integral consulting inc.

2022 Annual Monitoring and Five-Year (2017-2021) Offsite Sulfolane Plume Monitoring Report - Revision 1

City of North Pole and Surrounding Area

Prepared for
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CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

AAC	Alaska Administrative Code
DEC	Department of Environmental Conservation
bgs	below ground surface
FHRA	Flint Hills Resources Alaska
Integral	Integral Consulting Inc.
MK	Mann-Kendall
SGS	SGS North America, Inc.
TUL	Temporary Use License
Williams	Williams Alaska Petroleum, Inc.
WTZ	Water Table Zone

EXECUTIVE SUMMARY

On behalf of Williams Alaska Petroleum (Williams), Integral Consulting Inc. (Integral) has prepared this 2022 Annual Monitoring and Five-Year (2017-2021) Offsite Sulfolane Plume Monitoring Report (2022 Report) for the former Flint Hills Resources Alaska North Pole Refinery, located on H and H Lane in North Pole, Alaska (Site). This Report was prepared to document both the 2022 annual monitoring of offsite sulfolane and evaluate groundwater trends from 2017 through 2022. The 2022 sampling was generally conducted as described in the scope of work (Duncan 2020), approved by the Alaska Department of Environmental Conservation (DEC) on August 3, 2020 (Mulder 2020). The final work plan, Offsite Sulfolane Plume Monitoring Plan (2020 Plan), was submitted to DEC on August 19, 2020. The updated monitoring and private well list was approved in an email from DEC dated August 3, 2022.

The objective of the groundwater monitoring described in this report is to monitor and track sulfolane plume stability and plume migration, if any. This report uses historical groundwater monitoring data and newly collected data to evaluate the nature and extent of the sulfolane plume, as well as concentration trends in individual monitoring wells. Plume stability occurs when the overall plume mass and plume footprint and are stable or decreasing. Both of these are observed at the Site.

An evaluation of the plume mass over time using has shown that the overall mass (average concentration over the plume area) has decreased from the time of initial monitoring in 2013 to the present. This observation is consistent when looking at only monitoring wells or a combination of monitoring wells and residential wells. Trend analyses conducted using Mann-Kendall trend plots of individual wells show apparent migration of the center of sulfolane mass within the plume footprint to the north-northwest in accordance with seasonal groundwater flow. However, monitoring wells on the northern edge of the plume have remained non-detect, suggesting the plume is attenuating in the vicinity of Badger Slough. The Slough may act as both a hydraulic control and a source of oxygen to facilitate degradation of sulfolane in this area. In addition, the monitoring well and private well data indicate that the plume's maximum and average observed concentrations are decreasing over time as the plume attenuates.

Based on the results of the 2022 sampling and the trend analysis, proposed future activities include the following:

- Repair/replacement of damaged or abandoned monitoring wells in the offsite network.
- Review and update hydrogeologic and permafrost information and models, as applicable.
- Annual sampling of the monitoring well network.

- Sampling of a subset of private wells that represent the deeper aquifer beneath the permafrost.
- Propose future permanent monitoring well locations to replace private wells in key areas.

It is anticipated that the data generated from these activities will be used, in consultation with DEC, to develop a revised monitoring program that continues to be protective of human health and the environment, focusing on sampling of permanent monitoring wells and a more limited list of private wells which are known to be accessible.

1 INTRODUCTION

On behalf of Williams Alaska Petroleum, Inc. (Williams), Integral Consulting Inc. (Integral), has prepared this 2022 Annual Monitoring and Five-Year (2017-2021) Offsite Sulfolane Plume Monitoring Report (2022 Report) for groundwater downgradient of the former Flint Hills Resources Alaska (FHRA) North Pole Refinery, which is located on H and H Lane in North Pole, Alaska (Site; Figure 1).

This report satisfies annual reporting requirements for the Alternative Water Solutions Program, the five-year review (2017-2021), and provides results of sampling activities completed in 2022. The completed sampling activities included 47 monitoring wells and 51 private wells[1]. The locations of monitoring wells and private wells sampled as part of the 2022 monitoring program are presented on Figure 2. A list of monitoring well and private well locations is included as Table 1.

The objective of the groundwater monitoring described in this report is to monitor and track the sulfolane plume stability and plume migration, if any. This report uses historical groundwater monitoring data and newly collected data to evaluate the nature and extent of the sulfolane plume, as well as concentration trends in individual monitoring wells. Plume stability occurs when the plume footprint and overall plume mass are stable or decreasing. The results of the evaluation are presented in Sections 4 and 5 of this 2022 Report.

Field activities described in this report were completed by Shannon & Wilson during August, September, and December 2022 by qualified persons as defined by 18 Alaska Administrative Code (AAC) 75.990. All samples were collected and analyzed in accordance with 18 AAC 75.355(a).

[1] A total of 120 private wells were targeted for sampling; however, 73 wells could not be accessed during the limited sampling schedule due to the time of year, resident declining, or lack of resident response.

2 ENVIRONMENTAL CONDITIONS

The site and surrounding area are located on the Tanana River floodplain, a flat-lying alluvial plain situated between the Tanana River and the Chena River. A review of the U.S. Geological Survey Geologic Map of Alaska reveals that the site is underlain by unconsolidated surficial deposits. These deposits are characterized as being poorly to well-sorted, poorly to moderately well-stratified, and consisting of alluvial, colluvial, marine, lacustrine, eolian, and swamp deposits (Wilson et al. 2015). Glacial deposits have also been identified at the Site during characterization activities. Bedrock depth has been estimated at 400 to 600 ft below ground surface (bgs) (Arcadis 2013).

Discontinuous permafrost has been encountered at the site at depths ranging between 70 and 130 ft bgs and has been identified offsite in the area discussed in this report (Arcadis 2018). Permafrost does not transmit groundwater, and therefore directs the flow of groundwater and groundwater impacts by creating localized regions of converging and diverging horizontal and vertical flow around permafrost bodies (Carlson and Barnes 2011). As part of site investigation activities in 2013, a permafrost model was constructed using the geologic modeling software Leapfrog to define the horizontal and vertical extents of permafrost to the north of the North Pole Refinery (Arcadis 2013). To support the model, Arcadis installed monitoring wells to depths of 150 ft bgs or to the top of the permafrost, whichever came first.

The permafrost begins at the northern Site property boundary and extends approximately three miles north and at least three miles northwest. The encountered depth varies from 10 to 150 feet bgs, and the bottom of the permafrost ranges from approximately 20 to 245 feet (Arcadis 2013). The permafrost terminates abruptly south of Badger Slough, where two mixing zones are present. In these zones, supra- and subpermafrost aquifers make contact. The permafrost body appears to channelize north of the railroad, and the body dips to the southwest, which, combined with north/northwest groundwater flow, may account for the shape of the sulfolane plume.

The nearest surface water body is the Tanana River which flows in a northwest direction along the western site boundary. Badger Slough, a tributary to the Chena River, lies northeast of the site. Badger Slough is primarily a groundwater fed feature that is a remnant of a side channel of the Tanana River that was severed by Moose Creek Dam. The Chena River and Chena Lake are also located farther to then northeast of the site. The Tanana River, Badger Slough and Chena River act as recharge sources and/or sinks to the groundwater system depending on the seasonal relationship between river stage and the water table. Groundwater elevations fluctuate seasonally with the lowest elevations occurring from late March through May and the highest elevations in late July or August (Arcadis 2013). Flow direction varies up to 19 degrees with a north-northwest direction in spring and more northerly direction in summer and fall (Arcadis 2013).

3 CURRENT GROUNDWATER MONITORING PROGRAM AND METHODS

Activities completed as part of the 2022 reporting cycle include sampling of monitoring wells, sampling of private wells, surveying of monitoring wells, and maintenance activities including well abandonment.

3.1 PLUME MONITORING—OFF SITE MONITORING WELL SAMPLING

The objective of annual groundwater monitoring is to monitor sulfolane concentrations present within the aquifer system. As part of the 2022 field activities, groundwater elevation readings were collected from all accessible monitoring wells prior to sampling. Readings were collected from a total of 45 monitoring wells; three monitoring wells (MW-332-41, MW-332-110 and MW-332-150) were severely frostjacked and one monitoring well (MW-191B-60) was inaccessible during the gauging period.

Groundwater samples were then collected from a total of 47 monitoring wells. Monitoring wells are screened in the suprapermafrost aquifer (37 wells) as well as the deeper mixing zone (10 wells). The wells designated as the subpermafrost aquifer were installed as part of Arcadis' investigations to characterize the permafrost and associated mixing areas. However, the monitoring wells sampled as part of this ongoing monitoring are either screened directly above the permafrost layer (MW-185C-120) or were installed to the maximum depth of 150 ft bgs where no permafrost was encountered. While these monitoring wells are not screened beneath the permafrost, they are considered representative of groundwater at depths where flow direction has been impacted by the permafrost.

A list of the wells sampled is included as Table 1 and presented on Figure 2.

3.2 PLUME MONITORING PLAN—PRIVATE WELL SAMPLING

In addition to sample collection from monitoring wells, private well sampling was also completed in August and September 2022. A total of 120 private wells were targeted for sampling; however, 73 wells could not be accessed during the limited sampling schedule due to the time of year, resident declining, or no resident response. Thus, a total of 51 private wells were sampled as part of this program. Of the 51 private wells sampled, two are screened with the subpermafrost aquifer, twenty-four are screened within in the suprapermafrost aquifer, and twenty-five have an unknown screened interval. A list of the private wells sampled in 2022 is included as Table 1, and locations are presented on Figure 2.

3.3 MONITORING WELL MAINTENANCE ACTIVITIES

Offsite monitoring wells were resurveyed in September 2022 by Design Alaska, Inc., a licensed surveyor, to determine if the monitoring wells had been affected by permafrost freezing and thawing (Appendix A). The information from this survey was used to determine groundwater flow direction, as described in Section 3.1.

Twenty-two monitoring wells were decommissioned during this reporting period on August 9, 10, and 19, 2023. The monitoring wells targeted for decommissioning were in areas that required Fairbanks North Star Borough Temporary Use Licenses (TULs) and were identified as not essential to the sulfolane monitoring well network. All decommissioning activities were performed in accordance with DEC's Monitoring Well Decommissioning Guidance.

Monitoring wells chosen for decommissioning included the following:

- MW-169A-15
- MW-169B-50
- MW-169C-60
- MW-187-15
- MW-193A-15
- MW-193B-60
- MW-194A-15
- MW-194B-40
- MW-308-15
- MW-308-30
- MW-318-20
- MW-318-135
- MW-323-15
- MW-323-50
- MW-326-20
- MW-326-150
- MW-327-15
- MW-327-150
- MW-333-16
- MW-333-150

In addition to those on the list, MW-166A-15/MW-166B-30 were inadvertently decommissioned due to misidentification in the field. Field forms related to decommissioning activities are included as Appendix B.

4 GROUNDWATER SAMPLING RESULTS

A summary of the 2022 groundwater monitoring results is provided in the sections below.

4.1 GROUNDWATER ELEVATION

Prior to sampling, a synoptic water level event was completed at all accessible monitoring wells (43 out of the 47 sampled). A licensed surveyor was also present to collect elevation data for the monitoring wells that were suspected to have been affected by permafrost melt and freezing patterns. These revised survey results were used to determine groundwater elevation and flow direction.

The monitoring wells are divided into four depth zones: the Water Table Zone (WTZ); Zone 1, consisting of wells screened at depths between 10 and 55 ft bgs; Zone 2, consisting of wells screened at depths between 55 and 90 ft bgs; and Zone 3, consisting of wells screened at depths between 90 and 150 ft bgs.

In all zones, groundwater flow was to the north-northwest, as presented in Figures 3 through 6. A summary of synoptic gauging results is included as Appendix C, and the surveyor report is included as Appendix A.

4.2 MONITORING WELL SAMPLING

Between August 3rd and September 19th, 2022, qualified persons as defined by 18 AAC 75.990 mobilized to the offsite monitoring wells to collect groundwater samples for sulfolane analysis. Field parameters were collected at the time of sampling, including temperature, dissolved oxygen, conductivity, pH, oxidation reduction potential, and water clarity. A summary of field parameters and monitoring well sampling logs completed by Shannon & Wilson are included in Appendix D.

Samples were sent to SGS North America, Inc. (SGS), for sulfolane analysis. SGS is a certified laboratory that has historically been used as part of annual monitoring of sulfolane concentrations in this area. Five duplicate samples were submitted and analyzed for quality assurance purposes, as outlined below:

- MW-250A-10 (parent location MW-150A-10)
- MW-285C-120 (parent location MW-185C-120)
- MW-414-150 (parent location MW-314-150)
- MW-447-150 (parent location MW-347-150)
- MW-449-45 (parent location MW-349-45)

The parent samples and duplicate had consistent concentrations, suggesting that data quality was not adversely impacted during sampling. Analytical results provided by SGS met all appropriate quality assurance objectives for the monitoring program. In accordance with ADEC guidance, when duplicate samples were collected from a sampling location, only the higher reported result of the parent and duplicate samples is included in data analysis.

Of the 47 monitoring wells sampled, sulfolane was reported at concentrations ranging between non-detect and 76.4 µg/L (MW-346-65). Twenty-five of the 47 monitoring wells sampled reported no detections, and 13 contained detections of sulfolane below 20 µg/L. Nine monitoring wells reported concentrations of sulfolane that ranged between 20 and 76.4 µg/L.

Historically, sulfolane concentrations exceeded 100 µg/L at 35 wells in 20 locations (including multiple wells at one location screened in different zones). In 2022, no monitoring well sampled exceeded 100 µg/L. The maximum concentration in 2021 was 70.4 µg/L, with a similar maximum of 76.4 µg/L in 2022. Overall, the monitoring well data indicate that the plume's maximum observed concentrations are decreasing over time as the plume attenuates.

A summary of monitoring well analytical results is presented in Table 2, and laboratory analytical data packages are included in Appendix E. Figures 7 through 9 present monitoring well results within the various aquifer zones. Concentrations from monitoring wells in the mixing zone have been included with subpermafrost aquifer wells as historical concentrations have been representative of the subpermafrost aquifer.

4.3 PRIVATE WELL SAMPLING

Private well samples were collected from a total of 51 residential properties during August, September, and December 2022, and were sent to SGS for sulfolane analysis. Six duplicate samples were submitted and analyzed for quality assurance purposes, as outlined below:

- 9999 Badger (parent location PW-0370)
- 9999 Blackburn (parent location PW-2237)
- 9999 Christine (parent location PW-0753)
- 3373 Keeney (parent location PW-2219)
- 3289 Richardson (parent location PW-0977)
- 9990 Tanana (parent location PW-1230)

The parent samples and duplicate had consistent concentrations, suggesting that data quality was not adversely impacted during sampling. Analytical results provided by SGS met all appropriate quality assurance objectives for the monitoring program. In accordance with ADEC guidance, when duplicate samples were collected from a sampling location, only the higher reported result of the parent and duplicate samples is included in data analysis.

Sulfolane was not detected in any well sampled in 2022 north of Badger Slough (Figure 9). Sulfolane was reported in private wells at concentrations ranging between non-detect and 267 μg/L. Two wells showed concentrations above 20 μg/L: PW-1230 (267 μg/L) and PW-0623 (23.5 μg/L). PW-1230 is for outdoor use only as the home is on city water, but it is unknown if PW-0623 is presently connected to city water.

A summary of private well analytical results is presented in Table 3, and laboratory analytical data packages are included in Appendix E. A summary of the residential well network, 2022 sampling dates, and justification for missed sample locations, as applicable, as well as field sampling forms for all residential wells, are included in Appendix F.

Figures 7 through 9 present monitoring well results within the various aquifer zones. Concentrations from monitoring wells in the mixing zone have been included with subpermafrost aquifer wells as historical concentrations have been representative of the subpermafrost aquifer.

5 SULFOLANE CONCENTRATION TRENDS

Analysis completed as part of this report include Mann-Kendall (MK) trend tests and a plume mass analysis. Section 5.1 describes the MK analysis and Section 5.2 includes the plume mass analysis. MK graphs are included in Appendix G. The MK trend graphs are divided between two groupings. Trend graphs for data that includes 2022, are included in Appendix G1. Trend graphs for data that will meet the objectives of the 5-year report are included in Appendix G2 (graphs only include data through 2021). As such, there are two sets of graphs for the wells that were sampled in 2022. Overall, the MK analysis shows decreasing trends in the areas of the plume that previously had the highest concentrations in the past, with a relatively small cluster of wells in the northern portion of the plume showing some increasing trends but at lower concentrations (Figure 10). Figure 10 represents groundwater trends over time; it does not show current concentrations. The plume mass analysis shows a steadily decreasing trend in the average concentration over the plume footprint, indicating that the plume is actively attenuating (Figure 11 and 12).

5.1 MANN-KENDALL

As required by DEC, MK trend tests were completed to determine statistically significant increasing or decreasing trends from 2010 through 2022. The MK analysis yields an "s" value, which is used to determine trend direction. Positive s-values indicate an increasing trend, and negative s-values indicate a decreasing trend.

Sample locations included as part of the MK analysis were selected based on the number of available data points, and included wells that were not sampled as part of the 2022 investigation to provide a larger data set for analysis. A minimum of four data points is required for statistical significance; thus, any sample location with fewer than four data points was excluded from the MK analysis. If a well had eight or more "Not Detected" data points, the MK trend test was not performed as the test will not generate a meaningful trend. The analysis was performed using R statistical software, and the output table and MK plots are included as Appendix G.

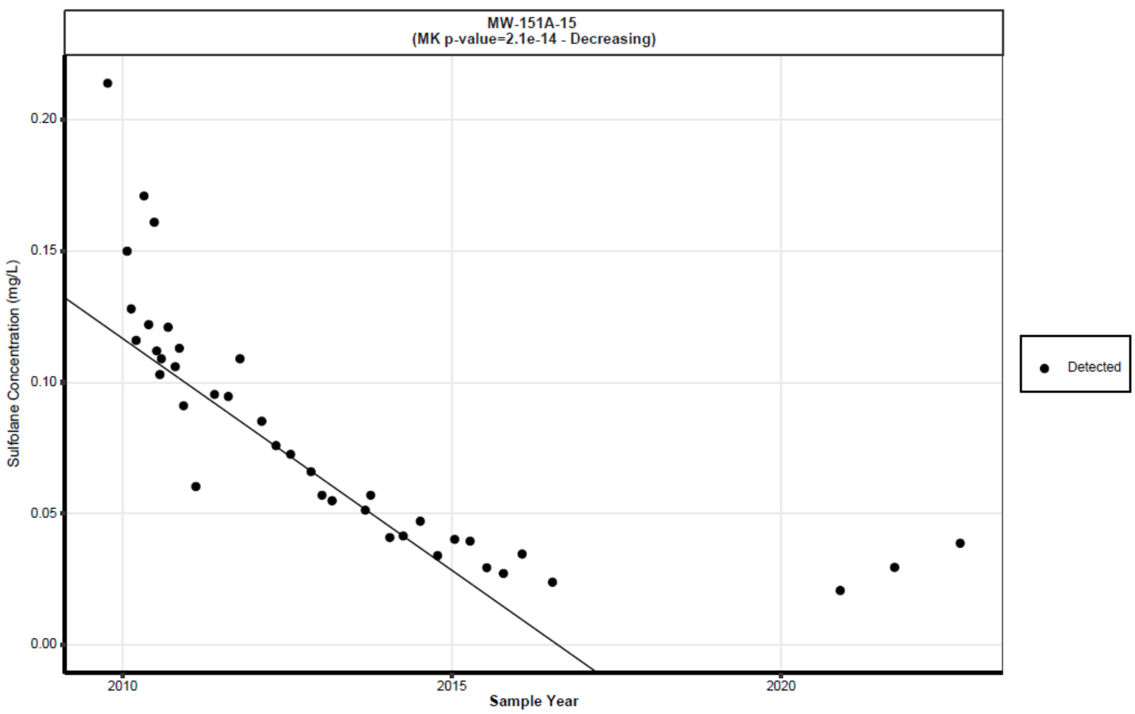
The results of the MK trend test help determine the concentration trends and center of mass flow direction of the plume. Theil-Sen trend lines were added to the plots for significant test results (p-value<0.05) to graphically represent trends. The slope of the Theil-Sen trend lines was also analyzed to determine the rate of change.

Based on the MK analysis and sampling results (Figure 10), key patterns and trends in sulfolane concentrations in the monitoring well network can be identified. This is not intended to be a comprehensive analysis of all locations, but a simplified analysis of points of interest to demonstrate that the MK trend test, while useful, does not provide a full picture of plume dynamics. A summary of key observations and points of interest based on the MK analysis is as follows:

- The plume footprint is stable. This is demonstrated by the monitoring wells that are consistently non-detect along the plume boundary, including: MW-171BR-40, MW-181A-15/MW-181B-50/MW-181C-150, MW-185B-50/MW-185C-120, MW-190BR-60/MW-190-150, MW-191A-15/MW-191B-60, MW-311-15/MW-311-46, MW-314-15/MW-314-150, MW-328-15/MW-328-151, and MW-357-65/MW-357-150.

- Sampling locations that are proximate and immediately downgradient of the site are either non-detect or show overall decreasing trends. However, since 2020 the monitoring wells MW-150B, MW-151A/B/C, MW-152C-65, and MW-153A-15 have shown increases in concentrations. The MK graph for MW-151A is included below to show the representative increase observed for this time period. The recent increase in sulfolane concentrations in these wells may be related to the shutdown of the groundwater extraction system in 2017.

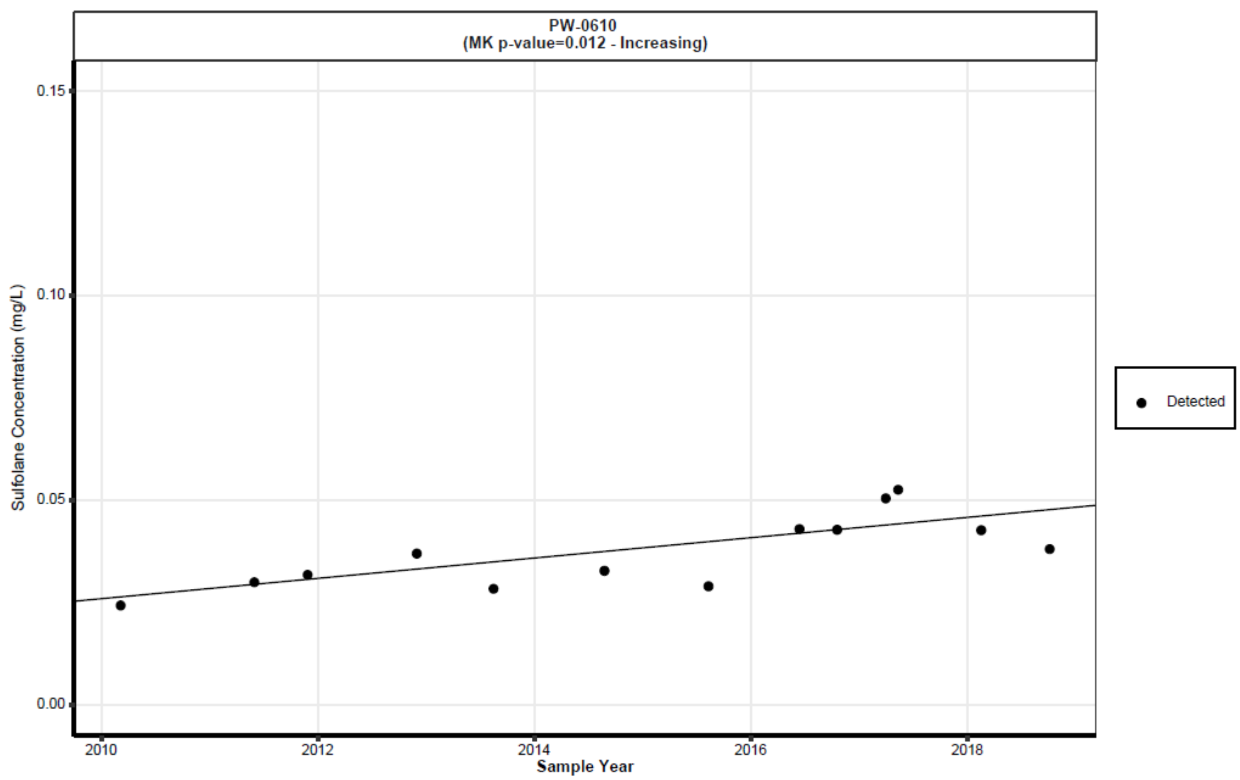
Exhibit 1. Mann Kendall Analysis for MW-151A-15



- The locations along the northern edge of the plume footprint that show both private wells and monitoring well locations with increasing trends often do not reflect the most recent sampling events (e.g., these wells are no longer sampled as the residential properties have been verified to be connected to the public water supply). The inclusion of all data available is to show that the area of interest is largely concentrated to the north-northwest. Wells of interest identified on Figure 10 can be explained as follows:

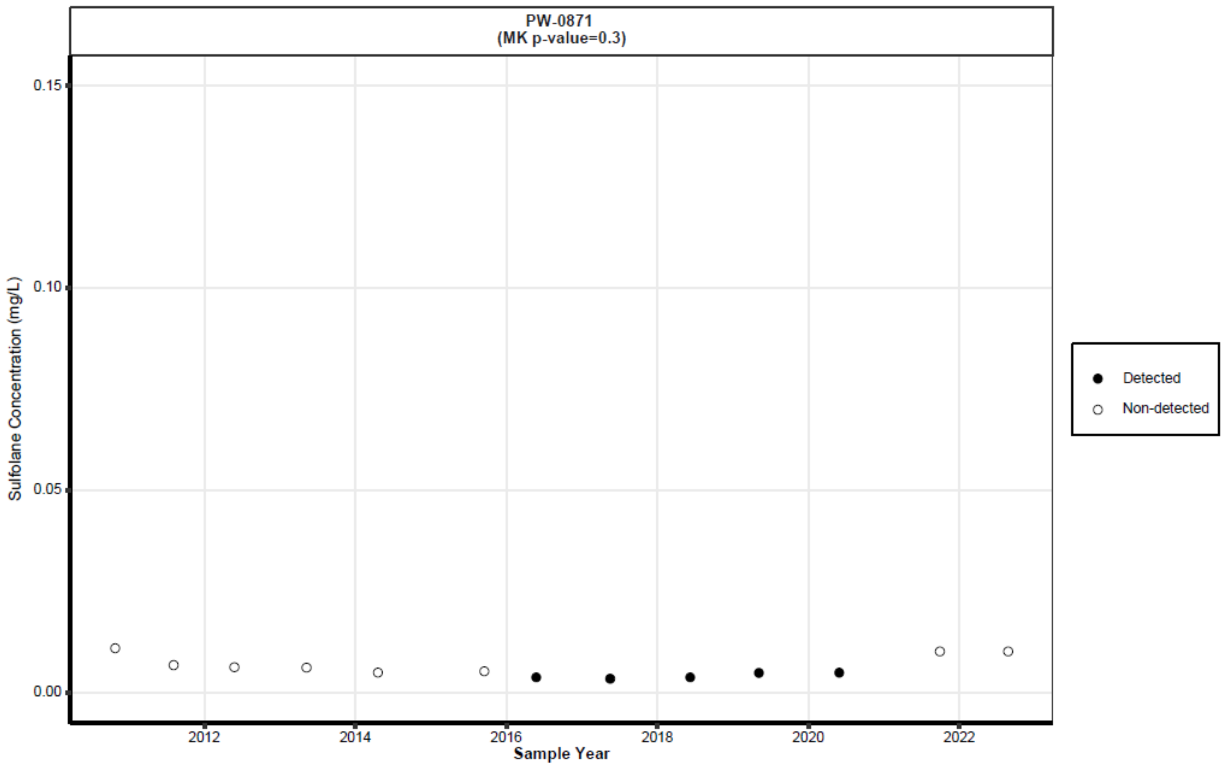
- Private well locations PW-0610, PW-0618, PW-1375 along the western side of the plume are reported as having increasing trends. The MK analysis showed an overall increasing trend. However, this overall trend masks that concentrations of sulfolane appear to have peaked between 2016 and 2018 and decreased from the peak in recent years. Due to the nature of the MK test, this is not immediately reflected in the long-term trend, but it can be observed in the individual plots for each private well location. Individual plots for each well are included in Appendix G. An example of this scenario (PW-0610) is below.

Exhibit 2. Mann-Kendall Analysis for PW-0610



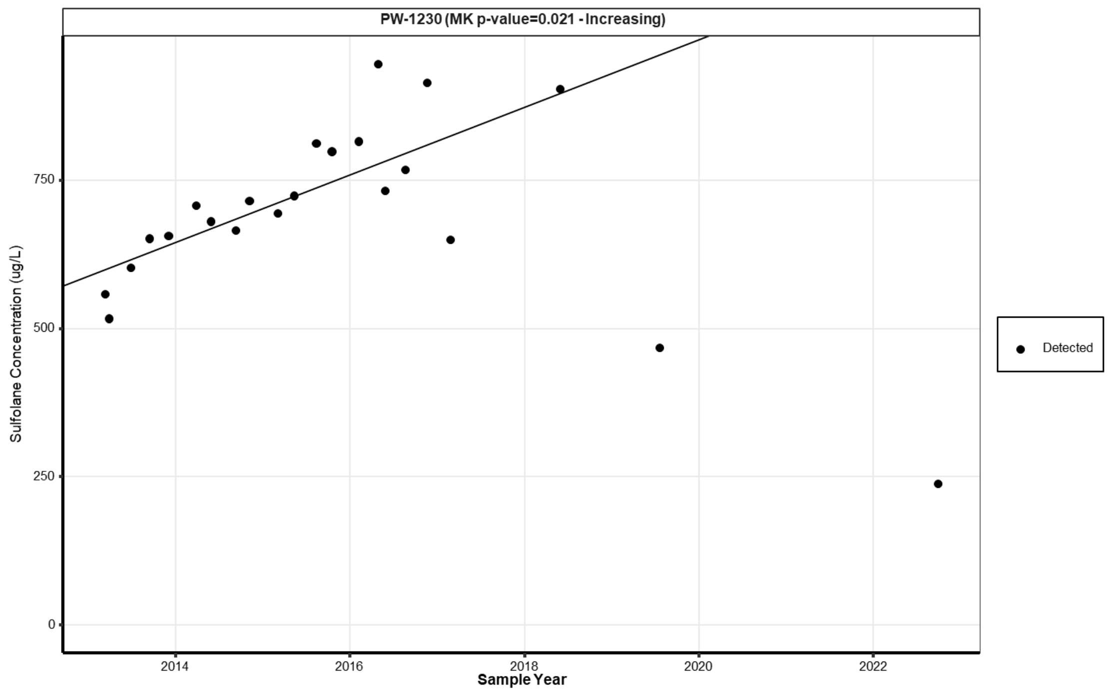
- Private well location PW-0871 has historically had detections of sulfolane less than 5 µg/L which indicate a slightly increasing trend. However, the most recent round of sampling is reported as non-detect as shown in Exhibit 3 below.

Exhibit 3. Mann-Kendall Analysis for PW-0871



- o Private well location PW-1230 in the center of the plume is the only private well screened in the subpermafrost aquifer that was sampled in 2022. The well screen is located at a depth of 231 feet. Permafrost at this well location has been observed between 33 to 205 feet bgs. PW-1230 is for outdoor use - the home is on city water. The concentration trend in PW-1230 showed consistent increases from 2013 until 2018, reaching a maximum concentration of 946 μg/L. Since that time concentrations have decreased, reaching 267 μg/L in 2022.

Exhibit 4. Mann-Kendall Analysis for PW-1230



- Private well locations PW-0755, PW-0757, PW-0758, and PW-0773 (which were not sampled in 2022) show increasing trends. This is believed to be the result of the core of the plume migrating over time to the north. The monitoring wells and private wells directly north and northeast of these locations have been consistently non-detect (Figure 10). Those non-detect locations indicate that while the core of the plume may be migrating, the plume extent is not changing.

- Monitoring well MW-166B-30, which was abandoned prior to sampling in 2022, did display an overall increasing trend, however, sampling events within the last five years have had consistently lower reported sulfolane concentrations than the highest values seen around 2015. The MK trend graph for the MW-166 well cluster is included in Appendix G.

5.2 PLUME MASS ANALYSIS

Sulfolane concentrations in groundwater have been monitored since 2009. Over this time, there have been changes in the magnitude and spatial distribution of concentrations and in the number of wells monitored. To better understand these changes, the concentrations of sulfolane in monitoring wells were contoured using the Surfer software package (Golden Software, version 22.3.185) and shown on Figure 11.

Data from the years 2013-2016 and 2020-2022 were utilized for this analysis using the same set of monitoring wells for each year. Earlier years had substantially fewer monitoring locations. The dates selected were based on the years that have the same (and longest) list of monitored wells with sulfolane data. Further, the approximately 10-year period provides a sufficient time to evaluate any changes in mass of sulfolane within the plume.

The kriging method was used to interpolate concentrations across the extent of the plume from observed concentration data for each of the years with sufficient data. Kriging is a commonly utilized interpolation method that results in the generation of a regularly spaced grid of points across the plume with each point assigned a geostatistcally determined concentration. The plume extent was defined as the non-detect line as shown on Figure 9 of this report. Plume-wide average concentrations were calculated as the arithmetic mean of modeled concentrations for all points within the plume extent.

The results of this analysis show that the plume-wide average concentration of sulfolane has decreased substantially from 2013 through 2022 (Figure 12). Concentrations have decreased from a high of approximately 51 ug/L in 2013 to approximately 10 ug/L in 2022 (Figure 12).

Following discussions with ADEC, additional analysis was conducted in Surfer using a combination of monitoring and private wells. To create the most comprehensive data set for each plot, time groupings were lengthened to create three collections: 2013-2014, 2017-2018, and 2021-2022. A review of data availability identified a total of 65 locations that were sampled during each of the collection periods. For each location, an average and maximum sulfolane concentration was calculated for each period. These data were then contoured using methods identical to the monitoring well-only analysis.

Conclusions remained the same with this revised analysis, showing that the plume has become smaller with an overall average decrease in concentration, most notably in the southwest portion of the plume. While there were increases in concentrations near Badger Slough, the plume boundary in this area remains stable. This shift is seen for both average concentrations (Figure 13) and maximum concentrations (Figure 14). The plume-wide average concentrations is also seen to decrease (Figure 15).

6 CONCLUSIONS AND RECOMMENDATIONS

The following presents the conclusions of the 2022 monitoring event and groundwater assessment under the five-year monitoring period.

Based on the results of 2022 monitoring activities, it can be confirmed that groundwater gradient and flow are consistent with historical trends (Figures 3 through 6). In addition, evaluation of 2022 data as depicted on Figures 7 and 9 have shown that the overall plume footprint is stable and the maximum and average overall concentrations are decreasing as the plume attenuates over time. Sulfolane was not detected to the north of Badger Slough in 2022 (Figure 9). Within the plume footprint, it appears that the center of mass of the plume is migrating north away from the Site. However, monitoring wells on the northern edge of the plume have remained non-detect, suggesting the plume is attenuating in the vicinity of Badger Slough. The Slough may act as both a hydraulic control and a source of oxygen to facilitate degradation of sulfolane in this area. Additional assessment and monitoring of this area will be conducted, as described below, to confirm these conclusions.

Field activities in 2022 included the inadvertent decommissioning of monitoring wells MW-166A-15 and MW-166B-30. These wells will be replaced proximate to the original location to allow for consistent delineation of the sulfolane plume footprint. In addition, the frostjacked monitoring wells (MW-332-41, MW-332-110 and MW-332-150) will be repaired. Following well repair and/or replacement, sampling of the monitoring well network will continue in 2023 with no modifications.

Evaluation of the 2022 data in the subpermafrost aquifer and mixing zones show that there is a potential for groundwater impacted with sulfolane to be directed beneath the permafrost and reemerge within the mixing zones. The data from residential well PW-1230 and monitoring well MW-332-150 indicate that there are concentrations of sulfolane in the subpermafrost aquifer that are not fully delineated. To evaluate if this is an ongoing possibility, it is recommended that a previous study completed by Arcadis be repeated to better understand the subpermafrost aquifer. This includes canvassing of the following private wells:

- PW-0217
- PW-0259
- PW-0296
- PW-0297
- PW-0332
- PW-0358
- PW-0463
- PW-0464
- PW-0466
- PW-0658
- PW-0932
- PW-0943
- PW-0972
- PW-1099
- PW-1109
- PW-1155
- PW-1230
- PW-1343
- PW-1626

There is limited available information regarding each of these residential wells, so initial activities will include contacting homeowners to confirm if the wells are still accessible for sampling. The accessible locations will be sampled for sulfolane.

Integral has historically worked on a comprehensive model of the hydrogeology and permafrost within the offsite sulfolane investigation area, particularly near Badger Slough. This model will be revisited and reviewed to better understand groundwater flow patterns in this area.

Sampling in recent years has demonstrated that many private wells have been decommissioned or rendered unusable for sampling as residential properties are connected to the municipal water supply system. The greater private well sampling list will also be canvased as part of this phase of investigation activities and implementation of the Alternative Water Supply Plan. Proposed activities include the following:

1. Williams will confirm with DEC its most up to date information related to which private wells have been connected to city water lines
2. Williams will reach out to the city of North Pole for any records related to water line installation activities.
3. The private well network will be canvassed by Williams' consultants. Each homeowner that has been listed as part of the sampling program will be contacted to confirm if their well remains in use and is accessible for sampling.

As needed, permanent monitoring well locations will be proposed to supplement the offsite groundwater monitoring program. These locations will be identified using the updated private well network information, the permafrost model, and the results of sulfolane samples collected from the deep private well network.

Finally, a revised groundwater monitoring program will be created. This program will be developed in consultation with DEC with the goal of being protective of human health and the environment. This program will focus on sampling of permanent monitoring wells and a more limited list of private wells which are known to be accessible.

7 REFERENCES

Arcadis. 2013. Onsite site characterization report – 2013 addendum. Arcadis U.S., Inc. December 20.

Arcadis. 2018. Annual 2018 onsite groundwater monitoring report. North Pole Terminal, North Pole, Alaska. Arcadis U.S., Inc. November 16

Carlson, A.E., and D.L. Barnes. 2011. Movement of trichloroethene in a discontinuous permafrost zone. Journal of Contaminant Hydrology 124(1): 1-13

Duncan, T. 2020. Response to State of Alaska's Requested Long-Term Offsite Monitoring of the Sulfolane Plume in North Pole, Alaska. Shook, Hardy, and Bacon. July.

Mulder, S. 2020. Long-Term Offsite Monitoring of the Sulfolane Plume in North Pole North Pole Refinery Litigation (Flint Hills) Case No. 4FA-14-01544 CI – Consolidated, AGO No. AN2014100495. Alaska Department of Law. August 3.

Wilson, F.H., Hults, C.P., Mull, C.G., and Karl, S.M., comps. 2015. Geologic map of Alaska: U.S. Geological Survey Scientific Investigations Map 3340, 197 p., 2 sheets, scale 1:1,584,000, http://dx.doi.org/10.3133/sim3340.

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MEMORANDUM

To:	James Fish, Alaska Department of Environmental Conservation
From:	Integral Consulting Inc.
Date:	January 5, 2024
Subject:	Response to Comment - 2022 Annual Monitoring and Five Year (2017-2022) Offsite Sulfolane Monitoring Report

On behalf of Williams Alaska Petroleum, Inc. (Williams), Integral Consulting Inc. (Integral) has prepared this document to reply to the comments provided by the Alaska Department of Environmental Conservation (ADEC) on the 2022 Annual Monitoring and Five Year (2017-2022) Offsite Sulfolane Monitoring Report ("2022 Sulfolane Report") dated November 6, 2023. This letter describes the responses to each comment provided by ADEC. These responses were discussed and finalized during the meeting between Williams, ADEC, and their respective environmental consultants on December 14th, 2023. A revision of the 2022 Sulfolane Report with associated comment matrix identifying the location of changes will be submitted to ADEC prior to January 5, 2024.

For clarity, comments from ADEC are in bold font with Williams' response directly following.

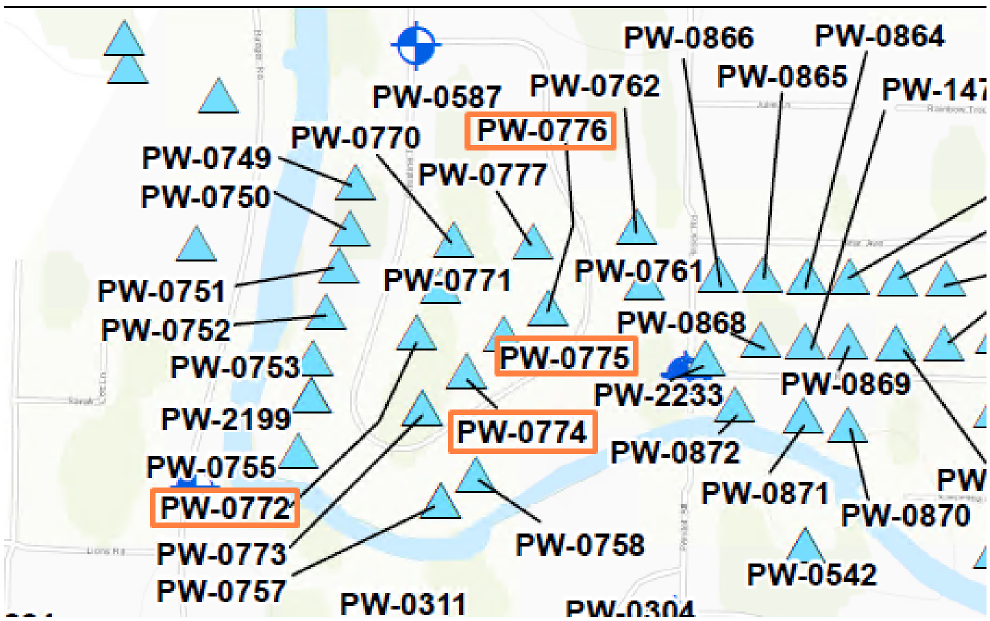
ADEC Comment 1. 2021 and 2022 sampling is insufficient to support the conclusions presented. Sampling of selected private wells with historically high and/or increasing sulfolane concentrations is necessary to evaluate plume migration and attenuation.

- **"An evaluation of historical data trends and 2022 sample results have shown that overall, the sulfolane plume has decreasing mass and a stable footprint with no significant change in the non-detect line."**
  - **The history of first-time detections in private wells located near and north of Badger Slough, including a 2020 first-time detection in PW-775, indicates that the plume is migrating slowly northward.**
  - **Recent sampling has been insufficient to evaluate sulfolane plume mass; see further comment below.**

- **"An evaluation of the plume mass over time has shown that the overall mass (average concentration over the plume area) has decreased steadily from the time of initial monitoring in 2013 to the present."**
    - **The plume mass evaluation is flawed because it did not include locations representing the highest sulfolane concentrations.**
        - **The plume mass evaluation did not include any private wells, even though a number of private wells located within the sulfolane plume between the Richardson Highway and Badger Slough exhibited high and/or increasing sulfolane concentrations through their most recent sampling event (generally between 2018 and 2020). There are no monitoring wells in this section of the plume, therefore, this section of the plume is not represented in the plume mass analysis.**
        - **The plume mass analysis did not consider or even discuss the subpermafrost, even though the highest offsite sulfolane concentrations historically were detected in the subpermafrost. An evaluation of sulfolane plume mass should include the locations with maximum sulfolane concentrations.**

- **"Trend analyses of individual wells show apparent migration of the center of sulfolane mass within the plume footprint to the north-northwest in accordance with seasonal groundwater flow. In addition, the monitoring well data indicate that the plume's maximum observed concentrations are decreasing over time as the plume attenuates."**
    - **These conclusions may be representative of the suprapermafrost sulfolane plume. However, historical data suggests a substantial portion of the sulfolane mass may be present in the subpermafrost zone. Groundwater flow patterns in the subpermafrost are not well understood. Recent monitoring of the subpermafrost is insufficient to draw any conclusions about the maximum observed concentrations.**

Williams Response: First time detection north of Badger Slough: While private well PW-775 did show its first-time detection in 2020 (4.64 μg/L, estimated), it should be noted that previous detection limits between 2010 and 2019 were all greater than 5 μg/L (ranging between 5.1 and 11.8 μg/L). Location PW-774, directly upgradient, reported no detections in 2020, though the reporting limit for that sample was 5.25 μg/L. It would be reasonable to conclude that sulfolane may have been present at similar concentrations in this vicinity for an extended period of time and is only visible due to decreased analytical detection limits. PW-775 was not sampled in 2022, but private wells PW-772 and PW-776, directly adjacent to this location were included in the 2022 data set. Each reported a non-detect value with a lowered detection limit of 3.2 µg/L. Locations for reference are provided in the image below. These results appear to indicate that there is some fluctuation of the non-detect line for sulfolane in the vicinity of Badger Slough, likely driven by a combination of seasonal fluctuation and small changes in laboratory detection limits. However, they do not support the conclusion that the plume is actively migrating north of Badger Slough.



Private well PW-775 is included in the locations targeted for sampling in 2023, and additional assessment will be completed after those results have been received.

Plume analysis: The plume analysis was conducted using all monitoring wells that had data for each of the years, and results from multiple depths at the same location (including any sub-permafrost locations) were averaged such that each location used had a single result for every year represented. The intent of the analysis was not a detailed assessment of the three-dimensional distribution of sulfolane in the supra- and sub-permafrost aquifers, but rather an overall assessment of whether the average concentration of sulfolane in the plume footprint was increasing, stable or decreasing over time. The analysis was meant to complement the Mann-Kendall results for individual wells, which show areas of decreasing concentration as well as areas of increasing concentration within the overall plume footprint.

Monitoring well data was used because it is considered more reliable as monitoring wells are installed to a known depth, with known construction and a known screened interval open to the aquifer. In contrast, there is limited information on the construction, depth and screened interval of the private wells; they are not set up for direct groundwater sampling or water level measurement, and the homeowner may refuse access. However, if DEC prefers the inclusion of private well data, Williams proposes the following:

- Update the plume analysis with private well data. As presented by Williams during the December 14, 2023 meeting, the inclusion of the private shows that the overall average concentration within the plume footprint is decreasing. This analysis also demonstrated an area of higher concentration in the center of the plume and a general shift in the center line of the plume towards the north that is contained within the stable plume footprint. These patterns are consistent when evaluated using average concentrations or maximum concentrations.
- Assessment of the sub-permafrost distribution of sulfolane (this is included as an action item in the 2022 report). The analysis will include a 3D plume mass assessment as well as center of mass assessments for the supra- and sub-permafrost aquifers.

ADEC Comment 2. The bullet at the bottom of page 5-4 states that, "The plume footprint is stable, as identified from the monitoring wells that are consistently non-detect along the plume boundary including MW-171BR-40, MW-181A-15/MW-181B-50/MW-181C-150, MW-185B-50/MW-185C-120, MW-190BR-60/MW-190-150, MW-191A-15/MW-191B-60, MW-311-15/MW-311-46, MW-314-15/MW-314-150, MW-328-15/MW-328-151, and MW-357-65/MW-357-150.

- **Private wells located in areas between the monitoring wells listed above have continued in recent years to experience first-time sulfolane detections, suggesting that the plume continues to migrate slowly northward.**
- **Note that MW-328-151 exhibited a sulfolane detection of 3.96J μg/L in 2019, although subsequent sampling has not indicated further detections.**

<u>*Williams Response*</u>: It is agreed that monitoring data show some private wells within the plume footprint are increasing in concentration, but that does not change the conclusion that the shape and areal extent of the plume remains stable. As part of the Mann-Kendall analysis, targeted private wells were chosen along the current "non-detect line" to demonstrate key behaviors that may not be properly communicated through a simple trend analysis. For example, location PW-0871 is along the northern edge of the plume near Badger Slough. This location has historically demonstrated concentrations of sulfolane near the reporting limit of approximately 5 μg/L, but the most recent groundwater result was

non-detect. The Mann-Kendall analysis identifies this location as an increasing trend, but when more closely examined, it is clear that concentrations have been generally consistent at this location since the first detection in 2016.

The detection identified at MW-328-151 is an estimated value, meaning that the result lies between the laboratory's reporting limit and method detection limit. The result is flagged by the laboratory because it is within the range of error. As stated in ADEC's comment, there have been no subsequent detections, including in 2022 where the method detection limit was 3.2 μg/L and reporting limit was 5.15 μg/L.

The exact footprint of the sulfolane plume may fluctuate slightly based on seasonal changes in groundwater flow, but the non-detect line has remained consistent in the area along Badger Slough over the last several years. It is not surprising that Badger Slough may act as a natural plume barrier as it is a groundwater drain. In addition, multiple studies have shown that ultraviolet light and aerobic bacteria degrade sulfolane, and the slough acts as a source of oxygen to groundwater. Williams and its consultants believe that groundwater modeling will help support this conceptual model and intends to provide results of this modeling exercise to ADEC as part of future submittals.

ADEC Comment 3. Second bullet from the bottom states, "Private well locations PW-0755, PW-0757, PW-0758, and PW-0773, which were not sampled in 2022 are showing increasing trends, which is believed to be the core of the plume migrating over time to the north, but within a stable plume footprint. The monitoring wells and private wells directly north and northeast of these locations have been consistently non-detect (Figure 10)."

- **There was a first-time detection in PW-0775 in 2020. PW-0775 is located to the northeast of PW-0758. The increasing trends and recent first-time detection suggest the plume footprint is expanding slowly northward in this area.**

- **There are other private wells showing increasing trends from the Mann-Kendall analysis that were not sampled in 2022. Some examples private wells with increasing trends are listed below. Note that this is not a complete list of private wells with increasing trends: PW-0298 through PW-0305; PW-0463 and PW-0464; PW-0559 through PW-0561; PW-0647, PW-067, and PW-0658; many PWs between PW-0931 and PW-0948; PW-1104, PW-1109, and PW-1118. It is unclear why only four locations are discussed in this section.**

Williams Response: A discussion directly related to the concentrations observed in PW-0775 is provided in the response to Comment 1 above. However, this comment mentions PW-0758 which Williams would like to address here. PW-0775 is located to the northeast, but based on groundwater flow direction, it is not downgradient from PW-0758. Downgradient from PW-0758 would be PW-0773 which was last measured as having a reported concentration of 8.10 μg/L (estimated) in July 2020. That concentration more accurately matches the expected groundwater gradient.

However, the comparison between PW-0775 and PW-0758 also demonstrates an example of the dangers of relying too heavily on private well data with limited construction information. PW-0758 is constructed to a total depth of 34 feet below ground surface (bgs) while PW-0775's total depth is 58 feet bgs. There is no evidence to suggest that groundwater that has already migrated towards the surface would then dive downwards at a steep angle to then impact PW-0775. The more directly downgradient well location, PW-0773, lacks construction information making it impossible to determine if it is useful for horizontal delineation of sulfolane. A lack of water level data and limited well construction information in the private wells makes it impossible to properly assess vertical hydraulic gradients, three-dimensional groundwater flow and sulfolane distribution at this micro scale.

To address the second bullet, the four locations discussed in the 2022 report were used as examples for why the Mann-Kendall trend analysis may not be providing a full understanding of groundwater concentration gradients. The chosen examples highlighted that in some locations, more recent sampling results demonstrate different behavior as compared to long term trends looking at data older than a decade. It was not intended to be an exhaustive evaluation of every well location; the discussion here was to show that a simplified analysis such as Mann-Kendall does not provide a full picture.

ADEC Comment 4. It is unclear why the plume mass analysis did not include any private wells. In particular, the area of the plume recently exhibiting relatively high and/or increasing sulfolane concentrations was entirely unrepresented in the plume mass analysis (see attached Power Point). Also, PW-1230, which has frequently exhibited the highest sulfolane concentration in the offsite plume, was not included in the analysis. Without including monitoring locations with the highest historical or recent sulfolane concentrations, the plume mass analysis misrepresents the actual plume mass distribution in the groundwater. Similarly, the plume-wide average concentrations are not representative of actual conditions since the analysis was based on few data points that did not include the areas of highest sulfolane concentrations.

Williams Response: The analysis was conducted using monitoring well data because the monitoring wells were sampled on a greater frequency than the private wells and, as discussed above, monitoring wells have more robust information on well construction. The goal of the plume analysis, was to use data from each location for each year of the analysis in order to assess year-over-year changes in the average plume concentration through time. This approach did result in not including private wells with higher sulfolane concentrations as pointed out in DEC comments; however, this decision was made to prevent bias introduced by having individual wells being present in one year's data and absent the next. Assessing the overall trend within the plume footprint requires data from each location for every year a plume-wide average concentration is calculated.

Williams has prepared an updated plume analysis and presented to ADEC in the meeting on December 14th, 2023. That plume analysis includes private well data that meets the criteria of the analysis. That analysis is also performed using both average and maximum concentrations. However, Integral notes that this results in a more limited temporal analysis. The text has been updated to include and discuss these additional analyses.

ADEC Comment 5. The method used for representing multiple depths in monitoring well nests is not explained nor obvious from the figure. For example, the 2022 sulfolane concentration in MW-346-46 was 76.4 ug/L but the 2022 map in Figure 11 shows sulfolane concentrations in the 20-50 ug/L range across MW-346. Similarly, the 2022 sulfolane concentration in MW-332-150 was 37.2 ug/L, but the 2022 map in Figure 11 shows sulfolane concentrations in the 10-20 ug/L range across MW-332. An explanation should be provided.

- **Does Figure 11 represent the average concentration for well nests? While average concentrations may be an appropriate approach for evaluating plume mass changes over time, displaying average concentrations is misleading in that the highest sulfolane plume concentrations are masked. For example, Figure 11 suggests that sulfolane concentrations in 2022 are everywhere less than 50 μg/L, which is not true.**

There is one "red dot" shown in the 2020 through 2022 sulfolane plume depictions that is not included on the identified on the key map. Is that MW-171R-40?

Williams Response: As has been described above, locations with multiple depths were averaged to represent the average plume concentration in two dimensions across the plume footprint. Figure 11 represents the results of this analysis and is not intended to be a map of maximum sulfolane concentration regardless of depth, and it is agreed that the analysis did not include private wells with higher sulfolane detections. As previously described, the plume analysis has been updated to include private well data where possible. That analysis is also performed using both average and maximum concentrations. A 3D analysis including the permafrost model and sulfolane distribution in supra- and sub-permafrost areas will be completed in the coming year.

Correct, the "red dot" in Figure 11 missing from the key is MW-171BR-40.

ADEC Comment 6. Comments regarding plume stability conclusions presented above. Concur with the recommendation to sample subpermafrost private wells. Concur with the recommendation to canvass the greater private well sampling as described in this section. DEC would be interested in learning more about Integral's groundwater model.

Williams Response: No response required.

ADEC Comment 7. Quality control duplicate results are not displayed consistently on Figures 8 and 9. If a single result is displayed, it should be the higher of the duplicate results, as directed by ADEC's August 15, 2022 Technical Memorandum 22-001 Guidelines for Data Reporting (https://dec.alaska.gov/media/25979/guidelines-for-data-reporting.pdf).

- **Only the lower of the MW-150-10 results are displayed on Figure 9.**
- **Only the lower of the PW-1230 results are displayed on Figure 8.**
- **Only a single MW-185C-120 result is displayed on Figure 8.**
- **Primary and duplicate results for MW-347-150 and MW-314-150 are both displayed on Figure 8.**

It is not clear why the nondetected results are not displayed on Figure 9 but they are displayed on Figure 8. It would be helpful to at least label the nondetected sample locations on Figure 9. Also, the nondetected results on Figure 8 are incorrectly reported to the MDL rather than the LOD (see comment #8). These inconsistencies should be remedied and revised Figures 8 and 9 submitted.

Williams Response: Revised figures will be included with the updated submittal.

ADEC Comment 8. Nondetects are incorrectly reported in these tables to the MDL, rather than the LOD. DEC guidance is clear that nondetects should never be reported to the MDL. Please revise and resubmit Tables 2 and 3. In addition, please revise and resubmit the spreadsheet containing the 2022 offsite sulfolane data.

Williams Response: Revised tables will be included with the updated submittal.

ADEC Comment 9. The report as submitted did not include data validation or DEC QC checklists. However, Integral provided the missing sections upon DEC's request. 10% data review is pending.

Williams Response: The DEC QC checklists have been added to the report as Appendix H.

ADEC Comment 10. Sampling notes indicate some owners inquired about previous sampling results. Did Williams provide current and previous sample results to the owners who requested them? Does Williams provide sample results to all well owners as a matter of course?

Williams Response: Letters were not previously provided to residents following the 2020 and 2021 sampling events. However, this has been remedied and results for 2022 sampling were mailed to the properties sampled in November 2023 prior to additional sampling for the 2023 season.

ADEC Comment 11. The graphs in this section represent the 2022 sampling results qualified as "UJ" as detections. The body of samples qualified as "UJ" include some private water wells used as residential drinking water sources. Is this intentional or a mistake? If intentional, please explain why the results are considered detections for the MK analysis but not detections throughout the body of the report. Also, per Comment #8, the nondetects are incorrectly reported to the MDL rather than the LOD.

Williams Response: ADEC's comments are understood, and graphs/representations have been revised to report the LOD rather than MDL.

Num.	Page	Section	Comment	Document Update
1	v	Exec. Summary	2021 and 2022 sampling is insufficient to support the conclusions presented. Sampling of selected private wells with historically high and/or increasing sulfolane concentrations is necessary to evaluate plume migration and attenuation. "An evaluation of historical data trends and 2022 sample results have shown that overall, the sulfolane plume has decreasing mass and a stable footprint with no significant change in the non-detect line." -The history of first-time detections in private wells located near and north of Badger Slough, including a 2020 first-time detection in PW-775, indicates that the plume is migrating slowly northward. -Recent sampling has been insufficient to evaluate sulfolane plume mass; see further comment below. "An evaluation of the plume mass over time has shown that the overall mass (average concentration over the plume area) has decreased steadily from the time of initial monitoring in 2013 to the present." -The plume mass evaluation is flawed because it did not include locations representing the highest sulfolane concentrations. The plume mass evaluation did not include any private wells, even though a number of private wells located within the sulfolane plume between the Richardson Highway and Badger Slough exhibited high and/or increasing sulfolane concentrations through their most recent sampling event (generally between 2018 and 2020). There are no monitoring wells in this section of the plume, therefore, this section of the plume is not represented in the plume mass analysis. The plume mass analysis did not consider or even discuss the subpermafrost, even though the highest offsite sulfolane concentrations historically were detected in the subpermafrost. An evaluation of sulfolane plume mass should include the locations with maximum sulfolane concentrations. "Trend analyses of individual wells show apparent migration of the center of sulfolane mass within the plume footprint to the north-northwest in accordance with seasonal groundwater flow. In addition, the monitoring well data indicate that the plume's maximum observed concentrations are decreasing over time as the plume attenuates." -These conclusions may be representative of the suprapermafrost sulfolane plume. However, historical data suggests a substantial portion of the sulfolane mass may be present in the subpermafrost zone. Groundwater flow patterns in the subpermafrost are not well understood. Recent monitoring of the subpermafrost is insufficient to draw any conclusions about the maximum observed concentrations.	The executive summary has been updated to reflect changes in the text. As discussed in comments 4 and 5 below, the plume analysis has been updated to include private well data. That analysis is intended to provide a broad-scale representation of overall plume conditions in two dimensions. The averaging of concentrations over multiple depths at a single location incorporates information from each depth (i.e., supra- and sub-permafromst), however it does not explicitly represent mulitple depths. In the coming year plume modeling will include 3-D modeling that will quantiatively evaluate supra- and sub-permafrost portions of the plume.
2	5-4	5.1 Mann-Kendall	The bullet at the bottom of page 5-4 states that, "The plume footprint is stable, as identified from the monitoring wells that are consistently non-detect along the plume boundary including MW-171BR-40, MW-181A-15/MW-181B-50/MW-181C-150, MW-185B-50/MW-185C-120, MW-190BR-60/MW-190-150, MW-191A-15/MW-191B-60, MW-311-15/MW-311-46, MW-314-15/MW-314-150, MW-328-15/MW-328-151, and MW-357-65/MW-357-150. - Private wells located in areas between the monitoring wells listed above have continued in recent years to experience first-time sulfolane detections, suggesting that the plume continues to migrate slowly northward. - Note that MW-328-151 exhibited a sulfolane detection of 3.96J µg/L in 2019, although subsequent sampling has not indicated further detections.	Section 5.1 text has been updated with clarifying language that this is not a comprehensive analysis of all location and focuses on points of interest within the MK analysis.
3	5-8	5.1 Mann-Kendall	Second bullet from the bottom states, "Private well locations PW-0755, PW-0757, PW-0758, and PW-0773, which were not sampled in 2022 are showing increasing trends, which is believed to be the core of the plume migrating over time to the north, but within a stable plume footprint. The monitoring wells and private wells directly north and northeast of these locations have been consistently non-detect (Figure 10)." - There was a first-time detection in PW-0775 in 2020. PW-0775 is located to the northeast of PW-0758. The increasing trends and recent first-time detection suggest the plume footprint is expanding slowly northward in this area. - There are other private wells showing increasing trends from the Mann-Kendall analysis that were not sampled in 2022. Some examples private wells with increasing trends are listed below. Note that this is not a complete list of private wells with increasing trends: PW-0298 through PW-0305; PW-0463 and PW-0464; PW-0559 through PW-0561; PW-0647, PW-067, and PW-0658; many PWs between PW-0931 and PW-0948; PW-1104, PW-1109, and PW-1118. It is unclear why only four locations are discussed in this section.	Section 5.1 text has been updated with clarifying language that this is not a comprehensive analysis of all location and focuses on points of interest within the MK analysis.

4	5-9	5.2 Plume Mass Analysis	It is unclear why the plume mass analysis did not include any private wells. In particular, the area of the plume recently exhibiting relatively high and/or increasing sulfolane concentrations was entirely unrepresented in the plume mass analysis (see attached Power Point). Also, PW-1230, which has frequently exhibited the highest sulfolane concentration in the offsite plume, was not included in the analysis. Without including monitoring locations with the highest historical or recent sulfolane concentrations, the plume mass analysis misrepresents the actual plume mass distribution in the groundwater. Similarly, the plume-wide average concentrations are not representative of actual conditions since the analysis was based on few data points that did not include the areas of highest sulfolane concentrations.	Additional analyses were conducted to evaluate and represent the extent and distribution of sulfolane in groundwater over time. This included evaluations using both average and maximum sulfolane concentrations. A summary of this analysis is included in Section 5.2 with additional figures 13 and 14 added to the report.
5		Figure 11 (Plume Mass Analysis)	The method used for representing multiple depths in monitoring well nests is not explained nor obvious from the figure. For example, the 2022 sulfolane concentration in MW-346-46 was 76.4 ug/L but the 2022 map in Figure 11 shows sulfolane concentrations in the 20-50 ug/L range across MW-346. Similarly, the 2022 sulfolane concentration in MW-332-150 was 37.2 ug/L, but the 2022 map in Figure 11 shows sulfolane concentrations in the 10-20 ug/L range across MW-332. An explanation should be provided. Does Figure 11 represent the average concentration for well nests? While average concentrations may be an appropriate approach for evaluating plume mass changes over time, displaying average concentrations is misleading in that the highest sulfolane plume concentrations are masked. For example, Figure 11 suggests that sulfolane concentrations in 2022 are everywhere less than 50 µg/L, which is not true. There is one "red dot" shown in the 2020 through 2022 sulfolane plume depictions that is not included on the identified on the key map. Is that MW-171R-40?	Additional analyses were conducted to evaluate and represent the extent and distribution of sulfolane in groundwater over time. This included evaluations using both average and maximum sulfolane concentrations. A summary of this analysis is included in Section 5.2 with additional figures 13 and 14 added to the report.
6	6-1	Conclusions and Recommendations	Comments regarding plume stability conclusions presented above. Concur with the recommendation to sample subpermafrost private wells. Concur with the recommendation to canvass the greater private well sampling as described in this section. DEC would be interested in learning more about Integral's groundwater model.	N/A
7		Figure 8 and Figure 9	Quality control duplicate results are not displayed consistently on Figures 8 and 9. If a single result is displayed, it should be the higher of the duplicate results, as directed by ADEC's August 15, 2022 Technical Memorandum 22-001 Guidelines for Data Reporting (https://dec.alaska.gov/media/25979/guidelines-for-data-reporting.pdf). - Only the lower of the MW-150-10 results are displayed on Figure 9. - Only the lower of the PW-1230 results are displayed on Figure 8. - Only a single MW-185C-120 result is displayed on Figure 8. - Primary and duplicate results for MW-347-150 and MW-314-150 are both displayed on Figure 8. It is not clear why the nondetected results are not displayed on Figure 9 but they are displayed on Figure 8. It would be helpful to at least label the nondetected sample locations on Figure 9. Also, the nondetected results on Figure 8 are incorrectly reported to the MDL rather than the LOD (see comment #8). These inconsistencies should be remedied and revised Figures 8 and 9 submitted.	Figures 8 and 9 have been revised.
8		Table 2 and 3	Nondetects are incorrectly reported in these tables to the MDL, rather than the LOD. DEC guidance is clear that nondetects should never be reported to the MDL. Please revise and resubmit Tables 2 and 3. In addition, please revise and resubmit the spreadsheet containing the 2022 offsite sulfolane data.	Revised tables will be included with the updated submittal. Revised 2022 sulfolane data has been provided.
9		Appendix D and E and Data Validation	The report as submitted did not include data validation or DEC QC checklists. However, Integral provided the missing sections upon DEC's request. 10% data review is p	Appendix H has been added to the report which includes the DEC QC checklists and data validation reports.
10		Appendix F Private Well Sample Documentation	Sampling notes indicate some owners inquired about previous sampling results. Did Williams provide current and previous sample results to the owners who requested them? Does Williams provide sample results to all well owners as a matter of course?	N/A
11		Appendix G1 2022 Mann-Kendall	The graphs in this section represent the 2022 sampling results qualified as "UJ" as detections. The body of samples qualified as "UJ" include some private water wells used as residential drinking water sources. Is this intentional or a mistake? If intentional, please explain why the results are considered detections for the MK analysis but not detections throughout the body of the report. Also, per Comment #8, the nondetects are incorrectly reported to the MDL rather than the LOD.	Appendix G has been revised.

Figures

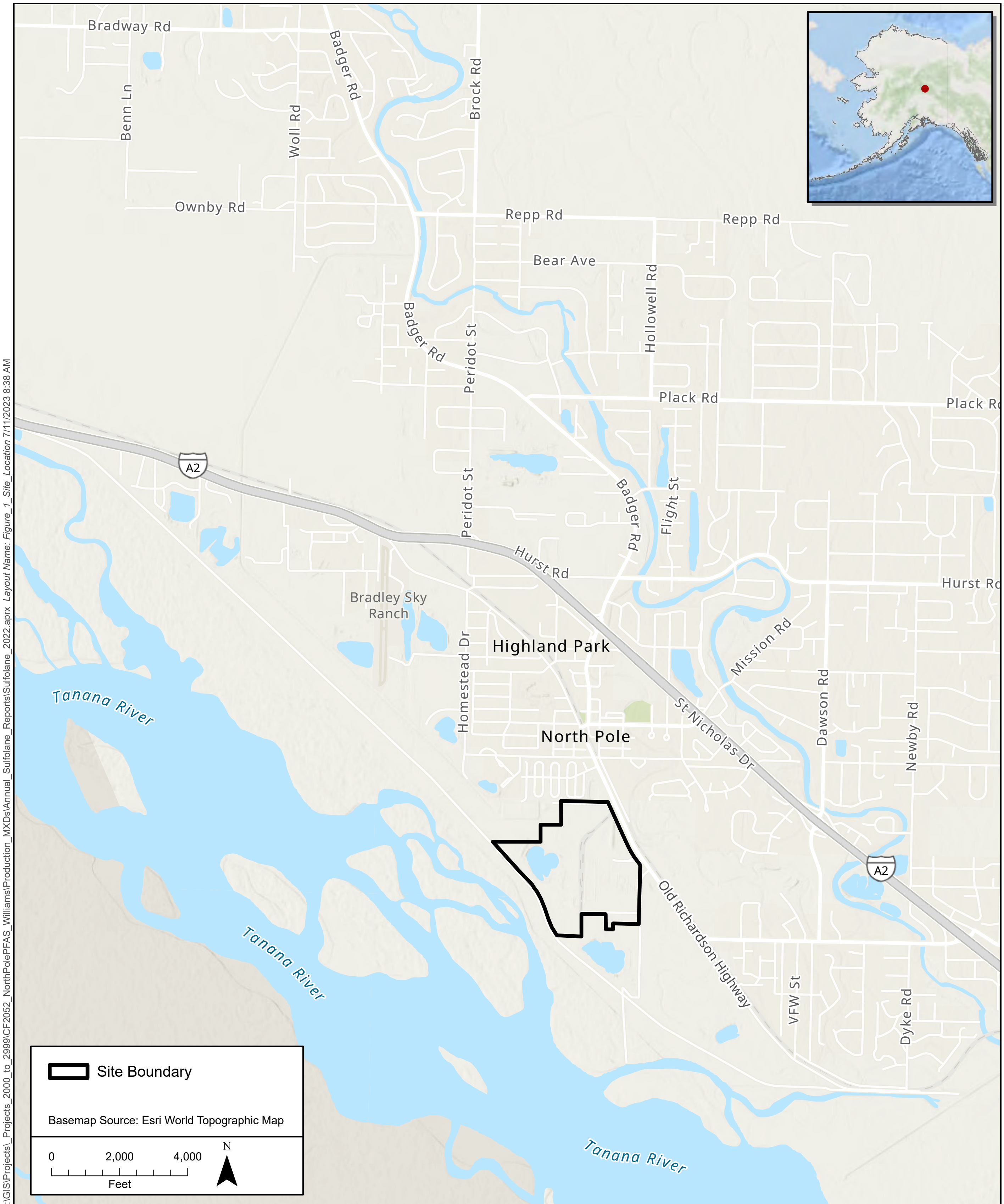


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Figure 1.
Site Location

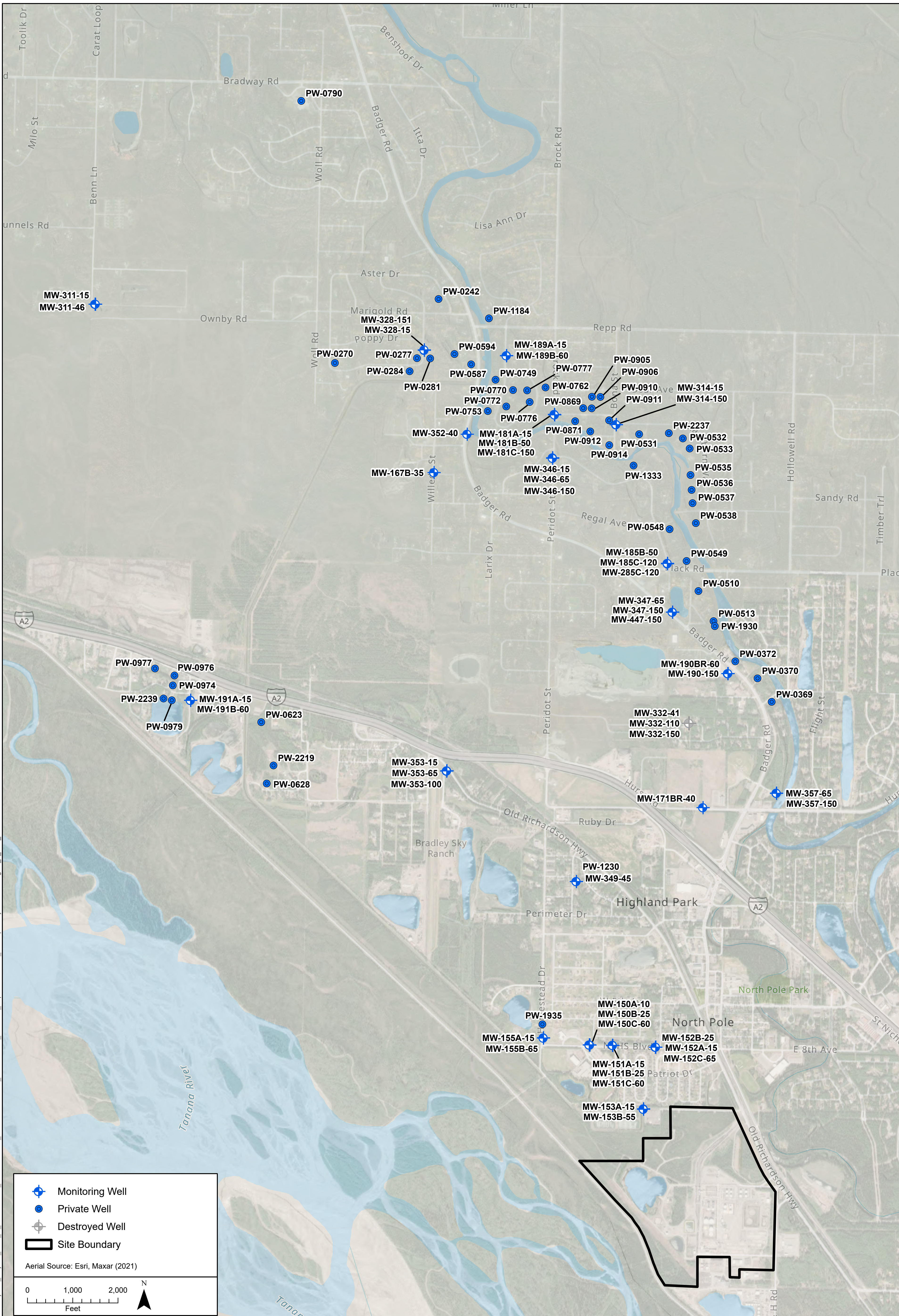

Figure 2.
Offsite Groundwater Sampling Locations

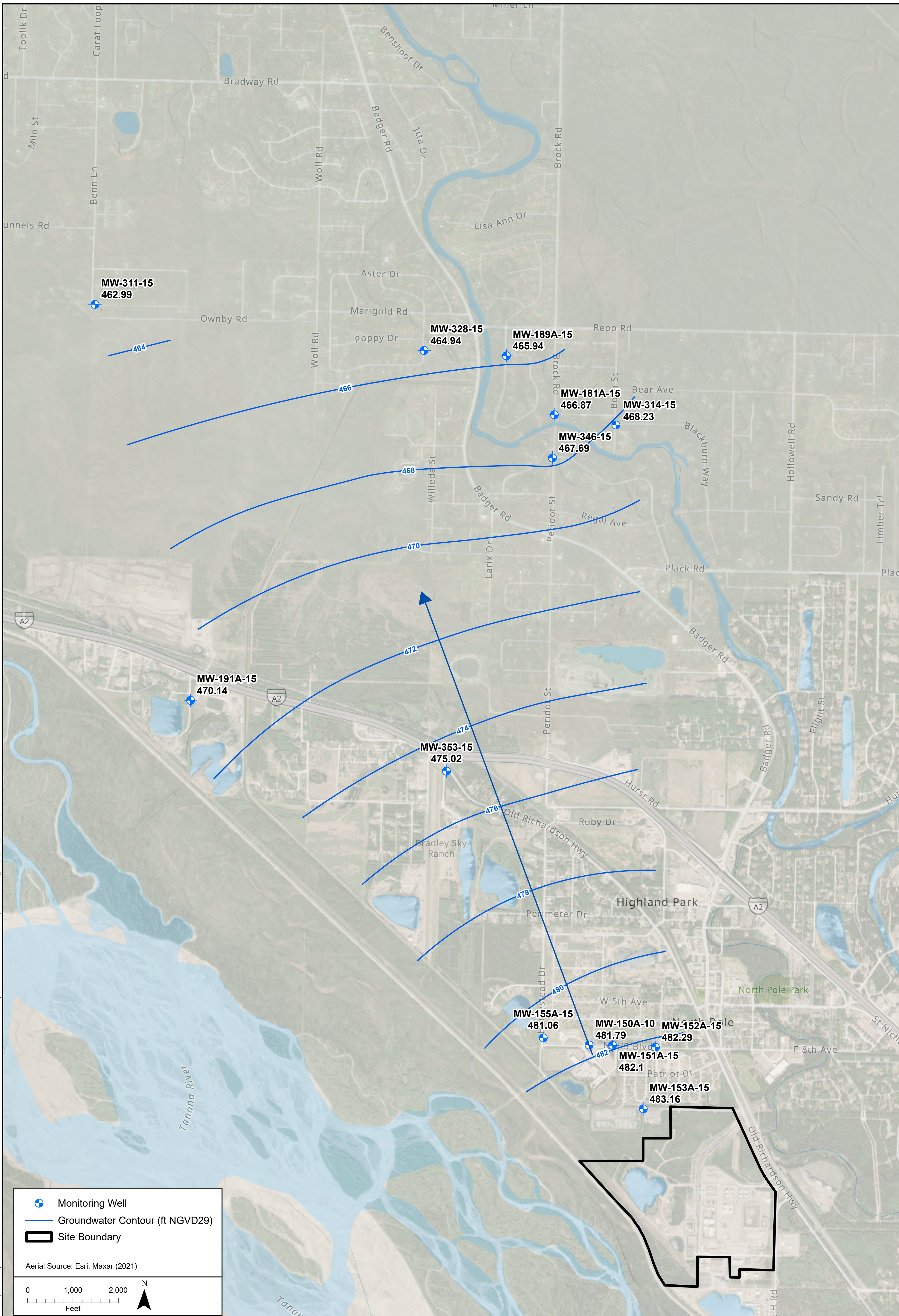

Figure 3.
Groundwater Contour Map (Offsite Wells) Water Table Zone

Figure 4.
Groundwater Contour Map (Offsite Wells) Zone 1 (10-55 ft)

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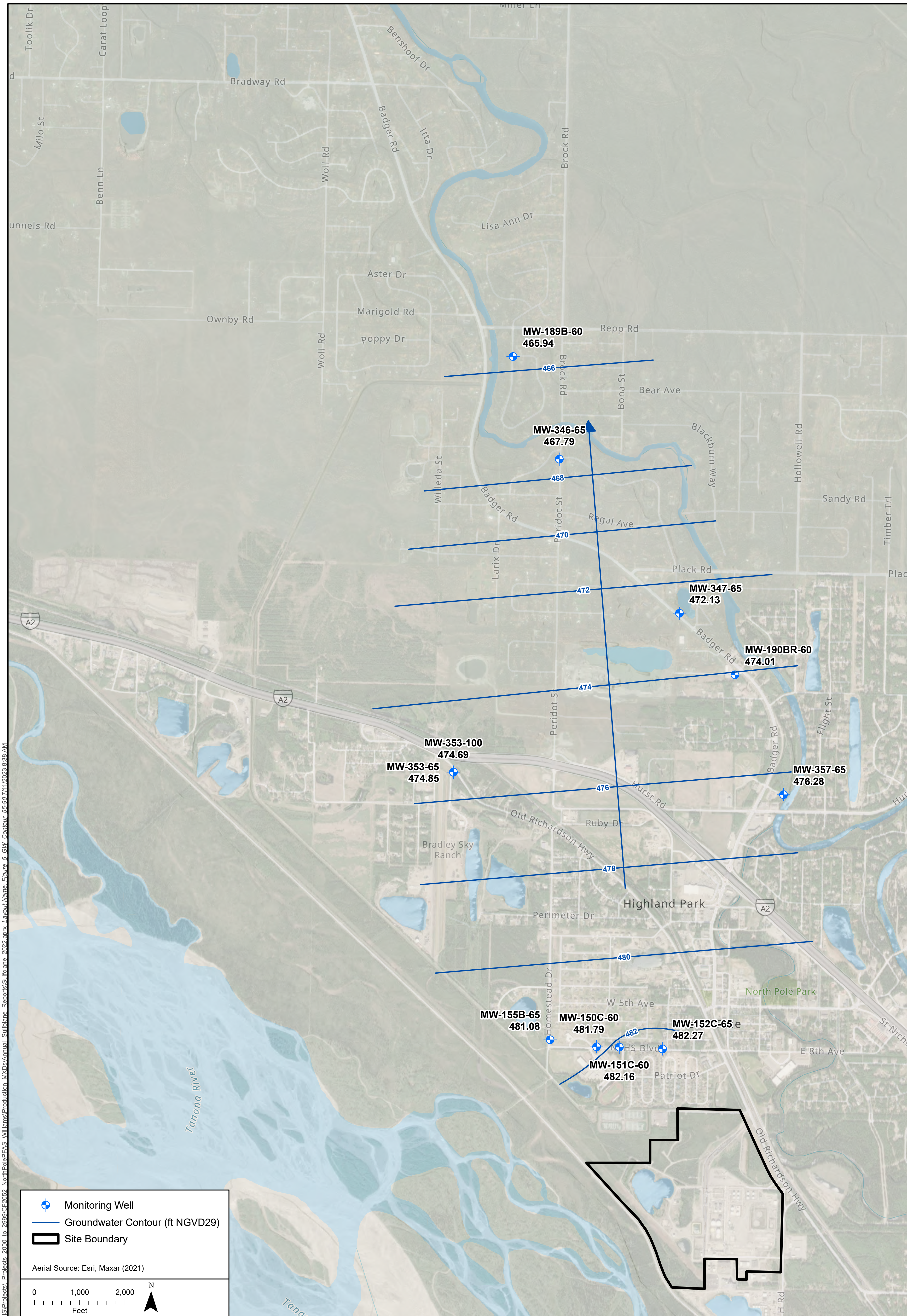

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Figure 5.
Groundwater Contour Map (Offsite Wells) Zone 2 (55-90 ft)

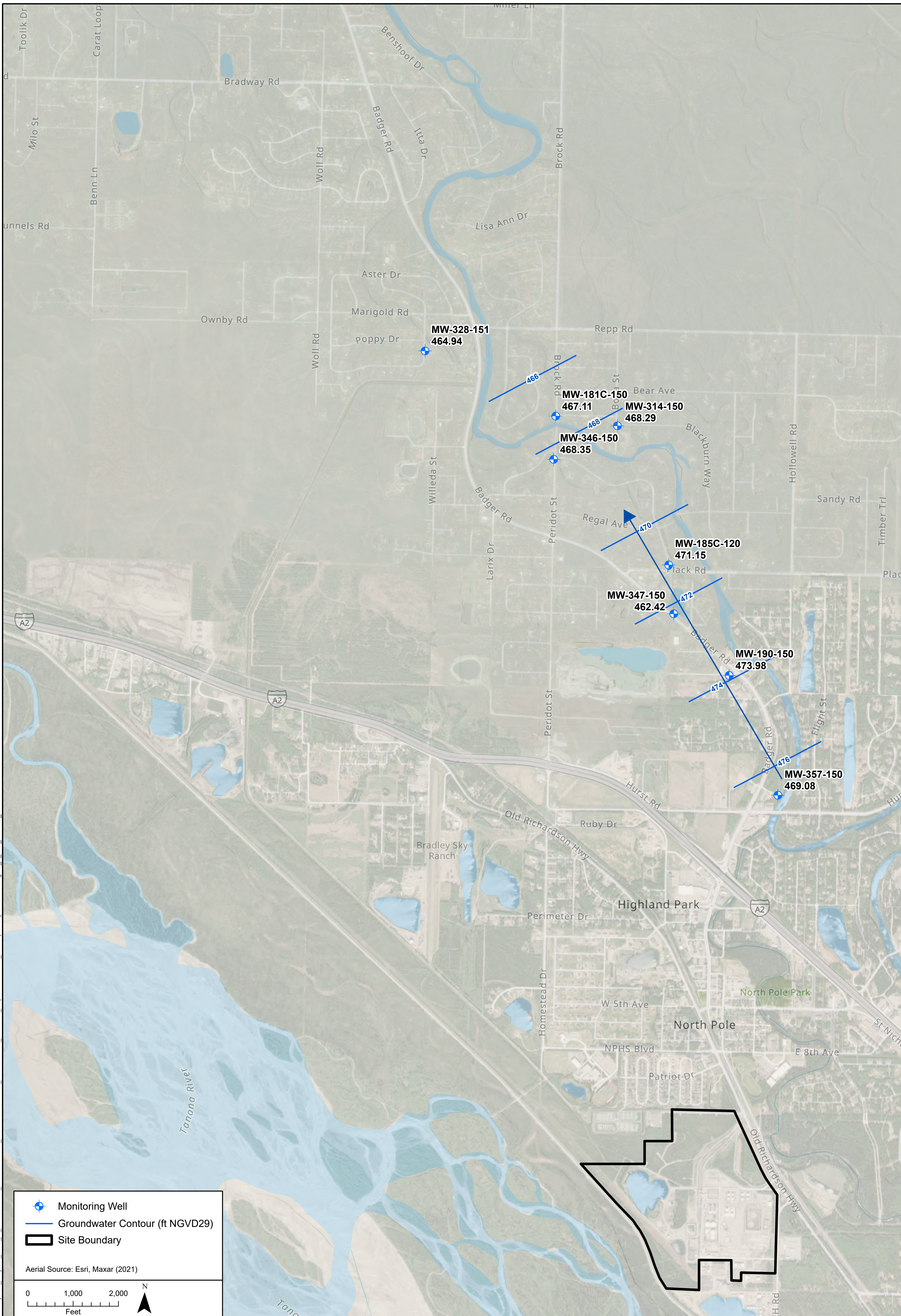

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Figure 6.
Groundwater Contour Map (Offsite Wells) Zone 2 (90-150 ft)

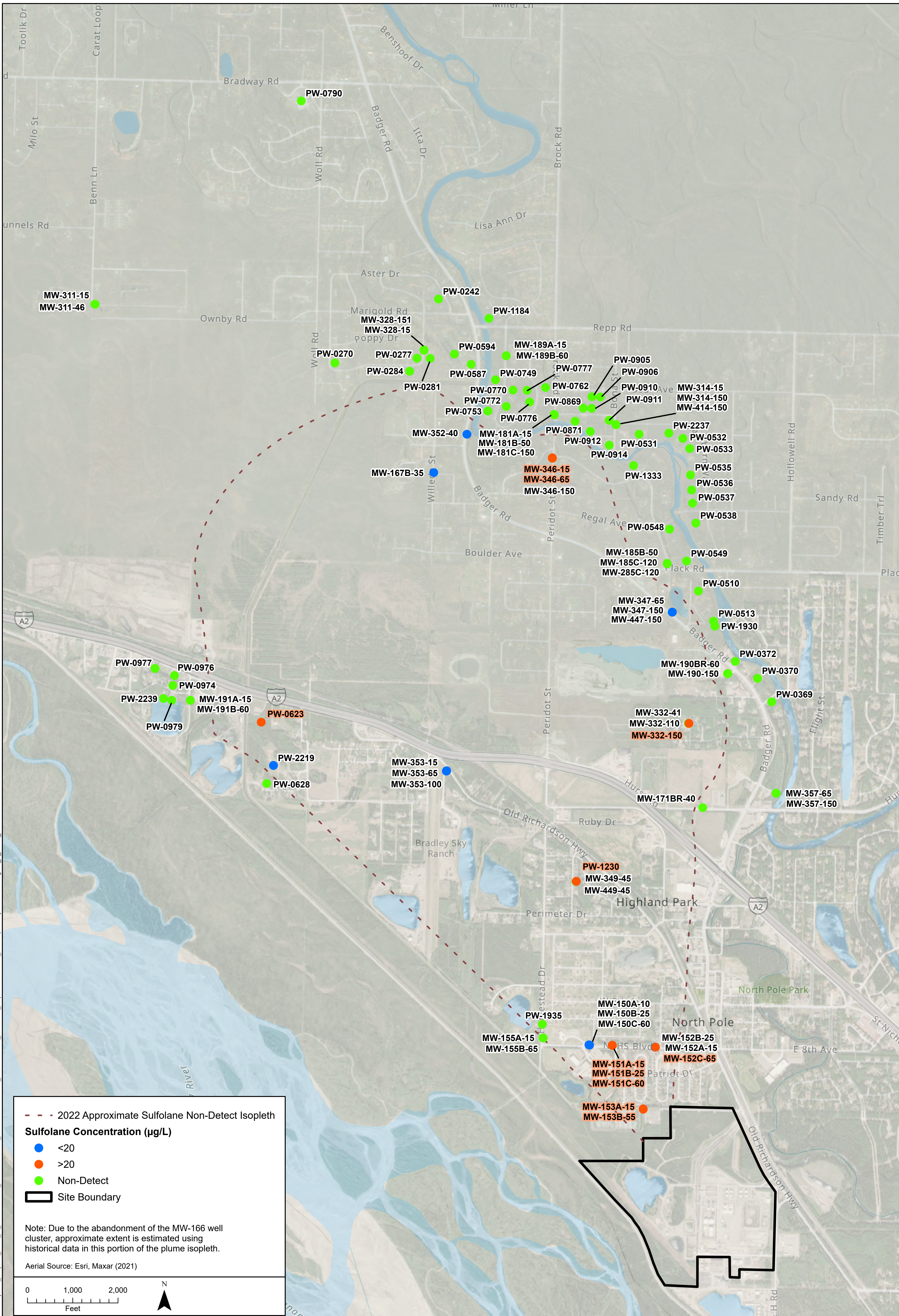

Figure 7.
Offsite Groundwater Sulfolane Concentrations

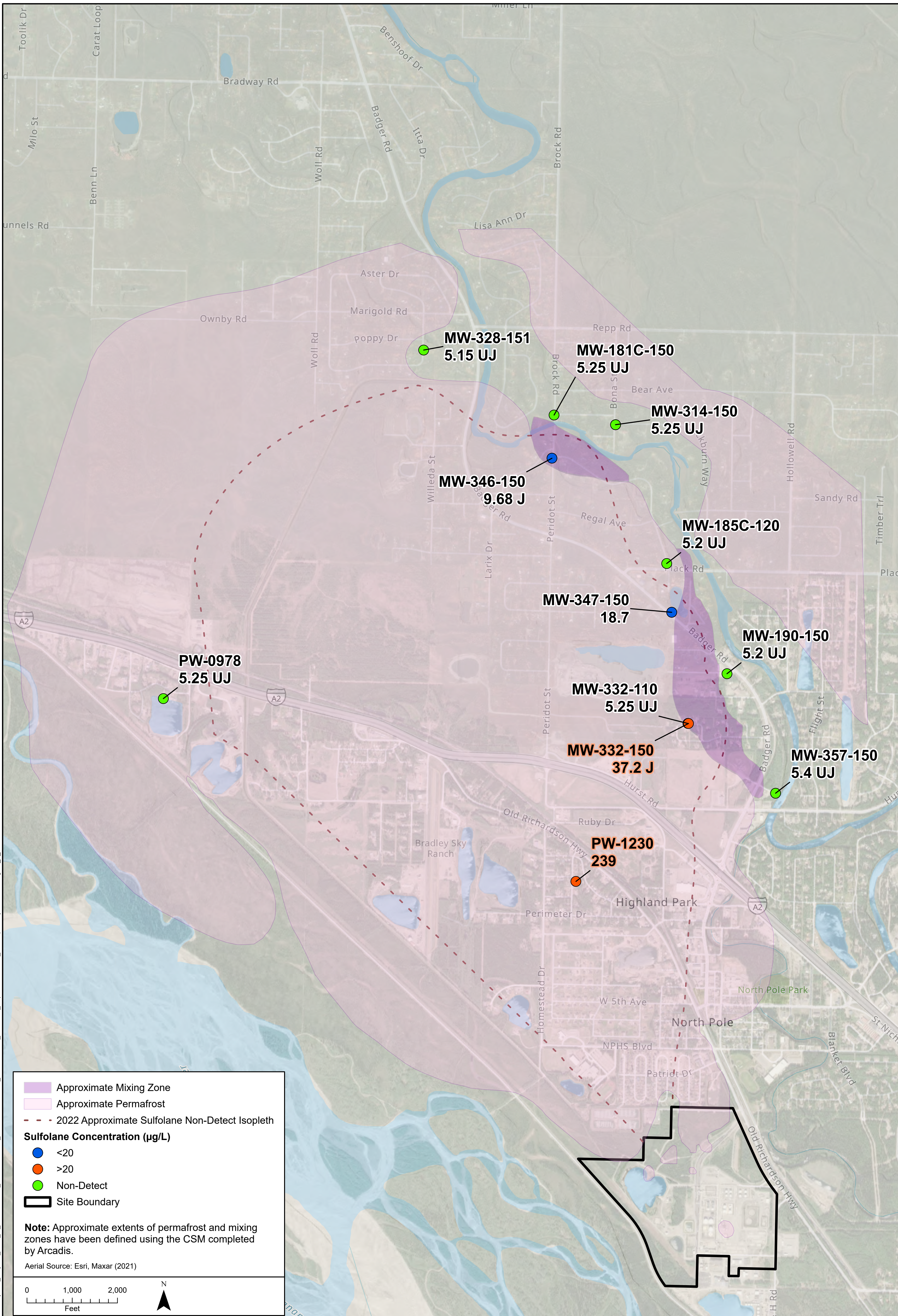

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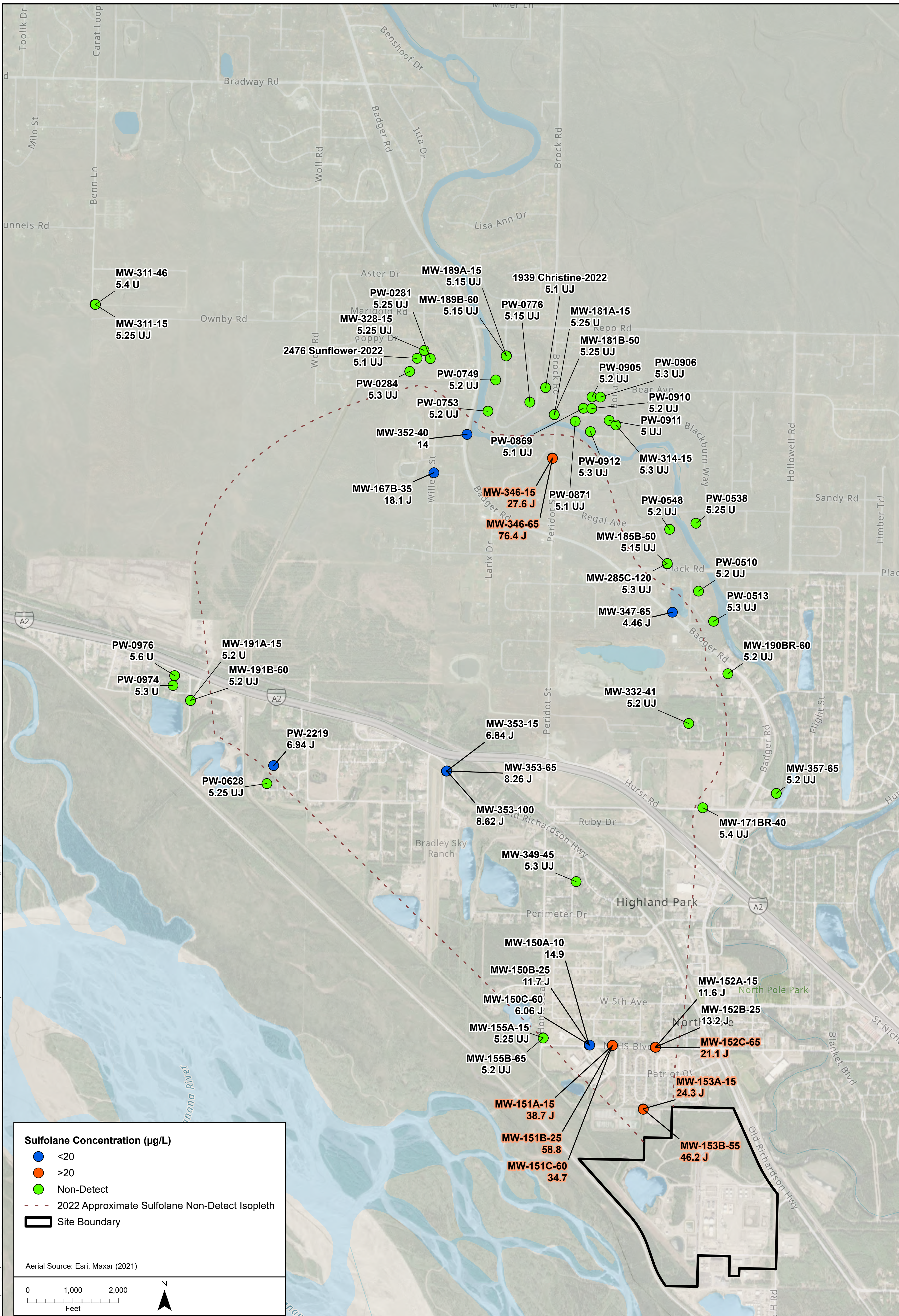
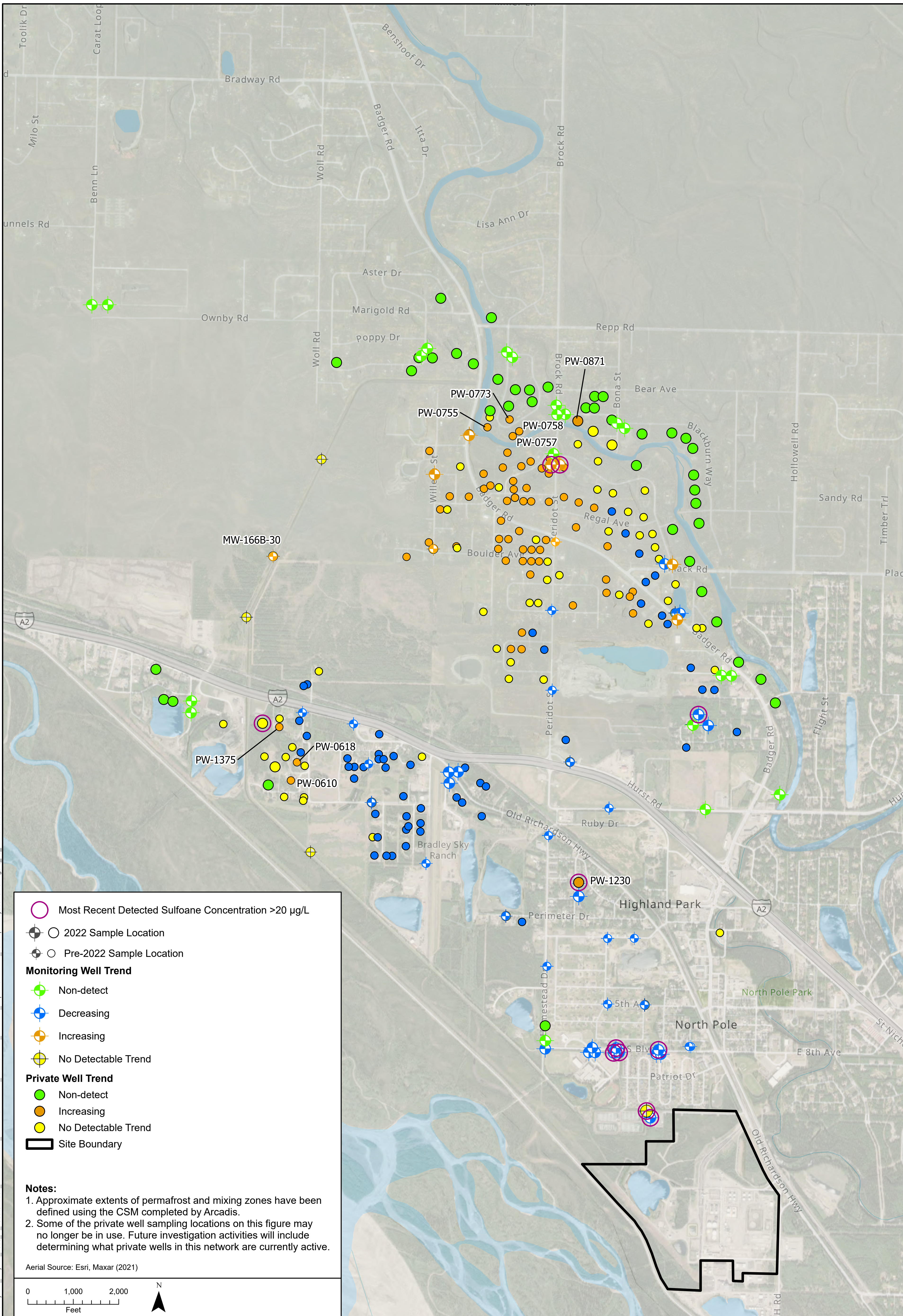
Figure 8.
Offsite Groundwater Sulfolane Concentrations
(Subpermafrost and Mixing Zone)



integral consulting inc.

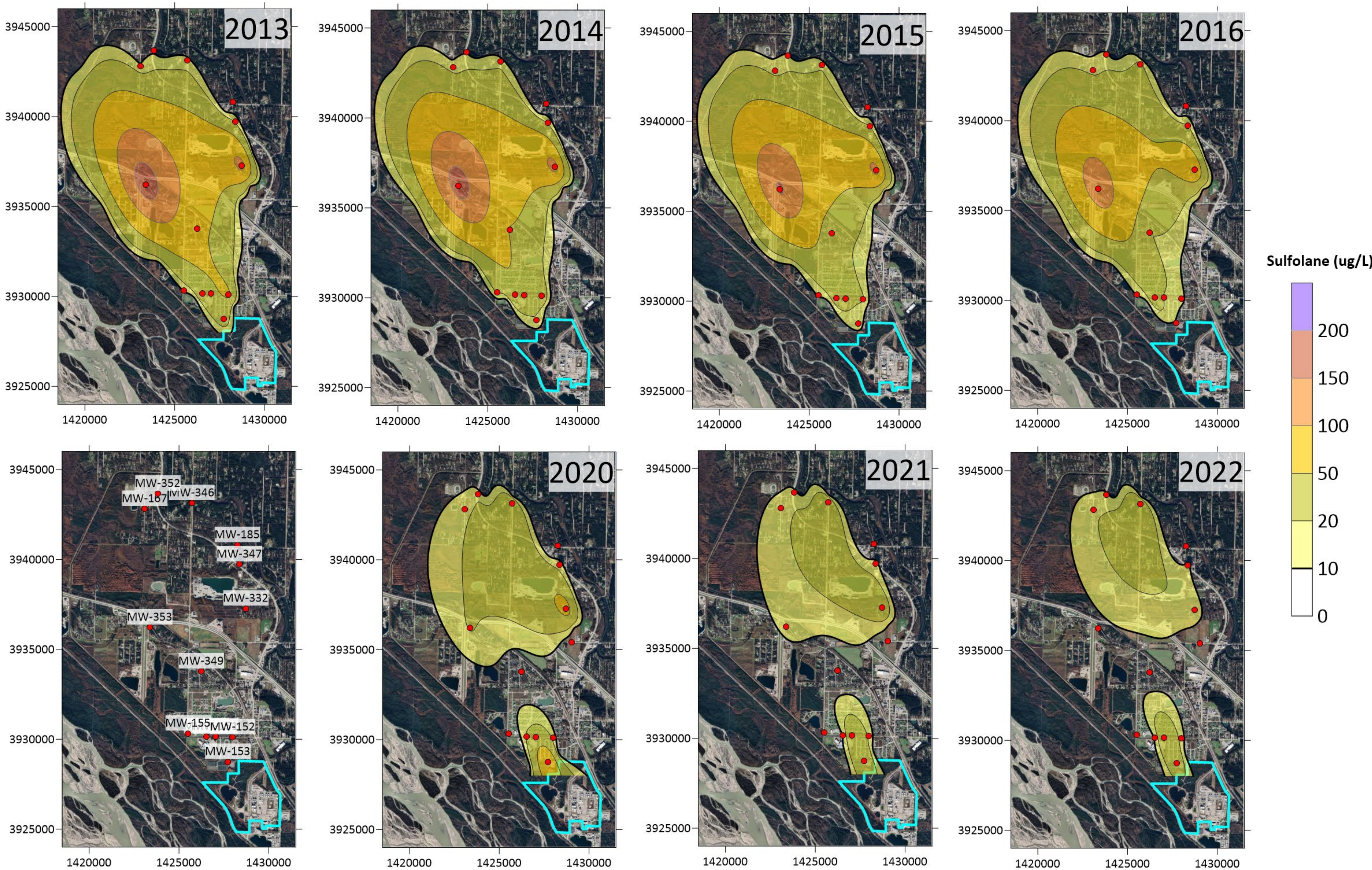
Figure 9.
Offsite Groundwater Sulfolane Concentrations (Suprapermafrost)



N:\GIS\Projects_Projects_2000_to_2999\CF2052_NorthPolePFAS_Williams\Production_MXDs\Annual_Sulfolane_Reports\Sulfolane_2022.aprx Layout Name: Figure_10_MK 7/11/2023 8:50 AM

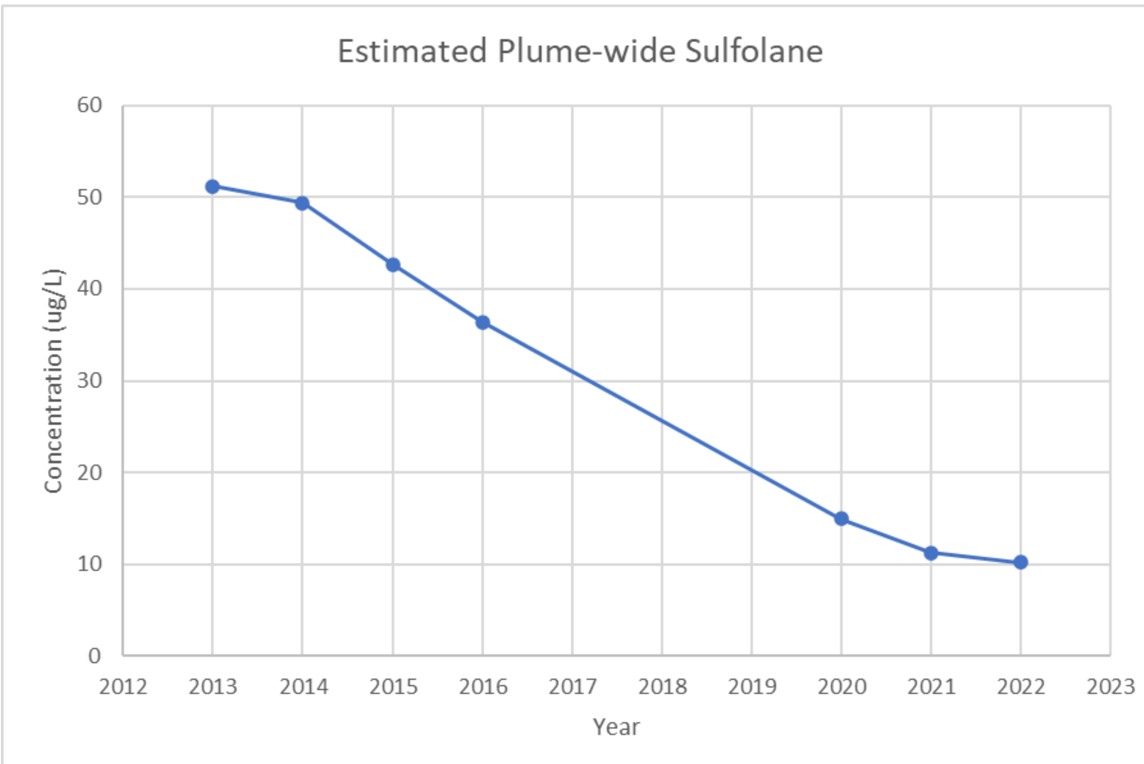
integral consulting inc.

Figure 10.
Mann Kendal Trend Analysis



integral

Figure 11.
Contour Maps of Sulfolane Concentrations
2013-2022



integral

Figure 12.
Plume-wide Average Sulfolane
Concentrations
2013-2022

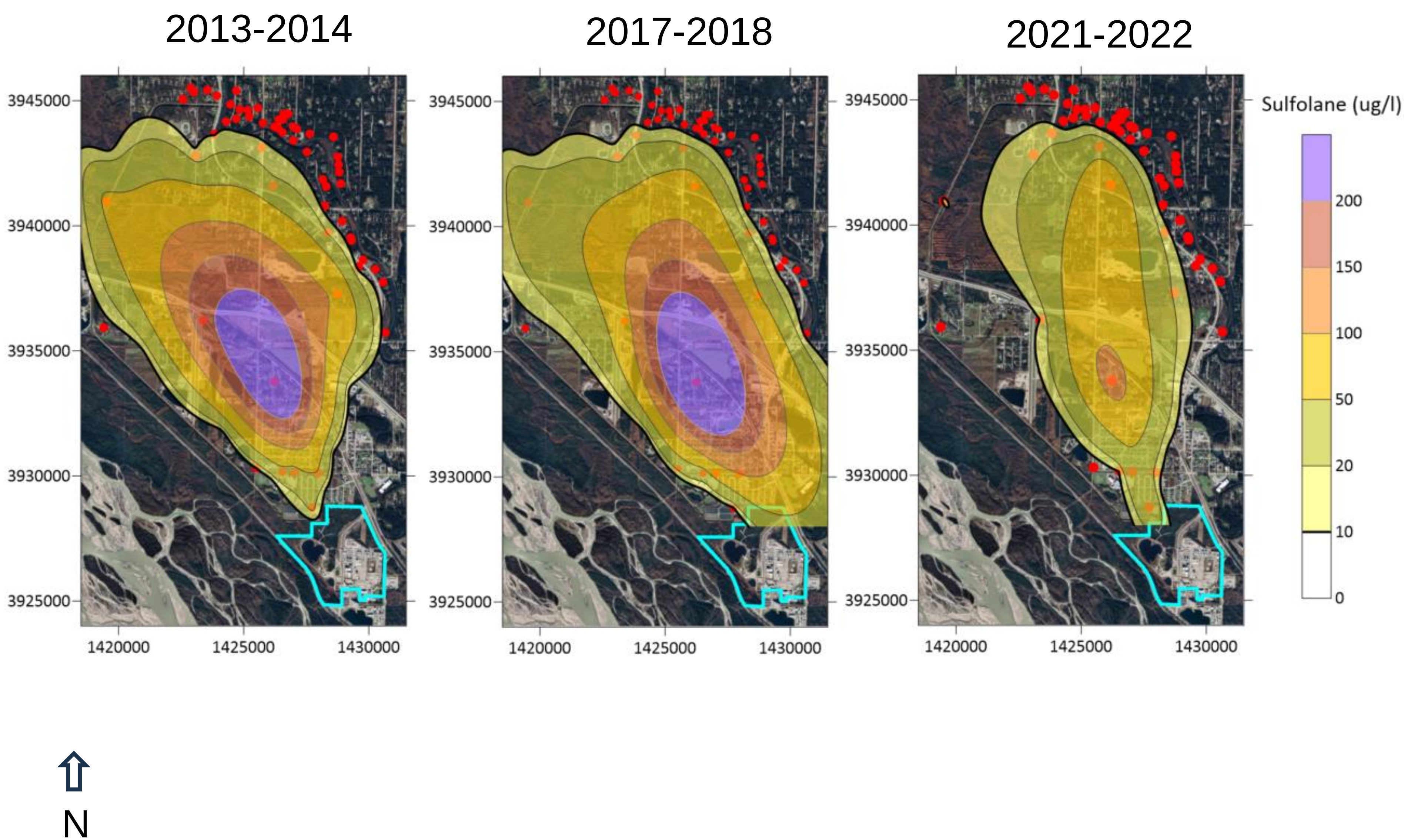


Figure 13.
Sulfolane Plume—Average Concentrations
2013 - 2022

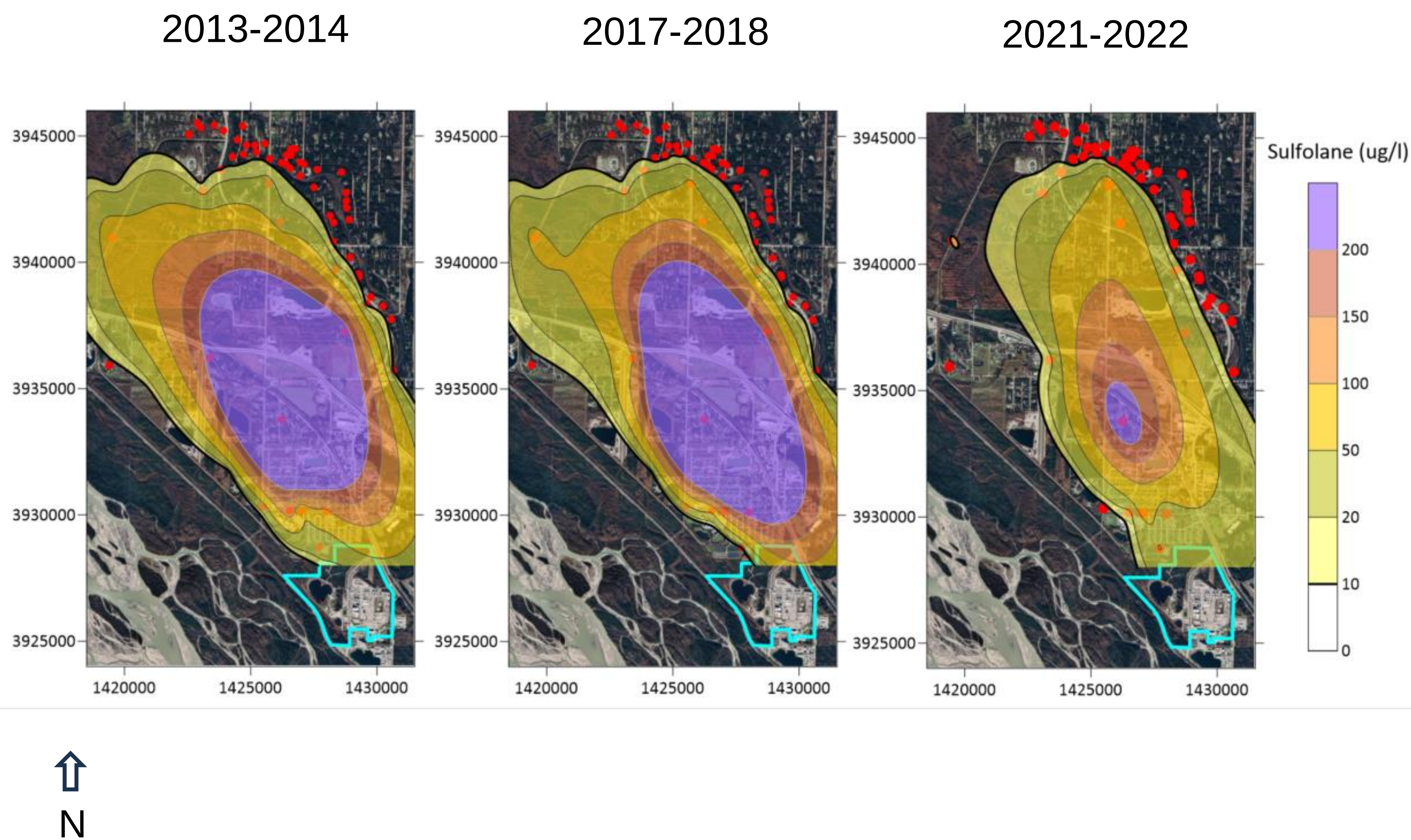


Figure 14.
Sulfolane Plume—Maximum Concentrations
2013 - 2022

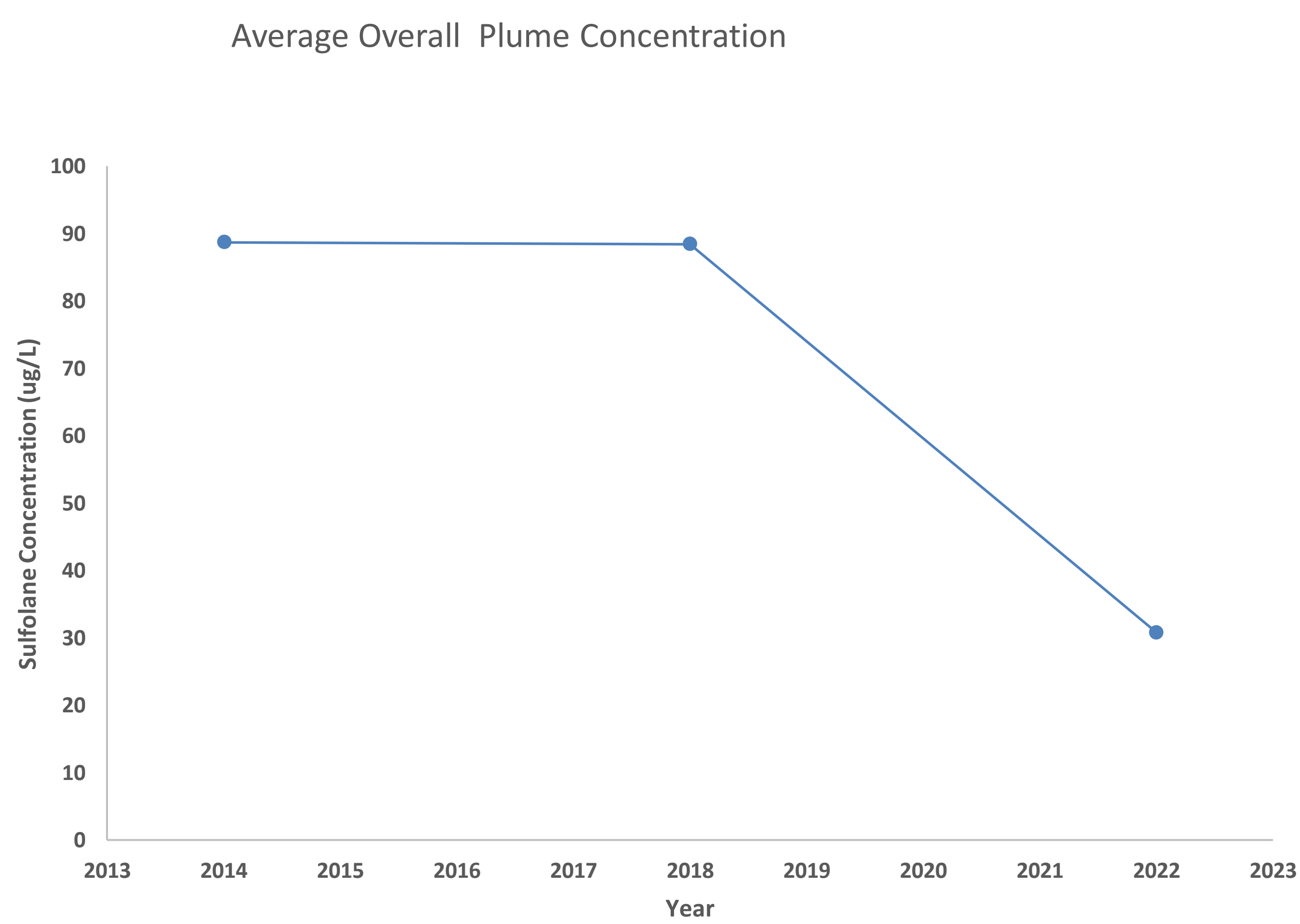


Figure 15.
Sulfolane Plume—Average Overall Concentrations
2014 - 2022

Tables

Table 1. Sample Locations

Monitoring Well	Sample Zone	Collection Date
MW-150A-10	WT	8/25/2022
MW-150B-25	10-55	8/24/2022
MW-150C-60	10-55	8/24/2022
MW-151A-15	WT	9/16/2022
MW-151B-25	10-55	8/24/2022
MW-151C-60	10-55	9/16/2022
MW-152A-15	WT	8/10/2022
MW-152B-25	10-55	8/10/2022
MW-152C-65	10-55	8/10/2022
MW-153A-15	WT	8/11/2022
MW-153B-55	10-55	8/11/2022
MW-155A-15	WT	8/10/2022
MW-155B-65	10-55	8/10/2022
MW-166B-30	10-55	Decommissioned
MW-167B-35	10-55	8/5/2022
MW-171BR-40	10-55	8/4/2022
MW-181A-15	WT	8/5/2022
MW-181B-50	10-55	8/8/2022
MW-181C-150	90-150	8/8/2022
MW-185B-50	10-55	8/3/2022
MW-185C-120	90-150	8/3/2022
MW-189A-15	WT	8/5/2022
MW-189B-60	10-55	8/5/2022
MW-190BR-60	10-55	8/5/2022
MW-190-150	90-150	8/5/2022
MW-191A-15	WT	8/9/2022
MW-191B-60	10-55	8/9/2022
MW-311-15	WT	8/8/2022
MW-311-46	10-55	8/8/2022
MW-314-15	WT	8/5/2022
MW-314-150	90-150	8/5/2022
MW-328-15	WT	8/8/2022
MW-328-151	90-150	8/8/2022
MW-332-41	10-55	8/4/2022
MW-332-110	90-150	8/4/2022
MW-332-150	90-150	8/4/2022
MW-346-15	WT	8/25/2022
MW-346-65	10-55	8/25/2022
MW-346-150	90-150	8/25/2022
MW-347-65	10-55	9/16/2022
MW-347-150	90-150	9/16/2022
MW-349-45	10-55	8/11/2022
MW-352-40	10-55	9/16/2022
MW-353-15	WT	8/9/2022
MW-353-65	10-55	8/9/2022
MW-353-100	55-90	8/9/2022
MW-357-65	10-55	8/3/2022
MW-357-150	90-150	8/4/2022

Notes:
WT = water table

Table 1. Sample Locations

Private Well	Sample ID	Collection Date
PW-0369	2961 Airway	8/30/2022
PW-0242	2519 Aster	8/24/2022
PW-0594	2581 Badger	8/17/2022
PW-0587	2599 Badger	8/24/2022
PW-0372	3078 Badger	8/17/2022
PW-0370	3114 Badger	8/16/2022
PW-0905	2705 Bear	8/23/2022
PW-0906	2715 Bear	8/23/2022
PW-0914	1755 Blackburn	8/23/2022
PW-2237	1803 Blackburn	8/23/2022
PW-0532	1831 Blackburn	8/23/2022
PW-0533	1851 Blackburn	8/23/2022
PW-0535	1891 Blackburn	8/22/2022
PW-0536	1911 Blackburn	8/23/2022
PW-0537	1921 Blackburn	8/23/2022
PW-0538	1959 Blackburn	8/25/2022
PW-0914	1853 Bona	9/9/2022
PW-0531	1775 Christine	8/18/2022
PW-0770	1780 Christine	8/19/2022
PW-0772	1800 Christine	8/25/2022
PW-0753	1811 Christine	8/19/2022
PW-0776	1910 Christine	8/19/2022
PW-0777	1930 Christine	8/19/2022
PW-0762	1939 Christine	8/18/2022
PW-0978	2131 Edward	8/30/2022
PW-0979	2141 Edward	9/7/2022
PW-1333	2770 Garnet	9/1/2022
PW-0548	2870 Garnet	9/1/2022
PW-0549	2910 Garnet	9/1/2022
PW-1935	2675 Homestead	9/9/2022
PW-0513	2098 Jackson	9/6/2022
PW-2219	2373 Keeney	9/7/2022
PW-0628	2379 Keeney	9/1/2022
PW-0510	2048 Kimi	9/7/2022
PW-0871	2691 Natalie	8/24/2022
PW-0869	2698 Natalie	8/24/2022
PW-0910	2710 Natalie	8/25/2022
PW-0911	2729 Natalie	8/30/2022
PW-1184	2560 Repp	8/22/2022
PW-0977	2289 Richardson	9/1/2022
PW-0623	2365 Richardson	8/30/2022
PW-0912	2710 Samantha	8/24/2022
PW-0270	2354 Sunflower	8/16/2022
PW-0284	2465 Sunflower	8/16/2022
PW-0277	2476 Sunflower	8/18/2022
PW-0281	2487 Sunflower	8/18/2022
PW-1230	2440 Tanana	9/27/2022
PW-0974	2136 Edward	12/15/2022
PW-0790	2301 Bradway	12/28/2022
PW-0976	2313 Richardson Hwy	12/15/2022
PW-1930	2875 Cochelle	11/14/2022

Table 2. Monitoring Well Analytical Results

Sample Location	Sample ID	Zone	Collection Date	Sulfolane Result (mg/L)		Sulfolane Result (µg/L)	
MW-150A-10	MW-150A-10	WT	8/25/2022	0.0149		14.9	
	MW-250A-10[a]	WT	8/25/2022	0.0155		15.5	
MW-150B-25	MW-150B-25	10-55	8/24/2022	0.0117	J	11.7	J
MW-150C-60	MW-150C-60	10-55	8/24/2022	0.00606	J	6.06	J
MW-151A-15	MW-151A-15	WT	9/19/2022	0.0372		37.2	
MW-151B-25	MW-151B-25	10-55	8/24/2022	0.0588		58.8	
MW-151C-60	MW-151C-60	10-55	9/19/2022	0.0347		34.7	
MW-152A-15	MW-152A-15	WT	8/10/2022	0.0116	J	11.6	J
MW-152B-25	MW-152B-25	10-55	8/10/2022	0.0132	J	13.2	J
MW-152C-65	MW-152C-65	10-55	8/10/2022	0.0211	J	21.1	J
MW-153A-15	MW-153A-15	WT	8/11/2022	0.0243	J	24.3	J
MW-153B-55	MW-153B-55	10-55	8/11/2022	0.0462		46.2	
MW-155A-15	MW-155A-15	WT	8/10/2022	0.00525	UJ	5.25	UJ
MW-155B-65	MW-155B-65	10-55	8/10/2022	0.0052	UJ	5.2	UJ
MW-167B-35	MW-167B-35	10-55	8/5/2022	0.0181		18.1	
MW-171BR-40	MW-171BR-40	10-55	8/4/2022	0.0054	UJ	5.4	UJ
MW-181A-15	MW-181A-15	WT	8/5/2022	0.00525	U	5.25	U
MW-181B-50	MW-181B-50	10-55	8/8/2022	0.00525	UJ	5.25	UJ
MW-181C-150	MW-181C-150	90-150	8/8/2022	0.00525	UJ	5.25	UJ
MW-185B-50	MW-185B-50	10-55	8/3/2022	0.00515	UJ	5.2	UJ
MW-185C-120	MW-185C-120	90-150	8/3/2022	0.0052	UJ	5.2	UJ
	MW-285C-120	90-150	8/3/2022	0.0053	UJ	5.3	UJ
MW-189A-15	MW-189A-15	WT	8/5/2022	0.00515	UJ	5.15	UJ
MW-189B-60	MW-189B-60	10-55	8/5/2022	0.00515	UJ	5.15	UJ
MW-190BR-60	MW-190BR-60	10-55	8/5/2022	0.0052	UJ	5.2	UJ
MW-190-150	MW-190-150	90-150	8/5/2022	0.0052	UJ	5.2	UJ
MW-191A-15	MW-191A-15	WT	8/9/2022	0.0052	U	5.2	U
MW-191B-60	MW-191B-60	10-55	8/9/2022	0.0052	UJ	5.2	UJ
MW-311-15	MW-311-15	WT	8/8/2022	0.00525	UJ	5.25	UJ
MW-311-46	MW-311-46	10-55	8/8/2022	0.0054	U	5.4	U
MW-314-15	MW-314-15	WT	8/5/2022	0.0053	UJ	5.3	UJ
MW-314-150	MW-314-150	90-150	8/5/2022	0.00515	UJ	5.15	UJ
	MW-414-150[a]	90-150	8/5/2022	0.00525	U	5.25	U
MW-328-15	MW-328-15	WT	8/8/2022	0.00525	UJ	5.25	UJ
MW-328-151	MW-328-151	90-150	8/8/2022	0.00515	UJ	5.15	UJ
MW-332-41	MW-332-41	10-55	8/4/2022	0.0052	UJ	5.2	UJ
MW-332-110	MW-332-110	90-150	8/4/2022	0.00525	UJ	5.25	UJ
MW-332-150	MW-332-150	90-150	8/4/2022	0.0372	J	37.2	J
MW-346-15	MW-346-15	WT	8/25/2022	0.0276		27.6	
MW-346-65	MW-346-65	10-55	8/25/2022	0.0764		76.4	
MW-346-150	MW-346-150	90-150	8/25/2022	0.00968	J	9.68	J
MW-347-65	MW-347-65	10-55	9/19/2022	0.00394	J	3.94	J
MW-347-150	MW-347-150	90-150	9/19/2022	0.0187		18.7	
	MW-447-150[a]	90-150	9/19/2022	0.0152		15.2	
MW-349-45	MW-349-45	10-55	8/11/2022	0.0053	UJ	5.3	UJ
	MW-449-45[a]	10-55	8/11/2022	0.00525	U	5.25	U

Table 2. Monitoring Well Analytical Results

Sample Location	Sample ID	Zone	Collection Date	Sulfolane Result (mg/L)		Sulfolane Result (µg/L)	
MW-352-40	MW-352-40	10-55	9/19/2022	0.014		14	
MW-353-15	MW-353-15	WT	8/9/2022	0.00684	*J*	6.84	*J*
MW-353-65	MW-353-65	10-55	8/9/2022	0.00826	*J*	8.26	*J*
MW-353-100	MW-353-100	55-90	8/9/2022	0.00862	*J*	8.62	*J*
MW-357-65	MW-357-65	10-55	8/3/2022	0.0052	*UJ*	5.2	*UJ*
MW-357-150	MW-357-150	90-150	8/4/2022	0.0054	*UJ*	5.4	*UJ*

Notes:

-- = not available

WT = water table

[a] field duplicate sample

Data Qualifiers:

J = Estimated concentration detected below the laboratory limit of quantitation (LOQ). Flag applied by laboratory.

U = Not detected; LOQ listed; code used by SGS.

Table 3. Private Well Analytical Results

PW ID	Sample ID	Collection Date	Sulfolane Result (mg/L)	Sulfolane Result (µg/L)
PW-0369	2961 Airway	8/30/2022	0.0051 *UJ*	5.1 *UJ*
PW-0242	2519 Aster	8/24/2022	0.00515 *UJ*	5.15 *UJ*
PW-0594	2581 Badger	8/17/2022	0.0051 *UJ*	5.1 *UJ*
PW-0587	2599 Badger	8/24/2022	0.0053 *UJ*	5.3 *UJ*
PW-0372	3078 Badger	8/17/2022	0.00505 *UJ*	5.05 *UJ*
PW-0370	3114 Badger	8/16/2022	0.0053 *UJ*	5.3 *UJ*
	9999 Badger[a]	8/16/2022	0.00515 *U*	5.15 *U*
PW-0905	2705 Bear	8/23/2022	0.0052 *UJ*	5.2 *UJ*
PW-0906	2715 Bear	8/23/2022	0.0053 *UJ*	5.3 *UJ*
PW-0531	1755 Blackburn	8/23/2022	0.0052 *UJ*	5.2 *UJ*
PW-2237	1803 Blackburn	8/23/2022	0.0051 *UJ*	5.1 *UJ*
	9999 Blackburn[a]	8/23/2022	0.00525 *UJ*	5.25 *UJ*
PW-0532	1831 Blackburn	8/23/2022	0.0051 *UJ*	5.1 *UJ*
PW-0533	1851 Blackburn	8/23/2022	0.0051 *UJ*	5.1 *UJ*
PW-0535	1891 Blackburn	8/22/2022	0.00515 *UJ*	5.15 *UJ*
PW-0536	1911 Blackburn	8/23/2022	0.00525 *UJ*	5.25 *UJ*
PW-0537	1921 Blackburn	8/23/2022	0.0052 *UJ*	5.2 *UJ*
PW-0538	1959 Blackburn	8/25/2022	0.00525 *U*	5.25 *U*
PW-0914	1853 Bona	9/9/2022	0.0051 *UJ*	5.1 *UJ*
PW-0749	1775 Christine	8/18/2022	0.0052 *UJ*	5.2 *UJ*
PW-0770	1780 Christine	8/19/2022	0.0052 *UJ*	5.2 *UJ*
PW-0772	1800 Christine	8/25/2022	0.0052 *UJ*	5.2 *UJ*
PW-0753	1811 Christine	8/19/2022	0.00515 *UJ*	5.15 *UJ*
	9999 Christine[a]	8/19/2022	0.0052 *U*	5.2 *U*
PW-0776	1910 Christine	8/19/2022	0.00515 *UJ*	5.15 *UJ*
PW-0777	1930 Christine	8/19/2022	0.00515 *UJ*	5.15 *UJ*
PW-0762	1939 Christine	8/18/2022	0.0051 *UJ*	5.1 *UJ*
PW-0978	2131 Edward	8/30/2022	0.00525 *UJ*	5.25 *UJ*
PW-0979	2141 Edward	9/7/2022	0.00555 *U*	5.55 *U*
PW-1333	2770 Garnet	9/1/2022	0.0052 *UJ*	5.2 *UJ*
PW-0548	2870 Garnet	9/1/2022	0.0052 *UJ*	5.2 *UJ*
PW-0549	2910 Garnet	9/1/2022	0.0054 *UJ*	5.4 *UJ*
PW-1935	2675 Homestead	9/9/2022	0.0052 *UJ*	5.2 *UJ*
PW-0513	2098 Jackson	9/6/2022	0.0053 *UJ*	5.3 *UJ*
PW-2219	2373 Keeney	9/7/2022	0.00694 *J*	6.94 *J*
	3373 Keeney	9/7/2022	0.00551 *J*	5.51 *J*
PW-0628	2379 Keeney	9/1/2022	0.00525 *UJ*	5.25 *UJ*
PW-0510	2048- Kimi	9/7/2022	0.0052 *UJ*	5.2 *UJ*
PW-0871	2691 Natalie	8/24/2022	0.0051 *UJ*	5.1 *UJ*

PW-0869	2698 Natalie	8/24/2022	0.0051	*UJ*	5.1	*UJ*
PW-0910	2710 Natalie	8/25/2022	0.0052	*UJ*	5.2	*UJ*
PW-0911	2729 Natalie	8/30/2022	0.005	*UJ*	5	*UJ*
PW-1184	2560 Repp	8/22/2022	0.0052	*UJ*	5.2	*UJ*
PW-0977	2289 Richardson	9/1/2022	0.0052	*UJ*	5.2	*UJ*
	3289 Richardson	9/1/2022	0.0052	*UJ*	5.2	*UJ*
PW-0623	2365 Richardson	8/30/2022	0.0235		23.5	
PW-0912	2710 Samantha	8/24/2022	0.0053	*UJ*	5.3	*UJ*
PW-0270	2354 Sunflower	8/16/2022	0.00515	*UJ*	5.15	*UJ*
PW-0284	2465 Sunflower	8/16/2022	0.0053	*UJ*	5.3	*UJ*
PW-0277	2476 Sunflower	8/18/2022	0.0051	*UJ*	5.1	*UJ*
PW-0281	2487 Sunflower	8/18/2022	0.00525	*UJ*	5.25	*UJ*
PW-1230	2440 Tanana	9/27/2022	0.267		267	
	9990 Tanana[a]	9/27/2022	0.239		239	
PW-0974	2136 Edward	12/15/2022	0.0053	*U*	5.3	*U*
PW-0790	2301 Bradway	12/28/2022	0.0052	*U*	5.2	*U*
PW-0976	2313 Richardson Hwy	12/15/2022	0.0056	*U*	5.6	*U*
PW-1930	2875 Cochelle	11/14/2022	0.00545	*U*	5.45	*U*

Notes:

[a] Sample is a duplicate collected for quality assurance purposes.

Data Qualifiers:

J = Estimated concentration detected below the laboratory limit of quantitation (LOQ). Flag applied by
U = Not detected; LOQ listed; code used by SGS.

UJ = Estimated concentration detected below the detection limit. Flag applied by laboratory.