-55	MW-248C-55	DUP	2/16/2022	55.5
MW-148-80	55-90	MW-148-80	--	2/16/2022	25.3
MW-176A-15	WT	MW-176A-15	--	2/23/2022	640
MW-186A-15	WT	MW-186A-15	--	2/23/2022	175
MW-303-CMT-19	WT	MW-303-CMT-19	--	2/22/2022	191
MW-304-CMT-20	WT	MW-304-CMT-20	--	2/22/2022	21.9
MW-330-20	WT	MW-330-20	--	2/16/2022	59.5J*
MW-334-15	WT	MW-334-15	--	2/24/2022	31.0
MW-336-20	WT	MW-336-20	--	2/23/2022	4470JL*
MW-345-15	WT	MW-345-15	--	2/18/2022	219
MW-354-35	10-55	MW-354-35	--	2/18/2022	139
MW-372-15	WT	MW-372-15	--	2/16/2022	544
O-1	WT	O-1	--	2/18/2022	930J*
O-2	WT	O-2	--	2/24/2022	106
O-24	WT	O-24	--	2/23/2022	<5.15
O-26	WT	O-26	--	2/23/2022	82.8
O-26	WT	O-126	DUP	2/23/2022	89.3
O-27	WT	O-27	--	2/23/2022	163
O-34	WT	O-34	--	2/23/2022	227

General Notes:

Only monitoring wells scheduled for sampling per Table 3-3 of the 2022 Long-Term Monitoring Plan Updates are shown here (Arcadis 2022).

Acronyms and Abbreviations:

-- = Not applicable

< = Not detected; limit of detection (LOD) listed. Unless otherwise noted due to quality control failures.

µg/L = micrograms per liter

DUP = Field-duplicate sample

J* = Result is considered estimated due to QC failures. Flag applied by Shannon & Wilson, Inc.

JL* = Result is considered estimated, biased low, due to QC failures. Flag applied by Shannon & Wilson, Inc.

Table 3-6b
Second Semiannual 2022 Onsite Sulfolane Analytical Results

Annual 2022 Onsite Groundwater Monitoring Report
North Pole Terminal, North Pole, Alaska

Well ID	Zone	Sample Name	DUP	Date	Sulfolane
					µg/L
MW-127-25	10-55	MW-127-25	---	8/2/2022	19.5J*
MW-139-25	10-55	MW-139-25	---	8/4/2022	149J*
MW-142-20	WT	MW-142-20	—	8/4/2022	96.7
MW-142-20	WT	MW-242-20	DUP	8/4/2022	104
MW-154B-95	10-55	MW-154B-95	---	8/4/2022	98.5J*
MW-154B-95	10-55	MW-254B-95	DUP	8/4/2022	88.3
MW-186A-15	WT	MW-186A-15	—	8/8/2022	129JL*
MW-186B-60	10-55	MW-186B-60	---	8/4/2022	9.43J
MW-301-CMT-20	WT	MW-301-CMT-20	—	8/9/2022	<5.10
MW-301-60	10-55	MW-301-60	---	7/29/2022	<5.15
MW-302-CMT-20	WT	MW-302-CMT-20	—	7/26/2022	16.5
MW-303-CMT-19	WT	MW-303-CMT-19	—	8/10/2022	170J*
MW-303-CMT-29	10-55	MW-303-CMT-29	—	7/27/2022	162J*
MW-303-CMT-39	10-55	MW-303-CMT-39	---	8/10/2022	105
MW-303-CMT-49	10-55	MW-303-CMT-49	—	7/27/2022	72.6
MW-303-CMT-59	10-55	MW-303-CMT-59	—	8/10/2022	44.1J*
MW-303-CMT-59	10-55	MW-403-CMT-59	DUP	8/10/2022	46.3
MW-303-80	55-90	MW-303-80	---	7/28/2022	3.40J
MW-304-CMT-40	10-55	MW-304-CMT-40	—	7/29/2022	25.4J*
MW-304-CMT-60	10-55	MW-304-CMT-60	---	7/29/2022	<5.10J*
MW-304-80	55-90	MW-304-80	—	8/9/2022	<5.05
MW-305-CMT-28	10-55	MW-305-CMT-28	—	7/29/2022	5.40J
MW-309-15	WT	MW-309-15	—	8/1/2022	61.9J*
MW-310-15	WT	MW-310-15	—	8/2/2022	33.3J*
MW-345-15	WT	MW-345-15	—	8/1/2022	210J*
MW-345-15	WT	MW-445-15	DUP	8/1/2022	187J*
MW-345-55	10-55	MW-345-55	—	8/1/2022	49.1J*
MW-345-75	55-90	MW-345-75	—	8/1/2022	41.2J*
MW-358-20	WT	MW-358-20	—	7/26/2022	61.8
MW-358-40	10-55	MW-358-40	---	7/26/2022	78.0J*
MW-359-15	WT	MW-359-15	—	7/25/2022	45.5
MW-359-35	10-55	MW-359-35	—	7/26/2022	185
MW-359-60	10-55	MW-359-60	—	7/25/2022	63.0J*
MW-359-80	55-90	MW-359-80	—	7/25/2022	23.0
MW-360-15	WT	MW-360-15	—	7/25/2022	6.31J
MW-360-35	10-55	MW-360-35	—	7/25/2022	32.6J*
MW-360-50	10-55	MW-360-50	—	7/26/2022	49.2
MW-360-80	55-90	MW-360-80	—	7/25/2022	13.6
MW-364-65	10-55	MW-364-65	—	7/30/2022	18.6
MW-364-90	55-90	MW-364-90	—	7/30/2022	21.1

Table 3-6b
Second Semiannual 2022 Onsite Sulfolane Analytical Results

Annual 2022 Onsite Groundwater Monitoring Report
North Pole Terminal, North Pole, Alaska

Well ID	Zone	Sample Name	DUP	Date	Sulfolane
					µg/L
MW-371-15	WT	MW-371-15	—	7/28/2022	108
MW-371-15	WT	MW-471-15	DUP	7/28/2022	104J*
O-2	WT	O-2	—	8/8/2022	116J*
O-26	WT	O-26	—	8/2/2022	35.8J*
O-26-65	10-55	O-27-65	---	8/3/2022	6.71J*
O-27	WT	O-27	—	8/2/2022	203J*
O-27-65	10-55	O-27-65	---	8/2/2022	37.3J*
S-51	WT	S-51	—	8/8/2022	208J*

General Notes:

MW-148 nest is located offsite near the property boundary, but is being monitored and reported as part of the onsite groundwater monitoring program.

Only monitoring wells scheduled for sampling per Table 3-3 of the 2022 Long-Term Monitoring Plan Updates are shown here (Arcadis 2022).

Acronyms and Abbreviations:

-- = Not applicable
< = Analyte not detected, listed as <LOD (limit of detection).
µg/L = micrograms per liter
DUP = Field-duplicate sample
J = Estimated concentration, detected greater than the detection limit (DL) and less than the limit of quantitation (LOQ). Flag applied by the laboratory.

J* = Result is considered estimated (no direction of bias), due to QC failures. Flag applied by Shannon & Wilson, Inc.

JL* = 'Result is considered estimated, biased low. Flag applied by Shannon & Wilson, Inc.

Table 3-7
Sulfolane Analytical Results - Point of Compliance

Annual 2022 Onsite Groundwater Monitoring Report
North Pole Terminal, North Pole, Alaska

Well ID	Zone	Sample Name	DUP	Date	Sulfolane
					µg/L
MW-358-20	WT	MW-358-20	—	7/26/2022	61.8
MW-358-40	10-55	MW-358-40	---	7/26/2022	78.0J*
MW-359-15	WT	MW-359-15	—	7/25/2022	45.5
MW-359-35	10-55	MW-359-35	—	7/26/2022	185
MW-359-60	10-55	MW-359-60	—	7/25/2022	63.0J*
MW-359-80	55-90	MW-359-80	—	7/25/2022	23.0
MW-360-15	WT	MW-360-15	—	7/25/2022	6.31J
MW-360-35	10-55	MW-360-35	—	7/25/2022	32.6J*
MW-360-50	10-55	MW-360-50	—	7/26/2022	49.2
MW-360-80	55-90	MW-360-80	—	7/25/2022	13.6
MW-364-65	10-55	MW-364-65	—	7/30/2022	18.6
MW-364-90	55-90	MW-364-90	---	7/30/2022	21.1

General Notes:
Only monitoring wells scheduled for sampling per Table 3-3 of the 2022 Long-Term Monitoring Plan Updates are shown here (Arcadis 2022).

Acronyms and Abbreviations:
-- = Not applicable
µg/L = micrograms per liter
DUP = Field-duplicate sample
J = Estimated concentration, detected greater than the detection limit (DL) and less than the limit of quantitation (LOQ). Flag applied by the laboratory.

Figures

Note:
Only Figures 1-2, 3-12, 3-16, 3-16, 5-1, and 5-2 are included in this pdf due to size considerations.

See DEC for other figures and appendices.

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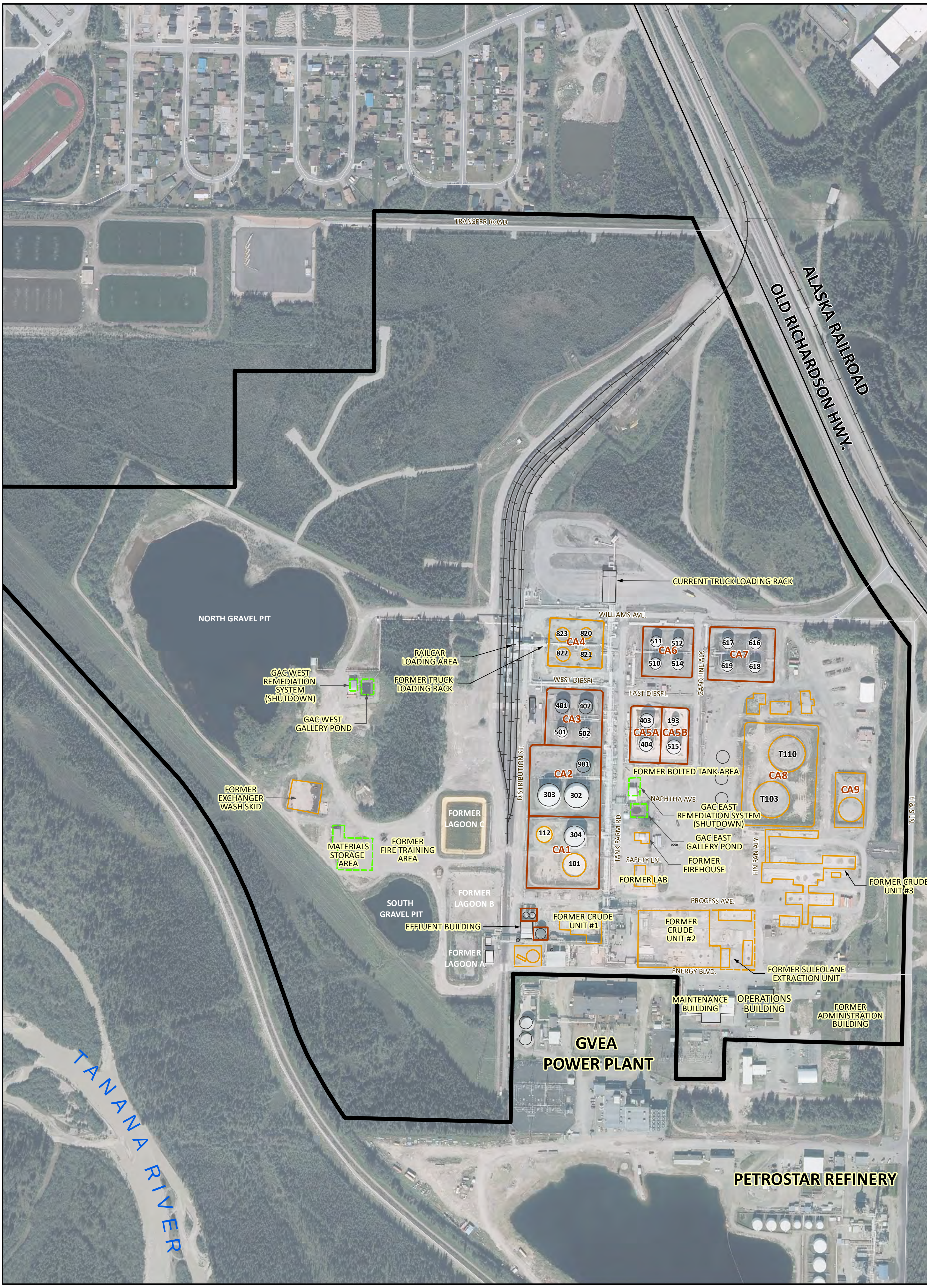


Legend

- Bermed Containment Areas (CA)
- Approximate Area
- Property Boundary
- Structure Demolished

Notes:
GAC: Granular Activated Carbon
GVEA: Golden Valley Electrical Authority
- July 21, 2018 Imagery provided by Quantum Spatial

0 400 800
SCALE IN FEET

NORTH POLE TERMINAL, NORTH POLE, ALASKA

ANNUAL 2022 ONSITE GROUNDWATER MONITORING REPORT

SITE FEATURES

ARCADIS

FIGURE
1-2

CITY: Citrix DIV/GROUP: IM/DV DB: K Sinsabaugh LD: G FRANCE
Path: T:_ENV\FHR\FHR_AK\NorthPoleRefinery\GW_Monitoring\2022_Q3\mxd\Fig 3-12 Second Semiannual 2022 Onsite Benzene Groundwater Analytical Results.mxd Date: 12/1/2022 Time: 12:25:51 PM

Notes:
- < = Not Detected; Detection limit listed.
- JH* = Result is considered estimated, biased high. Flag applied by Shannon & Wilson, Inc.
- Results are displayed in micrograms per liter (µg/L).
- Isopleths were drawn referencing both current and historical data.
- For locations with duplicate sample results, the highest result is shown.
- Only monitoring wells scheduled for sampling per Table 3-4 of the Long Term Monitoring Plan - 2017 Update, and one-time 2022 additions are shown on this figure.
- July 21, 2018 Imagery provided by Quantum Spatial.
- * = Monitoring wells that are a part of the annual sampling plan, but were sampled during the first semiannual 2022 sampling event.
- ** = O-3 is not included in isopleths.

Legend:

- Property Boundary
- Monitoring Well
- Observation Well

0 500 1,000
SCALE IN FEET

NORTH POLE TERMINAL, NORTH POLE, ALASKA

ANNUAL 2022 ONSITE GROUNDWATER MONITORING REPORT

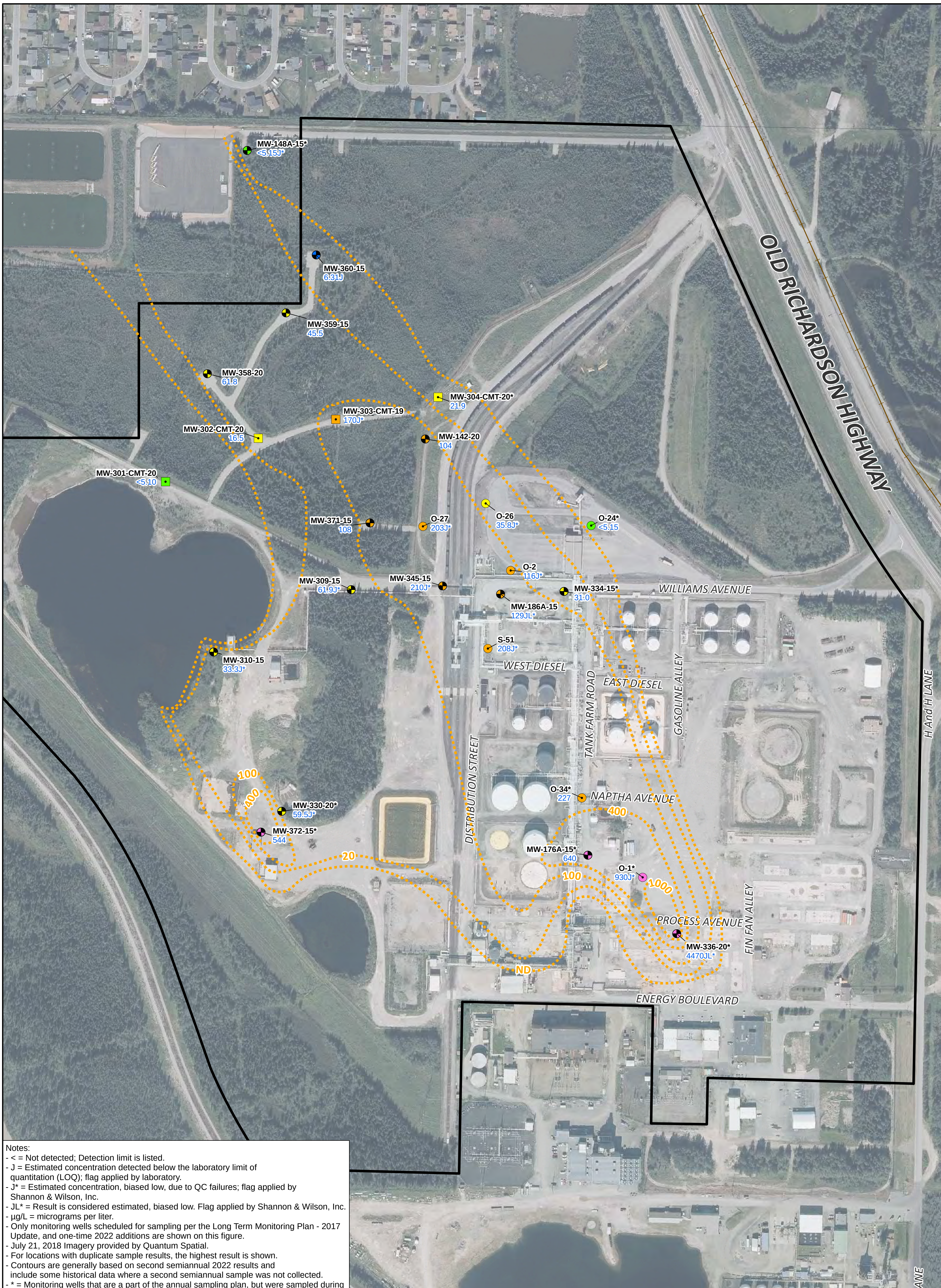
SECOND SEMIANNUAL 2022 ONSITE BENZENE GROUNDWATER ANALYTICAL RESULTS

ARCADIS

FIGURE

3-12

CITY: Citrix DIV/GROUP: IM/DV DB: K Sinsabaugh LD: G FRANCE
Path: T:_ENV\FHR\FHR_AK\NorthPoleRefinery\GW_Monitoring\2022_Q3\mxd\Fig 3-16 Second Semiannual 2022 Onsite Sulfolane Groundwater Analytical Results – Water Table.mxd Date: 12/1/2022 Time: 12:31:55 PM



Notes:
- < = Not detected; Detection limit is listed.
- J = Estimated concentration detected below the laboratory limit of quantitation (LOQ); flag applied by laboratory.
- J* = Estimated concentration, biased low, due to QC failures; flag applied by Shannon & Wilson, Inc.
- JL* = Result is considered estimated, biased low. Flag applied by Shannon & Wilson, Inc.
- µg/L = micrograms per liter.
- Only monitoring wells scheduled for sampling per the Long Term Monitoring Plan - 2017 Update, and one-time 2022 additions are shown on this figure.
- July 21, 2018 Imagery provided by Quantum Spatial.
- For locations with duplicate sample results, the highest result is shown.
- Contours are generally based on second semiannual 2022 results and include some historical data where a second semiannual sample was not collected.
- * = Monitoring wells that are a part of the annual sampling plan, but were sampled during the first semiannual 2022 sampling event.

Legend
- Monitoring Well
- Observation Well
- Vertical Profile Transect Well
- Property Boundary
- Approximate Sulfolane Isopleth in µg/L

Sulfolane Results
- Not Detected
- 3.14 - < 20 µg/L
- 20 - < 100 µg/L
- 100 - < 400 µg/L
- 400 µg/L

0 350 700
SCALE IN FEET

NORTH POLE TERMINAL, NORTH POLE, ALASKA

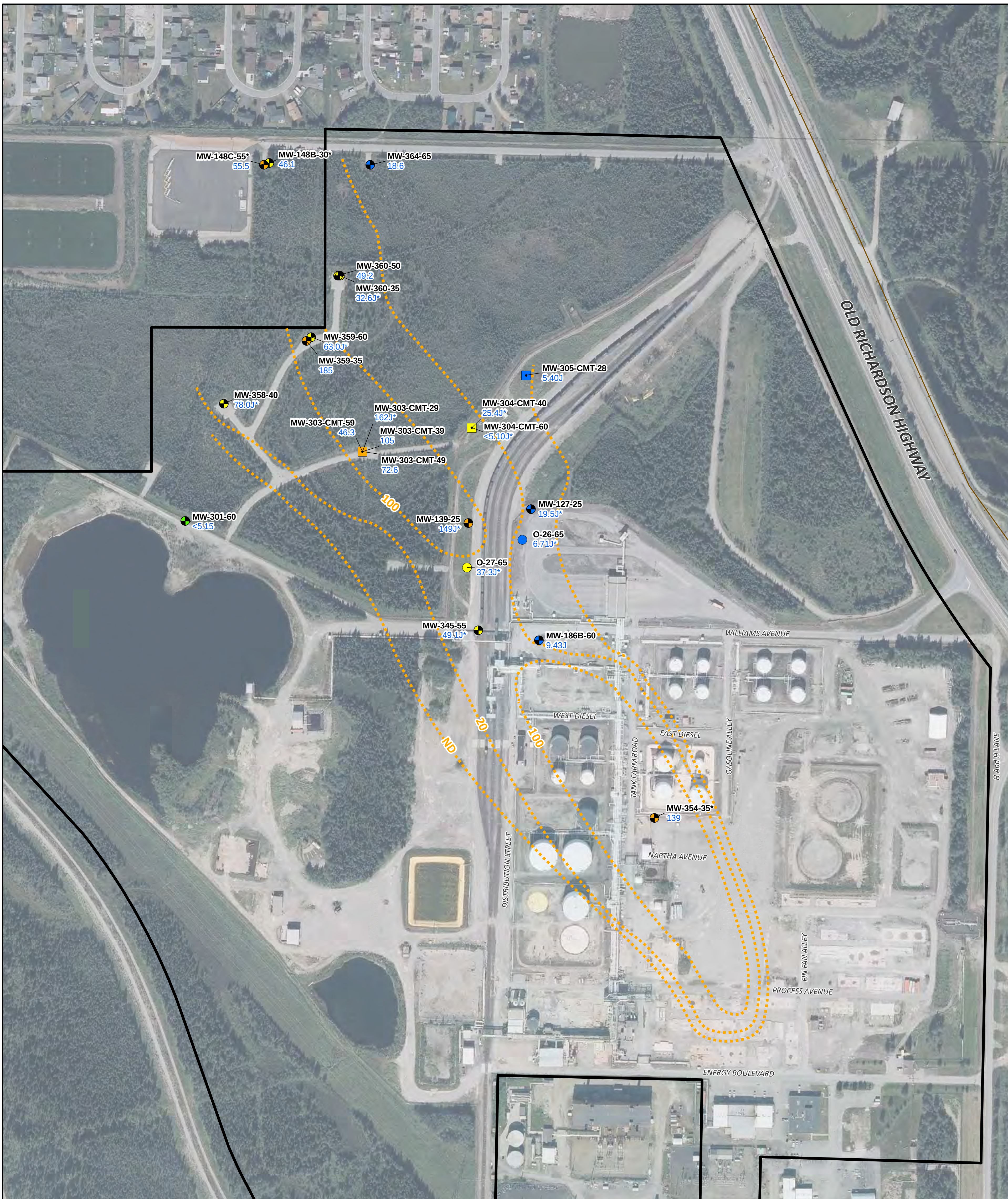
ANNUAL 2022 ONSITE GROUNDWATER MONITORING REPORT

SECOND SEMIANNUAL 2022 ONSITE SULFOLANE GROUNDWATER ANALYTICAL RESULTS WATER TABLE

ARCADIS

FIGURE
3-16

CITY: Citrix DIV/GROUP: IM/DV DB: K Sinsabaugh LD: G FRANCE
Path: T:_ENV\FHR\FHR_AK\NorthPoleRefinery\GW_Monitoring\2022_Q3\mxd\Fig 3-17 Second Semiannual 2022 Onsite Sulfolane Groundwater Analytical Results – 10 to 55 Feet Below Water Table.mxd Date: 12/1/2022 Time: 12:18:08 PM



Notes:
- < = Not detected; presented as <LOD (limit of detection). Unless otherwise noted by quality control failures.
- J = Estimated concentration detected below the laboratory limit of quantitation (LOQ); flag applied by laboratory.
- J* = Result is considered estimated (no direction of bias), due to QC failures. Flag applied by Shannon and Wilson, Inc.
- µg/L = micrograms per liter.
- Only monitoring wells scheduled for sampling per the Long Term Monitoring Plan - 2017 Update, and one-time 2022 additions are shown on this figure.
- July 21, 2018 Imagery provided by Quantum Spatial.
- For locations with duplicate sample results, the highest result is shown.
- Contours are generally based on second semiannual 2022 results and include some historical data where a second semiannual sample was not collected.
- * = Monitoring wells that are a part of the annual sampling plan, but were sampled during the first semiannual 2022 sampling event.

Legend

- Monitoring Well
- Observation Well
- Property Boundary
- Approximate Sulfolane Isopleth in µg/L

Sulfolane Results

- Not Detected
- 3.14 - < 20 µg/L
- 20 - < 100 µg/L
- 100 - < 400 µg/L
- 400 µg/L

0 350 700
SCALE IN FEET

NORTH POLE TERMINAL, NORTH POLE, ALASKA

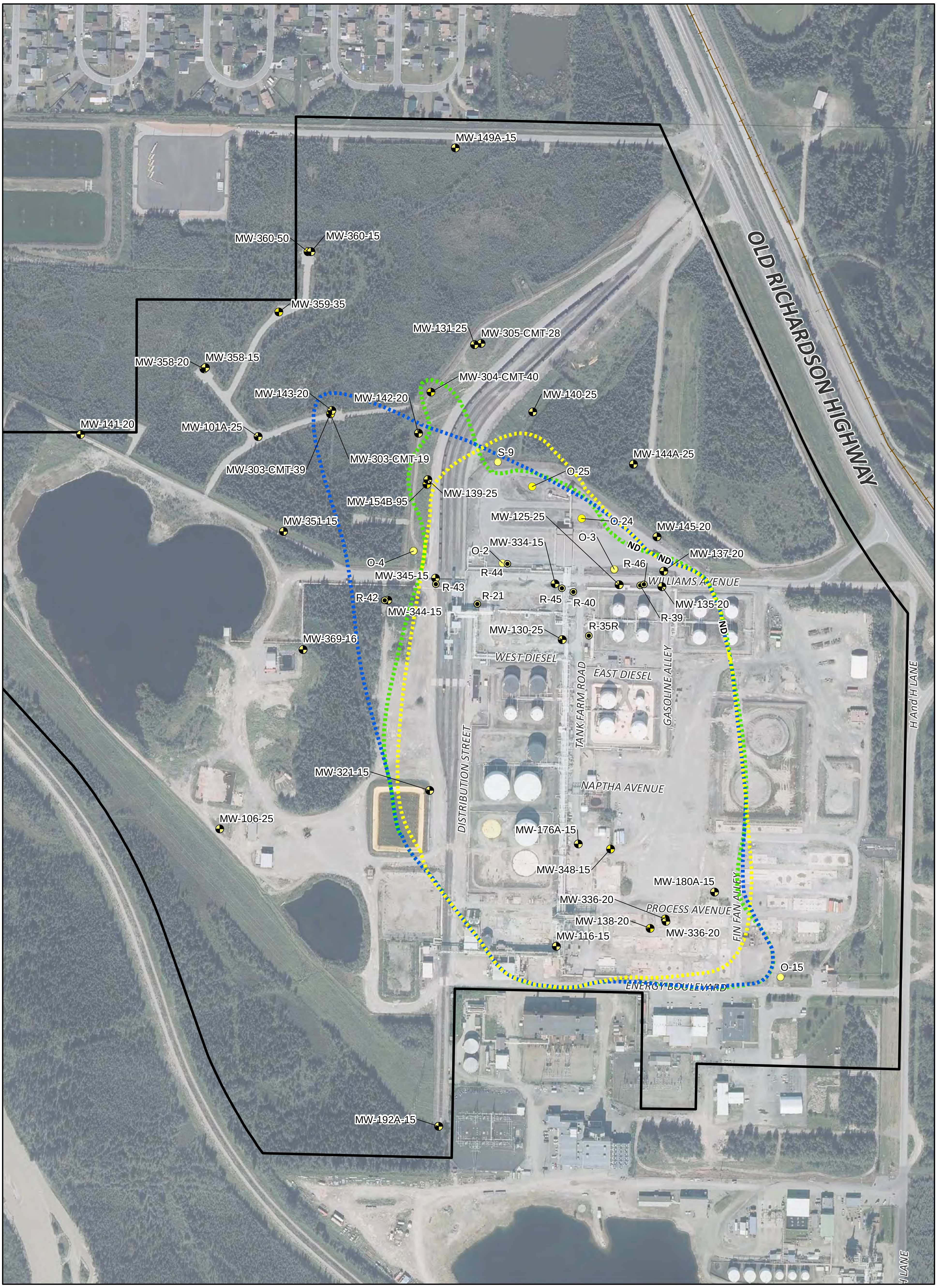
ANNUAL 2022 ONSITE GROUNDWATER MONITORING REPORT

SECOND SEMIANNUAL 2022 ONSITE SULFOLANE GROUNDWATER ANALYTICAL RESULTS - 10 TO 55 FEET BELOW WATER TABLE

ARCADIS

FIGURE
3-17

CITY: Citrix DIV/GROUP: IM/DV DB: K Sinsabaugh LD: G FRANCE
Path: T:_ENV\FHR\FHR_AK\NorthPoleRefinery\GW_Monitoring\2022_Q3\mxd\Fig 5-1_Benzene plume changes over time.mxd Date: 1/19/2023 Time: 10:52:43 AM



Legend:

- Monitoring Well
- Observation Well
- Recovery Well
- 2017 Inferred benzene isopleth in µg/L
- 2019 Inferred benzene isopleth in µg/L
- 2022 Inferred benzene isopleth in µg/L
- Property Boundary

0 300 600
SCALE IN FEET

NORTH POLE TERMINAL, NORTH POLE, ALASKA

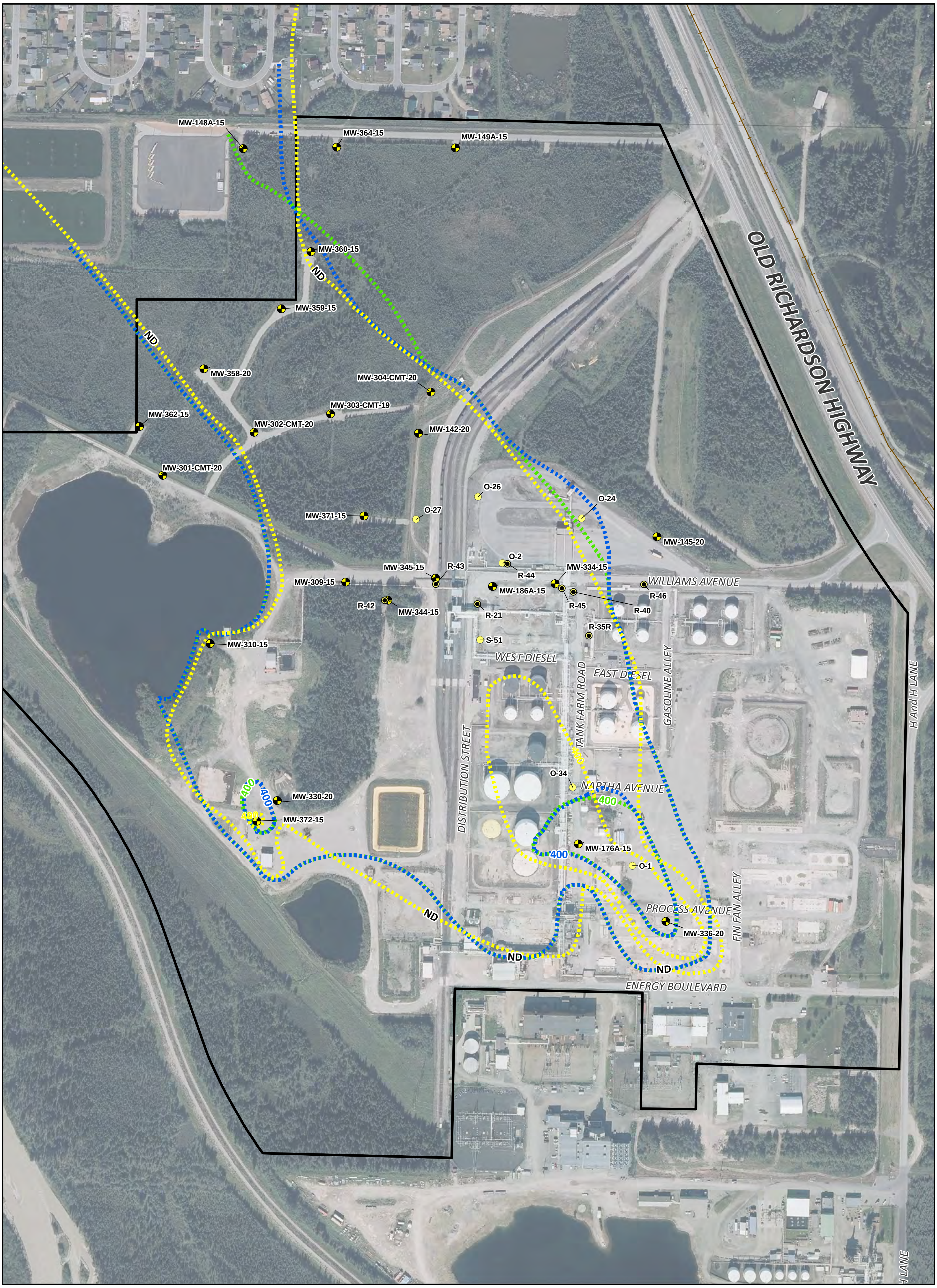
ANNUAL 2022 ONSITE GROUNDWATER MONITORING REPORT

BENZENE PLUME CHANGES OVER TIME

ARCADIS

FIGURE
5-1

CITY: Citrix DIV/GROUP: IM/DV DB: K Sinsabaugh LD: G FRANCE
Path: T:_ENV\FHR\FHR_AK\NorthPoleRefinery\GW_Monitoring\2022_Q3\mxd\Fig 5-2_Sulfolane plume changes over time.mxd Date: 1/19/2023 Time: 10:56:13 AM



Legend

- Monitoring Well
- Observation Well
- Recovery Well
- 2017 Approx Sulfolane Isopleth in µg/L
- 2019 Approx Sulfolane Isopleth in µg/L
- 2022 Approx Sulfolane Isopleth in µg/L
- Property Boundary

0 350 700
SCALE IN FEET

NORTH POLE TERMINAL, NORTH POLE, ALASKA

ANNUAL 2022 ONSITE GROUNDWATER MONITORING REPORT

SULFOLANE PLUME CHANGES AT THE WATER TABLE OVER TIME

ARCADIS

FIGURE
5-2