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3 January 2023
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10471 20th Street, Ste 347
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Ginna Quesada
Alaska Department of Environmental Conservation
610 University Avenue
Fairbanks, AK 99709

Re: Final Groundwater Remedy Study for Port Heiden RRS, AK
Contract: FA8903-16-D-0041 Task Order: FA8903-20-F-1103
CDRLs: A001a, A005

Dear Mr. Johnston and Ms. Quesada:

BEM Systems, Inc. (BEM) is pleased to submit the Final Groundwater Remedy Study for Sites OT001 & WP002 at Port Heiden RRS, Alaska (CDRL: A001d and A005). This report was prepared under contract FA8903-16-D-0041, Task Order FA8903-20-F-1103. Edits based on draft deliverable comments and input have been incorporated in Sections 3.3 and 4.0 of the report, as appropriate. If you have any questions or require additional information, please contact me directly at 575.635.6432 or via email at cwatts@bemsys.com.

Sincerely,

BEM Systems, Inc.

Cheyenne Watts

Cheyenne Watts
Project Manager, Sr Environmental Scientist

/attachment
cc: Tracy Kissler (AFCEC COR)
Chris Pisarri (BEM Program Manager)

Sites OT001 & WP002
Groundwater Remedy Study

FINAL

Port Heiden Radio Relay Station

AFCEC Contract: FA8903-16-D-0041
Task Order: FA8903-20-F-1103

January 2023

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FINAL

Sites OT001 & WP002 Groundwater Remedy Study
Port Heiden Radio Relay Station, Alaska

January 2023

Prepared for:

Prepared by:

Prepared under:

AFCEC Contract: FA8903-16-D-0041

Task Order: FA8903-20-F-1103

Site Names: OT001-Former Composite Building and WP002-Black Lagoon

ADEC File ID(s): 2637.38.002.05 and 2637.38.002.08

CS Hazard ID(s): 185 and 186

Qualified professional responsible for data reporting:

Cheyenne Watts, CES
BEM Systems, Inc.
Senior Environmental Scientist, Project Manager

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LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
AFCEC	Air Force Civil Engineer Center
ARAR	Applicable or Relevant and Appropriate Requirement
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
COC	contaminant of concern
CSM	Conceptual Site Model
CUL	cleanup level
CY	cubic yards
°F	degrees Fahrenheit
DCE	dichloroethylene
DNAPL	dense nonaqueous-phase liquid
DRO	diesel range organics
EPA	U.S. Environmental Protection Agency
ERP	Environmental Restoration Program
FS	Feasibility Study
FYR	Five Year Review
GAC	Granular Activated Carbon
LUC	Land Use Control
LUCMP	Land Use Control Management Plan
LTM	Long Term Monitoring
MCLs	maximum contaminant levels
M-K	Mann-Kendall
µg/L	micrograms per liter

mg/kg	milligrams per kilogram
MNA	Monitored Natural Attenuation
MSL	mean sea level
NVPH	Native Village of Port Heiden
PCB	polychlorinated biphenyls
PCE	perchloroethylene
percent	%
POL	petroleum, oil and lubricants
RA	Remedial Action
RAO	Remedial Action Objectives
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RRS	Radio Relay Station
RRO	residual range organics
SVOCs	semi-volatile organic compounds
TAH	Total Aromatic Hydrocarbons
TAqH	Total Aqueous Hydrocarbons
TCE	trichloroethylene
TPH	total petroleum hydrocarbons
TSCA	Toxic Substances Control Act
USACE	United States Army Corps of Engineers
USAF	United States Air Force
USGS	US Geological Survey
USTs	underground storage tanks
VOCs	volatile organic compounds

E1 EXECUTIVE SUMMARY

This Groundwater Remedy Study was prepared for the United States Air Force (USAF) under contract FA8903-16-D-0041 and task order FA8903-20-F-1103. The purpose of this study was to evaluate existing groundwater data to determine if the current selected remedy of Long Term Monitoring (LTM) with annual groundwater monitoring, Monitored Natural Attenuation (MNA) and Land Use Controls (LUCs) remains appropriate, or if a new revised remedy is necessary to achieve cleanup level (CUL) goals by 2035, as predicted in the 2009 Record of Decision (ROD) for groundwater at Port Heiden Radio Relay Station (RRS), Alaska Sites OT001 and WP002.

The primary source of contamination at Site OT001 (Former Composite Building) was historic installation operational and maintenance activities in and around the former concrete composite structure, including vehicle maintenance and fuel storage in both underground and aboveground tanks which experienced historic leaks or spills. The OT001 garage floor drain was also found to act as a conduit for disposal of waste to the adjacent drain outfall at the Site WP002 (Black Lagoon Outfall). As a result of these historic activities, previous investigations identified polychlorinated biphenyls (PCBs), petroleum, oil and lubricants (POLs), and chlorinated solvents in soil and groundwater around the perimeter of the former concrete foundation of the Former Composite Building. POLs and chlorinated solvents were also identified at the adjacent septic outfall area. Much of the contaminated soil at OT001 and WP002 has been excavated and either shipped offsite for disposal or landfarmed during implementation of the previous remedial efforts conducted from 1981 to 2020 (USAF; 1996, 2021a). Approximately 50,000 tons of PCB and/or POL-contaminated soil has been remediated to date. An estimated 450 tons of PCB and/or POL-contaminated soil above the applicable 18 Alaska Administrative Code (AAC) 75 soil CULs for PCBs and/or POLs remains in place at the RRS, with the vast majority (approximately 80 percent) remaining at the North Landfill Site LF007, outside of the Sites OT001 and WP002 zone of influence.

Groundwater monitoring conducted at Port Heiden from 2013 through 2020 was performed according to the 2009 ROD. The intent of the groundwater monitoring program was to evaluate for the presence of benzene, trichloroethylene (TCE) and related daughter products (cis and trans-1,2-dichloroethylene [DCE], and vinyl chloride), perchloroethylene [PCE] as well as the additional petroleum hydrocarbon components (diesel range organics [DRO] and residual range organics [RRO]) to monitor the trends of the dissolved POL and chlorinated solvent concentrations over time. Analytical results for this groundwater remedy analysis were compared to 2009 ROD CULs, which for benzene and TCE were defined as 5 micrograms per liter (µg/L), as well as the respective 18 AAC 75 Table C Groundwater CULs for cis- and trans-1,2-DCE, vinyl chloride, PCE, DRO, and RRO.

TCE & Related Daughter Products: The results of the groundwater monitoring program have indicated that TCE, PCE and/or related daughter products cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride have been present in most of the monitoring wells (15 of 17 evaluated) at Sites WP002 and OT001. Historic exceedances of applicable 2009 ROD-based or Table C groundwater CULs are limited to that of TCE in 5 wells and PCE in 3 wells, while concentrations of cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride have remained below their respective ADEC Table C CULs for the duration of the groundwater monitoring program. The trend analysis associated with this groundwater remedy study conclude that TCE concentrations for 4 of the 5 exceeding monitoring wells will remain above the 5 µg/L cleanup goal by 2035.

Benzene: Benzene has been detected above the laboratory detection limit in less than half of the monitoring wells (7 of 17 evaluated) included in the groundwater monitoring program for Sites WP002 and OT001. There have been no exceedances of benzene above the applicable 2009 ROD-based groundwater CUL. The maximum reported concentration of benzene in groundwater was collected from WP002 monitoring well BLO-MW-01 in September 2014, with a result of 1.4 µg/L which is well below the 2009 ROD CUL of 5 µg/L and demonstrates a slight decreasing concentration trend over time. The ROD cleanup goal of 5 µg/L for benzene has been achieved, as evidenced by 5 consecutive groundwater sampling events reporting dissolved concentrations below the 2009 ROD CUL.

DRO and RRO: While the presence of dissolved DRO and RRO above the laboratory method detection limit was reported for approximately half of the monitoring wells (8 of 17 evaluated) in the monitoring well network for Sites WP002 and OT001, exceedances of their respective Table C groundwater CULs are limited to 1 well for both DRO and RRO. The maximum reported concentration of DRO is associated with WP002 monitoring well BLO-MW-01 obtained in September 2014, with a reported analytical result of 1,600,000 µg/L, which was well above the Table C CUL of 1,500 µg/L. Since the September 2014 sampling event, DRO concentrations at this monitoring well have decreased drastically, ranging between 15,000 µg/L and 63,000 µg/L. Based upon the most-recent sampling event (September 2020) included in this groundwater analysis, DRO concentrations at BLO-MW-01 remain above the Table C CUL but with a sharply decreasing trend that is estimated to reduce below the Table C CUL by 2035. The DRO trend at OT001 well DSA-MW-02 (downgradient from WP002 well BLO-MW-01) also stands out. Although the dissolved DRO concentration for this monitoring well remain below the Table C CUL to date, its concentration has been doubling each year, and is anticipated to exceed the Table C CUL as soon as 2022 if that increasing trend continues in the future.

The maximum reported concentration of RRO is also associated with WP002 monitoring well BLO-MW-01 for the September 2014 monitoring event, with a result of 150,000 µg/L, which is above the Table C CUL of 1,100 µg/L. Since the September 2014 monitoring event, the RRO concentration at this monitoring well reduced to 4,200 µg/L as reported for the October 2016 monitoring event, which remained above the Table C CUL. RRO was not analyzed at well BLO-MW-01 between 2017 and 2020, therefore the actual dissolved concentration of RRO in groundwater for this portion of the site is undetermined. Assuming a similar degradation as DRO, it is estimated that the dissolved RRO concentration at monitoring well BLO-MW-01 would have achieved concentrations below the Table C CUL of 1,100 µg/L by 2020.

Based upon the evaluation of historic groundwater analytical trends, the current selected remedy for Sites OT001 and WP002 of LTM with annual groundwater monitoring, MNA and LUCs will not achieve the chemical-specific applicable or relevant and appropriate requirements (ARAR) for TCE as stated in the 2009 ROD. Due to this fact, a revised remedy is needed to assure protection of human health and the environment from the risks posed by solvent (TCE and PCE) and fuels (DRO and RRO) present in the dissolved phase within the groundwater at Sites OT001 and WP002.

The remedial alternatives proposed and evaluated through the 2006 Remedial Investigation/Feasibility Study (RI/FS) for response to contaminated groundwater at Sites OT001 and WP002, which were selected from for the remedy selection documented in the 2009 ROD included:

1) No Action
2) Long Term Monitoring with MNA
3) Long Term Monitoring with Enhanced Bioremediation
4) In-situ Treatment by Chemical Oxidation

Additional remedial alternatives considered as part of this Groundwater Remedy Study with the intent to eliminate, control, and reduce contamination and exposure risks include:

5) On-Site Treatment by Pump and Treat with Air Stripping and Granular Activated Carbon (GAC) Filtration
6) In-situ Treatment by Thermal Remediation Using Electrodes and/or Steam
7) In-situ Treatment and Containment by Permeable Reactive Barrier

While neither of the passive Alternatives 1 (No Action) or 2 (Long Term Monitoring with MNA) were able to meet the ARARs within the previously estimated 25-year period, it is estimated that Alternatives 3, 4, 5, 6, and 7 may be successful in reducing TCE concentrations to below the 5 µg/L CUL by 2035 if implemented by 2025 (within 10 years). Through the detailed evaluation of site conditions, it is shown that these potential alternatives are capable of achieving remedy goals by 2035 for Sites OT001 and WP002. Prior to implementation of a future revised remedy, the proposed remedy would be presented for public consideration in a Proposed Plan or Explanation of Significant Difference.

The success of each of the remedial alternatives for treatment of groundwater at Port Heiden RRS Sites OT001 and WP002 is dependent upon the continued remediation by excavation and offsite disposal or onsite landfarming of the contaminated soil source term by the USAF, as indicated in the latest Remedial Action Report (USAF, 2021a) which reported that soil excavation and characterization efforts would continue in 2022.

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1.0 INTRODUCTION

The purpose of this Groundwater Remedy Study is to evaluate dissolved groundwater contaminant trends to determine if the current selected remedy of Long Term Monitoring (LTM) with annual groundwater monitoring, Monitored Natural Attenuation (MNA) and Land Use Controls (LUCs) as defined in the 2009 Record of Decision (ROD) is appropriate, or if a new revised remedy will be necessary to achieve the 2009 ROD cleanup goals for Sites OT001 (Former Composite Building) and WP002 (Black Lagoon Outfall) at the former Port Heiden Radio Relay Station (RRS), Alaska. This Groundwater Remedy Study presents the relevant site information, environmental setting, previous findings, historic decision documentation and review; and conclusive evidence to determine the best response for contaminated groundwater at Port Heiden RRS Sites OT001 and WP002.

The Groundwater Remedy Study objectives include:

- Review the existing groundwater data available;
- Confirm if the current remedy of LTM with annual groundwater monitoring, MNA and LUCs as defined in the 2009 ROD is on track to achieve cleanup levels (CULs) for trichloroethylene (TCE) and benzene in groundwater within 25 years of implementation, by 2035;
- Evaluate the previously proposed and new potential groundwater remedial alternatives, and identify those alternatives that can eliminate, control and reduce contaminant concentrations and potential exposure risk.

Evaluations of existing groundwater monitoring data, and the proposed and potential groundwater remedies were performed in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process and U.S. Environmental Protection Agency (EPA) guidance under the United States Air Force (USAF) authority. This Groundwater Remedy Study is being prepared on behalf of the USAF's Environmental Restoration Program (ERP), which is designed to identify, quantify, and rectify impacted sites associated with past and current waste management practices at their installations. The ERP is consistent with the CERCLA process, which includes a Five Year Review (FYR) to provide an effective and standardized method for re-evaluating the remedy selection to confirm RAOs are met, and the selected remedy remains protective of human health and the environment.

This Groundwater Remedy Study incorporates information associated with the following previous investigations and evaluations conducted by the USAF:

- Final *Remedial Investigation/Feasibility Study (RI/FS) for Port Heiden RRS, AK,* dated April 2006. This RI/FS report provides a history of site contamination supported by a variety of soil and groundwater characterization techniques such as soil test pits, drilled soil cores, groundwater monitoring well installation and aquifer testing. Based on the information gained through investigation, a baseline risk assessment was also performed.
- Final *Record of Decision for Port Heiden RRS, AK*, dated February 2009. This ROD summarizes site background information and the remedy selected for Site OT001, WP002, and other Port Heiden RRS CERCLA sites. Contamination and appropriate action levels or CULs were also defined in the 2009 ROD.

- Final *Second CERCLA Five-Year Review for Sites OT001, WP002, SS004, LF007, and Four Unnumbered Sites and First Non-CERCLA Periodic Review Report for Site SS006 at the Former Port Heiden RRS, AK*, dated December 2019. This second FYR evaluates the ongoing protectiveness of the remedy for Sites OT001 and WP002. The second FYR concluded that the protectiveness evaluation would be deferred until future studies can be conducted to determine if the Black Lagoon Outfall (WP002) and Former Composite Building (OT001) remediation goals are achievable within the estimated time frame of 25 years (by 2035), and if ROD CULs remain applicable given remaining contaminant concentrations.
- Final *Technical Project Report for the 2019 Remedial Action Operations, Land Use/Institutional Control at Sites OT001, WP002, SS006, and LF007, Port Heiden RRS, AK*, dated April 2020. The 2019 Technical Project Report summarizes LTM results from the July 2019 groundwater monitoring event conducted at Sites OT001 and WP002.
- Final *Technical Project Report for the 2020 Remedial Action Operations, Land Use/Institutional Control at Sites LF007, SS004, SS006, OT001, and WP002, Port Heiden RRS, AK*, dated May 2021. The 2020 Technical Project Report summarizes LTM results from the September 2020 groundwater monitoring event conducted at Sites OT001 and WP002.

Appendix A includes the above-listed prior site documentation pertaining to the history of Port Heiden RRS Sites OT001 and WP002, its regulatory requirements and source of groundwater sample data and contaminant trends. **Appendix B** presents the groundwater monitoring well network construction and condition records, as well as historic sample results for Sites OT001 and WP002. The results of statistical and trend analysis performed for TCE and benzene in groundwater at Sites OT001 and WP002 for this Groundwater Remedy Study is summarized within **Appendix C**.

Based upon the outcome and recommendations of this Groundwater Remedy Study, either the implemented remedy of LTM with MNA and LUCs will continue as detailed in the 2009 ROD, or a revised remedy will be identified that is capable of achieving the site objectives. If a revised remedy is selected, would be included in a future Proposed Plan or Explanation of Significant Difference for public consideration, and later confirmed in a ROD amendment.

1.1 Port Heiden RRS History

The former Port Heiden RRS is located roughly 2.5 miles north of the village of Port Heiden, 1.5 miles east of Bristol Bay, and 400 miles southwest of Anchorage on the northern coast of the Alaska Peninsula (**Figure 1**). Access to the installation is by commercial air carrier to the nearby village airstrip or by barge via the barge landing area located approximately 2 miles toward the southwest. The RRS site was an active Distant Early Warning Line radar station from the mid-1950s through 1981. The RRS was constructed from 1955 to 1960 over a small portion of the former Fort Morrow Army Installation, which housed as many as 5,000 personnel during World War II over a footprint of several square miles. Historical activities supporting the former RRS included a former Marine Terminal Area with petroleum storage tanks, a pump house, and a fuel transfer pipeline referred to as the Former Pipeline Corridor, which extended from the terminal to the RRS. Groundwater and soil contaminated by historic spills of petroleum, oil, and lubricants (POL) has been documented during past assessments conducted at the Port Heiden RRS.

The Native Village of Port Heiden (NVPH) monitored groundwater and landfarmed POL contaminated soil from 2008 to 2012 under the "Remediate Former Port Heiden RRS" Cooperative Agreement administered by the United States Army Corps of Engineers (USACE) Alaska District (NVPH, 2012 and USAF, 2010b). Groundwater monitoring was performed by the USAF in 2013, 2014, 2016, 2017, 2019 and 2020 as part of the Port Heiden RRS annual LTM program (USAF; 2014c, 2015b, 2016d, 2019a, 2019b, 2020a, 2021b). **Figures 2** and **3** present the surrounding location and detailed layout of Sites OT001 and WP002, respectively. **Figure 4** identifies monitoring well locations, provides an overview of maximum TCE and benzene concentrations detected at each monitoring well between 2013 and 2020. It also distinguishes those wells that have had TCE concentrations reported in exceedance of the 2009 ROD-based CUL between 2013 and 2020. **Appendix B** offers a summary of both monitoring well network construction and location detail. Also included in this appendix is a summary of historic sample results for analytes of interest, including not only benzene and TCE, but also diesel range organics (DRO) and residual range organics (RRO), as well as known breakdown products of TCE and perchloroethylene (PCE) of (cis and trans-1,2-dichloroethylene [DCE] and vinyl chloride) from 2013 to 2020.

1.1.1 Site OT001 - Former Composite Building

Site OT001 is located near the center of the former Port Heiden RRS. The site consists of a gravel pad that contained the Former Composite Building along with four former underground storage tanks (USTs) around the building. The structure, built on reinforced concrete slabs, held offices, dormitories, storage space, a generator room and a garage. There are multiple contaminant sources from former underground and above ground storage tanks leaks, and contaminants released into a floor drain that discharged into adjacent soils identified as the Black Lagoon (WP002). Investigations conducted at OT001 identified polychlorinated biphenyls (PCBs) and chlorinated solvent-contaminated soil around the perimeter of the former concrete foundation of the Former Composite Building. Much of the PCB, petroleum, and asbestos contaminated soil was excavated and shipped offsite for disposal during the implementation of previous remedial efforts conducted from 1981 to 1990 (USAF, 1996). **Figure 2** provides a view of the site location and layout of Site OT001.

1.1.2 Site WP002 – Black Lagoon Outfall

Site WP002, also referred to as POL Waste Disposal Pit No. 1 at Former Composite Building in the 2019 *Land Use Control Management Plan* (LUCMP), is located adjacent and southwest of OT001 (USAF, 2019c). POL wastes were reported to have been disposed of in a floor drain that connected the auto shop in the OT001 Former Composite Building to the WP002 Black Lagoon (USAF, 1996). A review of the analytical results from soil samples collected in 1987 and 1988 reported total petroleum hydrocarbons, PCBs and semi-volatile organic compounds (SVOCs) in exceedance of 18 Alaska Administrative Code (AAC) 75 action levels. Based on these results, it was estimated that approximately 4,000 cubic yards (CYs) of soil impacted with total petroleum hydrocarbon concentrations above 5,000 parts per million were present at WP002 (USAF, 1996). Groundwater sampling conducted during a 2004 investigation identified two chlorinated solvent contaminant plumes within the underlying aquifer (USAF, 2006). **Figure 3** provides a view of the site location and layout of Site WP002.

1.2 Environmental Summary

The former Port Heiden RRS site encompasses approximately 172 acres (USAF, 1994) and is comprised of two separate study areas: the Former Facility Area (location of OT001 and WP002) and the Former Pipeline Corridor. The RRS is located in the northern portion of the Alaska Peninsula on the coastal plain of Bristol Bay. The installation is situated atop a low glacial moraine at an elevation of 95 feet above mean sea level (MSL), in Section 27, Township 37 South, Range 59 West, Seward Meridian. The following information summarizes the environmental setting for Sites OT001 and WP002 at Port Heiden RRS.

1.2.1 Demographics and Land Use

The nearby community of Port Heiden, AK located approximately two and a half miles south-southeast of the central portion of the former Port Heiden RRS installation, where Sites OT001 and WP002 are located, has a population of approximately 109 (2010-2020 City and Town Population Totals, 2018 US Census). Land use within the community is primarily residential, with some commercial property that includes a school, grocery store, health clinic and several lodging establishments (USAF, 2009). Although the village was not formally incorporated until 1972, historic records indicate the village was established as early as 1880, appearing in the 1880 US Census as the unincorporated Aleut village of Mashikh (US Geological Survey [USGS], 1959). Drinking water is supplied by several supply wells within the community that are screened from 40 to 110 feet, and are located no less than 2.5 miles upgradient from the RRS (US Department of Health and Human Services, 2019). Subsistence hunting and fishing activities are common in the area, and residents are known to harvest terrestrial plants and animals, as well as marine animals. While future land use of the RRS property is anticipated to remain industrial, future land use of the area surrounding the former Port Heiden RRS and within the community of Port Heiden is anticipated to remain primarily residential, in addition to the uninhabited wilderness that is expected to persist.

1.2.2 Climate

The former Port Heiden RRS lies in the Southwest Ecoregion and the Bristol Bay-Nushagak Lowlands ecological subregion of Alaska. The Bristol Bay-Nushagak Lowlands occupy 61,000 square kilometers of the Bristol Bay-Kodiak ecoregion (USAF, 2006). The cold, maritime climate of the Alaska Peninsula is characterized by high humidity, considerable cloudiness, frequent fog, and light rain or snow. Mean annual precipitation is 15.22 inches, with the majority falling between July and October. Average snowfall is 53.8 inches. Summer temperatures average 50.6 degrees Fahrenheit (°F) and winter temperatures average 22.8 °F (USAF, 2006). Long, warm, summer days and high available moisture promote high primary production in both terrestrial and aquatic communities.

1.2.3 Soil and Aquifer Characteristics

Port Heiden RRS is located on the north side of the Alaska Peninsula on the coastal plain of Bristol Bay. The Alaska Peninsula is primarily volcanic, composed of volcanoclastic sedimentary deposits and occasional plutons. Aniakchak Crater is located approximately 20 miles east Sites OT001 and WP002. The most recent ash-producing eruption from Aniakchak took place in 1931. Mount Veniaminof is located approximately 60 miles southwest of the site but is not known to produce large ash eruptions (USAF, 2006).

The major geologic deposits in the area consist of volcanic, glacial, lake, swamp, and marine terrace deposits (USAF, 2009). The former Port Heiden RRS was constructed on a glacial moraine at an elevation of approximately 95 feet above MSL. Near the former RRS, soils are composed of glacial till. Well drilling data from the nearby village of Port Heiden, and soil trenching data from the former Port Heiden RRS indicates that surface soil is comprised of sand and pumice deposits that extend approximately 15 to 25 feet below ground surface (bgs). These shallow porous layers are underlain by silty clay transitioning to silty gravel, which extend to depths of approximately 50 to 90 feet bgs. Beneath these strata is a layer of saturated coarse sand and gravel (USAF, 1996; USACE, 2006).

An unconfined aquifer with no immediately underlying aquitard was encountered at the former RRS (USAF, 2006). Groundwater near the center of the former RRS flows to the east and northeast away from the village of Port Heiden at an estimated linear velocity of 35 feet per year. Groundwater gradient in the area is approximately 0.004 feet per foot. Groundwater beneath the site occurs in unconsolidated glacial and volcanic sediments consisting of the silty clay to silty gravel transitional layer described above. The depth to groundwater is approximately 40 to 60 feet bgs in the Port Heiden RRS vicinity. Studies of residential wells no less than 2.5 miles south of the site determined that groundwater exists in a confined aquifer at a depth of approximately 60 feet (Alaska Department of Environmental Conservation [ADEC], 2003a), indicating locally-confining clay layers exist, but lack confinement at the former RRS with no confining clay layer observed present at Sites OT001 and WP002. A detailed description of hydrogeology at Port Heiden is also provided in the 2006 RI/FS which is included in **Appendix A** of this report (USAF, 2006).

1.2.4 Topography and Drainage Patterns

The former RRS area is approximately 300 acres and is located approximately one and a half miles east of Bristol Bay of the Bering Sea. The topography of the area slopes gently to the west and southwest. Surface water runoff is expected to drain to the surrounding tundra, then percolate into the ground or evaporate (USAF, 1994). The prominent surface water features in the area include Reindeer Creek (locally known as North River) located approximately one mile to the north of the former RRS. Small shallow ponds are located east and southeast of the project area. These ponds extend south toward Abbott Creek located an approximate distance of one and a half to two miles south of the former RRS.

The lowlands are characterized by rolling terrain with relatively well-drained soils and many lakes. The Port Heiden area is generally free of permafrost (USGS, 1995). The Nushagak and Kvichak Rivers are the largest flowing water bodies in the region, but numerous other smaller creeks and rivers are present.

1.2.5 Area Ecology

This section summarizes the diverse habitat surrounding the former Port Heiden RRS, to highlight what key potential ecological receptors were considered during the evaluation of the current remedy's effectiveness.

1.2.5.1 Flora

The former RRS is sparsely vegetated, with a majority of the historic sampling events taking place within the portion of the site formerly containing buildings, storage tanks, lagoons, and other site-related features that were set upon manmade gravel pads. The resulting flora within the former RRS footprint is non-continuous and contains lichens, mosses, and low growing shrubs interspersed with few trees, primarily alder (USAF, 2006). In comparison the area surrounding the former RRS consists primarily of upland tundra and low-shrub lands. Species known to occur in this area include crowberry, bearberry, yarrow, fireweed, lichens, sedges, Labrador tea, and mosses. Dominant species in the subregion are crowberry and lichens.

1.2.5.2 Fauna

The Bristol Bay lowlands are considered good wildlife habitat. Seasonal variations contribute to large numbers of species utilizing the area. Although the former RRS area itself is not ideal for many wildlife species, the surrounding areas are known to be good habitat for supporting wildlife. Carnivorous mammals present in the region include red fox, wolves, wolverine, mink, least weasel, ermine, lynx, and Arctic fox. Herbivores and omnivores include bears, muskrat, lemmings, porcupines, voles, Arctic ground squirrels, moose, and caribou. Moose are frequently abundant in the subregion because of the large amount of water. Caribou are common locally, in winter. Aquatic mammals such as mink, muskrat, and beaver are common in the myriad of water bodies of the subregion.

The Bristol Bay area is particularly important as a staging area for spring and fall waterfowl migrations. A large variety of migratory bird species utilize the area. The principle aquatic species include scaup, Pintail, scoters, wigeons, Mallards, Shovelers, Green-winged Teal, and Canvasbacks. Swans, geese, loons, grebes, and Sandhill Cranes also are common. Bird species associated with the terrestrial habitats include Rock and Willow Ptarmigan, ravens, juncos, gulls, swallows, and raptors. Birds of prey such as Sharp-shinned Hawk, Red-tailed Hawk, kestrel, Great-Horned Owl, shrikes, and Short-eared Owl are all common to the area, and the endangered Peregrine Falcon is an inhabitant of the subregion (USAF, 2006).

1.2.5.3 Invertebrates

Invertebrates are numerous in the area. Species include nematodes, worms from the family Enchytraeidae, and a large number of mites. The discontinuous permafrost allows for an active root zone, which provides habitat for invertebrates year-round.

1.2.5.4 Fish

No water bodies providing habitat for fish are present within the affected area of the former RRS. The following anadromous salmon species use the local rivers to migrate to upstream spawning beds: chinook, coho, sockeye, pink, and chum. Resident fish species may include northern pike, grayling, whitefish, sucker, sheefish, burbot, sculpin, and stickleback. Regional lakes provide ideal habitat for large populations of salmon, grayling, and rainbow trout.

1.3 Previous Investigations and Actions

This section provides background information and summarizes the series of previous site activities, investigations, and removal actions that have taken place at Sites OT001 and WP002.

1.3.1 Site OT001

In 1986, soil samples were collected throughout the former Port Heiden RRS and tested for PCBs, metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver), SVOCs, and halogenated volatile organic compounds (VOCs). Site OT001 results indicated the presence of PCBs up to 15 milligrams per kilogram (mg/kg) near the auto shop, and the halogenated VOC, trichlorofluoromethane, at a maximum concentration of 84.2 parts per billion outside the generator room (USAF, 2006).

In 1987 and 1988, 80 soil samples were collected from the north end of the Former Composite Building and analyzed for PCBs. Analytical results identified PCB-contaminated soil along the entire northern wall of the Former Composite Building at concentrations up to 190 mg/kg. The highest concentrations were found generally at the east edge of the concrete slab in front of the large garage doors. The north end of the Former Composite Building was subsequently the focus for soil excavation and removal during the 1990 investigation and restoration activities (USAF, 2006).

In 1990, contaminated soil excavation activities were conducted with removal of approximately 170 CY of PCB-impacted soil from the former RRS and from a nearby Federal Aviation Administration site were sent offsite for disposal. The exact amount of PCB-contaminated soil removed only from the former RRS was not estimated (USAF, 2006). Surface soil with total petroleum hydrocarbons (TPH) concentrations above 5,000 mg/kg on the north side of the Former Composite Building was removed in 1-foot-thick intervals; the remaining soil was then retested. The cleanup goal for the 1990 remedial action was to achieve TPH concentrations below 100 mg/kg throughout the excavation area. This cleanup goal was not achieved.

In 1991, ADEC agreed to a 5,000 mg/kg TPH cleanup concentration. Soil with TPH concentrations below 5,000 mg/kg and PCB concentrations below 10 mg/kg was placed into the soil covers of Landfills A and B. Soil with analytical results above 5,000 mg/kg TPH and PCB concentrations below 25 mg/kg were stockpiled on site for subsequent remediation (USAF, 2006).

In 1995, additional soil was excavated along the north wall of the Former Composite Building. The site inspection report concluded that no further action was needed at OT00l, as analytical results indicated that POL- and PCB-contaminated soil with TPH concentrations above 5,000 mg/kg and PCBs above 25 mg/kg had been removed (USAF, 1996). The onsite USTs were also removed during the 1995 remedial action event (USAF, 2006).

In 1999, nine subsurface soil samples were collected from immediately beneath the vegetated cover (2 to 6 inches bgs) near the Former Composite Building and analyzed for benzene, toluene, ethylbenzene, and xylenes (BTEX). No BTEX constituents were detected above the laboratory's method detection limits (USAF, 2006).

In 2004, a Remedial Investigation (RI) was performed to conduct soil sampling and perform a baseline human health risk assessment and an ecological risk assessment for Port Heiden RRS. The RI also validated that a 30,000-gallon gasoline UST shown to exist on previous as-built drawings had been removed (USAF, 2006). Additional USTs formerly located at the site but removed prior to 1990 activities included a 600-gallon ADEC-registered UST and two 20,000-gallon diesel USTs. During the 2004 RI, Aroclor 1260 (PCB) was detected above the screening criteria (1 mg/kg) in four of the initial nine surface soil samples. The SVOC compound benzo(a)pyrene was also found slightly above the screening criteria (1 mg/kg) in one sample and its duplicate. Based on the initial analytical results, an additional six soil samples were collected laterally, away from the initial samples, and were analyzed for PCBs. Of the soil samples collected during the 2004 RI, eight (four of the nine original samples and four of the six step-out samples) reported concentrations of PCBs above the screening criteria (1 mg/kg), with a maximum detected concentration of 6.4 mg/kg (USAF, 2014a).

In 2011, the drivable surfaces and shoulders of Site Road were remediated to remove soils with PCB concentrations at or above 1 mg/kg as part of a Time Critical Removal Action (TCRA). Two locations that were the focus of the removal had been reported with concentrations of PCBs above TSCA level (50 mg/kg). With the upcoming subsistence season and associated higher vehicle traffic anticipated, the TCRA was completed, and Site Road reopened in mid-June 2011, to avoid substantial threat to public health, welfare, and the environment posed by PCB-laden fugitive dust. A total of 9,400 CY of non-TSCA regulated PCB soil, and 10 CY of TSCA regulated PCB soil were removed and disposed of offsite (USAF; 2012a, 2012b).

In 2014 and 2015, a combined total of approximately 23,000 tons of PCB-contaminated soil was excavated from across the RRS, including OT001, WP002, and multiple other sites and disposed offsite. Excavations continued in 2016 and 2017, with the removal of approximately 9,000 tons of additional soil containing PCBs above the 1 mg/kg CUL. Two Explanations of Significant Differences have been prepared since preparation of the 2009 ROD, in May 2010 and May 2017 (USAF; 2010a, 2017a), which document the increased quantities of contaminated soil above ROD expectations (USAF, 2019d). Follow-on removal action was performed in 2020 at the former RRS to remove an additional 5,000 tons of PCB-contaminated soil above 1 mg/kg, to continue the gridded step-out characterization, and continue the RRS cleanup efforts.

While an estimated 50,000 tons of PCB and/or POL-contaminated soil have been removed or treated onsite by landfarming between 2009 and 2020 (USAF; 2015c, 2016b, 2016c, 2019d, 2020b, 2021a), an additional estimated 450 tons of soil located approximately 0 to 3 feet bgs, across central and northern portions of the RRS at Sites OT001 and LF007 exceed the applicable 18 AAC 75 soil CUL for PCBs (1 mg/kg). The remaining PCB-contaminated soil is present at non-Toxic Substances Control Act a (TSCA) levels ranging between 1-50 mg/kg. A more concentrated pocket of soil and debris, estimated at 80% of the remaining 450 tons of contaminated soil, are contained within the footprint of the North Landfill Site LF007 that range in PCB concentrations of non-TSCA levels of 1-50 mg/kg to TSCA-levels greater than 50 mg/kg (USAF, 2021a). Further removal action for Sites OT001 and LF007 are planned by the USAF for continuation in 2022.

Groundwater monitoring conducted between 2005 to 2020 from the existing monitoring well network associated with Site OT001 resulted in detections of benzene, DRO, RRO, cis-1,2-DCE, and trans-1,2-DCE below applicable CULs, and exceedances of applicable groundwater CULs for TCE, PCE, and 1,1,2-trichloroethane. Monitoring wells included in the OT001 groundwater monitoring network include the following 13 locations: DSA-MW-01, DSA-MW-02, DSA-MW-04, DSA-MW-05, DSA-MW-06, DSA-MW-07, GLO-MW-03, GLO-MW-04, PG1-MW-01, RRS-MW-02, RRS-MW-05, RRS-MW-06, and UST-MW-02.

1.3.2 Site WP002

In 1987, four soil samples collected from the Black Lagoon Outfall identified the presence of fuels, PCBs, and chlorinated solvents at low concentrations. In 1988, 16 additional soil samples were collected and analyzed for metals; no samples reported detectable concentrations of metals above the laboratory method detection limit (USAF, 2006). A review of the analytical results from the soil samples collected between 1987 – 1988 confirmed TPH, PCB, and SVOCs in exceedance of preliminary 18 AAC 75 action levels for soil.

In 1990, further soil delineation efforts were conducted at the Black Lagoon Outfall with the excavation of four exploratory trenches, and the collection of surface and subsurface soil samples for analysis of TPH and PCBs. No PCBs were identified above the laboratory method detection limit. POL-impacted soil reporting concentration of TPH above 5,000 mg/kg was found from the depth interval of 0-12 feet bgs.

During the 2004 RI, potential soil contaminants of concern (COCs) were identified as gasoline range organics, DRO, RRO, metals, PCBs, VOCs, SVOCs, and herbicides for WP002. PCE and DRO were the only two COCs that reported concentrations above their respective CULs (USAF; 2006, 2015a; 2016a). The 2006 RI/FS reported an estimated 4,000 CY of impacted soil with TPH concentrations above 5,000 mg/kg were present at WP002. Since then, multiple soil removal actions have taken place, lastly in 2020, with the RRS-wide removal of 5,000 tons of POL and PCB-contaminated soil. Based upon the 2020 removal action results, no POL or PCB-impacted soil remains at WP002 above applicable CULs (USAF, 2021a).

The 2004 RI results confirmed two distinct plumes were present in the aquifer underlying the former Port Heiden RRS. These plumes include an area of TCE contamination that is approximately 700 feet long, 400 feet wide, and at a depth of 50 feet bgs underlying the OT001 pad, and a smaller area of benzene and TCE contamination that is approximately 100 feet long, 100 feet wide, and at a depth of 50 to 60 feet bgs underlying the WP002 Black Lagoon Outfall (USAF, 2014a).

Groundwater monitoring conducted between 2005 to 2020 from the existing WP002 monitoring well network reported detections of benzene and the TCE breakdown products of cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride below their respective CULs and reported exceedances of TCE, DRO, RRO, naphthalene and PCE above their respective groundwater CULs. Monitoring wells included in the WP002 network include the following four locations: BLO-MW-01, BLO-MW-05, BLO-MW-06, and BLO-MW-07.

From 2014 through 2020 the soil characterization and cleanup efforts continued at WP002 in conjunction with OT001 and the remaining former RRS areas covered under the 2009 ROD as previously described above. An estimated 50,000 tons of POL- and PCB-contaminated soil have been removed from the former RRS, or treated onsite by landfarming, between 2009 and 2020 (USAF; 2019d, 2020b, 2021a).

1.4 Remedial Action Objectives

RAOs provide a general description of what the selected remedy should accomplish upon its implementation. The 2009 ROD-established RAOs specific to groundwater at Sites OT001 and WP002 include (USAF, 2009):

- Reduce dissolved concentrations of TCE and benzene in groundwater to chemical-specific applicable or relevant and appropriate requirements (ARAR). When addressing TCE in groundwater through MNA, the expected daughter or breakdown products of TCE (cis and trans-1,2- DCE and vinyl chloride) are also monitored until they have met the required Federal maximum contaminant levels (MCLs) (National Primary Drinking Water Regulation Table, EPA, 2009) and State CULs (18 AAC 75 Table C, ADEC, 2021);
- Prevent exposure (via ingestion, inhalation, and/or dermal contact) to contaminated groundwater until such time as the Federal drinking water standards and State CULs are met;
- Restrict excavations and the installation of water wells (except for the purposes of contamination monitoring) where contamination levels exceed CULs to reduce the possibility of exposure to contaminants present in the aquifer;

- Prevent the possible migration of groundwater containing dissolved concentrations of TCE and benzene to the tributary stream of Reindeer Creek resulting in surface water concentrations in excess of Alaska fresh surface water criteria for aquatic organisms (18 AAC 70, ADEC 2020).

1.5 Groundwater Cleanup Levels

The CULs applicable to Port Heiden RRS, Site OT001 and WP002 groundwater are provided below in **Table 1**. These action levels are a combination of those promulgated for benzene and TCE in the 2009 ROD based upon both the then-current industrial/non-residential land use and the potential unrestricted future land use of the area (USAF, 2009), as well as contaminated groundwater CULs established by ADEC's 18 AAC 75 Table C Groundwater CULs (ADEC, 2021).

Table 1 OT001 & WP002 Groundwater CULs

Contaminant	Groundwater Cleanup Levels (µg/L)	CUL Source
Benzene	5	2009 ROD
TCE	5	
cis-1,2-DCE	36	18 AAC 75, Table C
trans-1,2-DCE	360	
Vinyl Chloride	0.19	
PCE	41	
DRO	1,500	
RRO	1,100	

Notes:

µg/L = micrograms per liter
Current source of ADEC Table C CULs is: 18 AAC 75.345; as amended June 2021.

1.6 Current Remedy Components

The 2009 ROD-selected remedy for groundwater applies to the Former Composite Building (OT001) plume and the Black Lagoon Outfall (WP002) plume, includes LTM with annual groundwater monitoring, MNA and LUCs. Specific elements of the groundwater remedy include (USAF, 2009):

- <u>Human Health RAOs</u>:
  - MNA of groundwater contaminated with dissolved concentrations of TCE and benzene.
  - Periodic groundwater monitoring to assess changes in groundwater contaminant concentrations (trends) over time.
- Environmental Protection RAO:
  - LUCs shall include limitations on groundwater use, and notices to the landowner and Village Council of site status. The LUCs would remain in place until the groundwater CULs are achieved through natural attenuation.

Under the current selected remedy, MNA will continue until groundwater contamination is no longer a threat to human health and the environment, verified by a minimum of two years of consecutive sampling events where analytical results show that COCs are less than the ROD CULs, as well as the expected daughter products (cis-1,2-DCE, trans-l,2-DCE and vinyl chloride) derived from the COCs. Sampling for individual groundwater COCs and their associated daughter products may be discontinued at any time after a minimum of two years of consecutive sampling events report concentrations below chemical-specific Federal MCLs and State groundwater CULs (USAF, 2009).

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Figure 1 Port Heiden RRS Vicinity Map

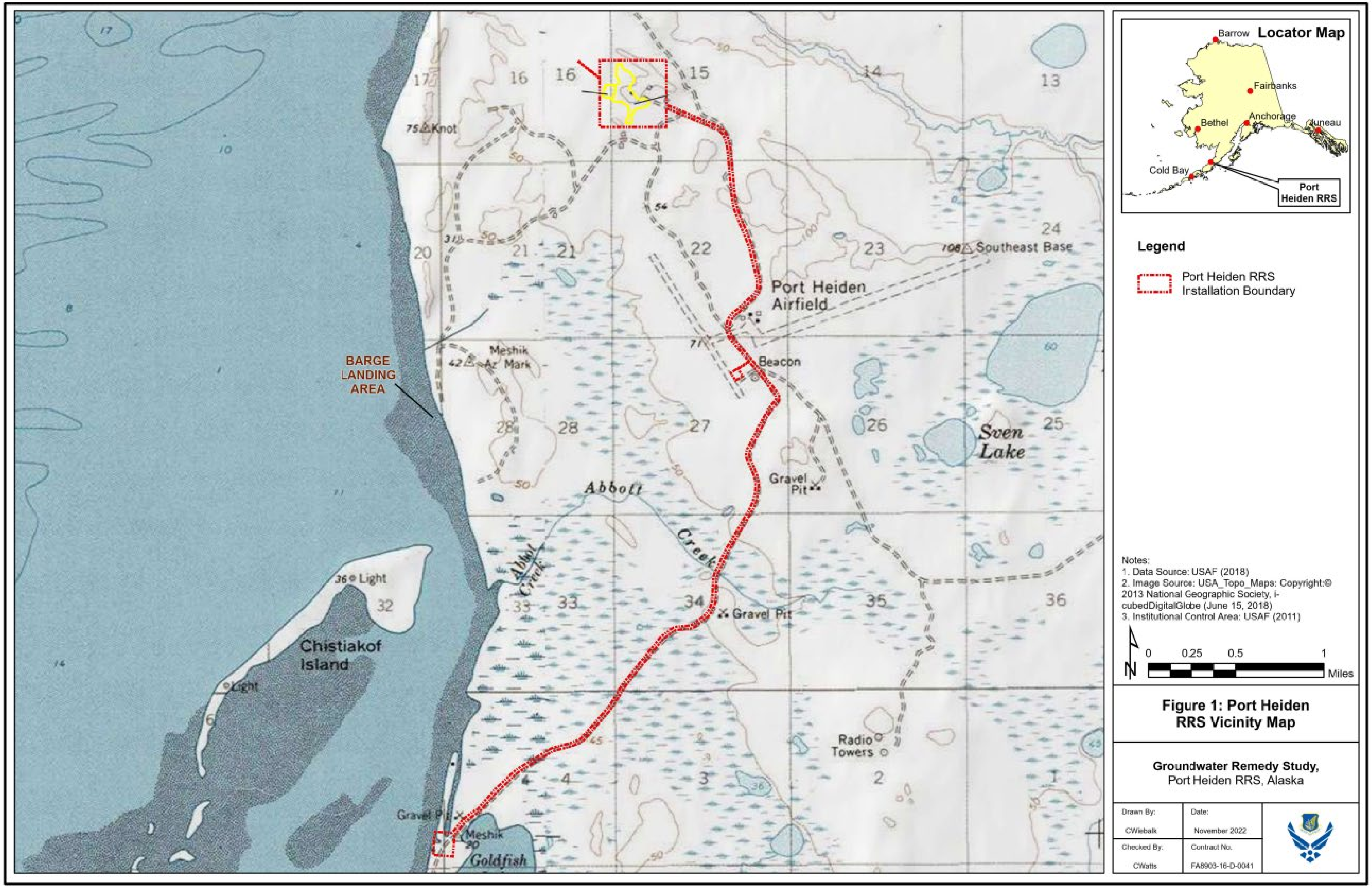

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Figure 2 OT001 Former Composite Building Site Layout

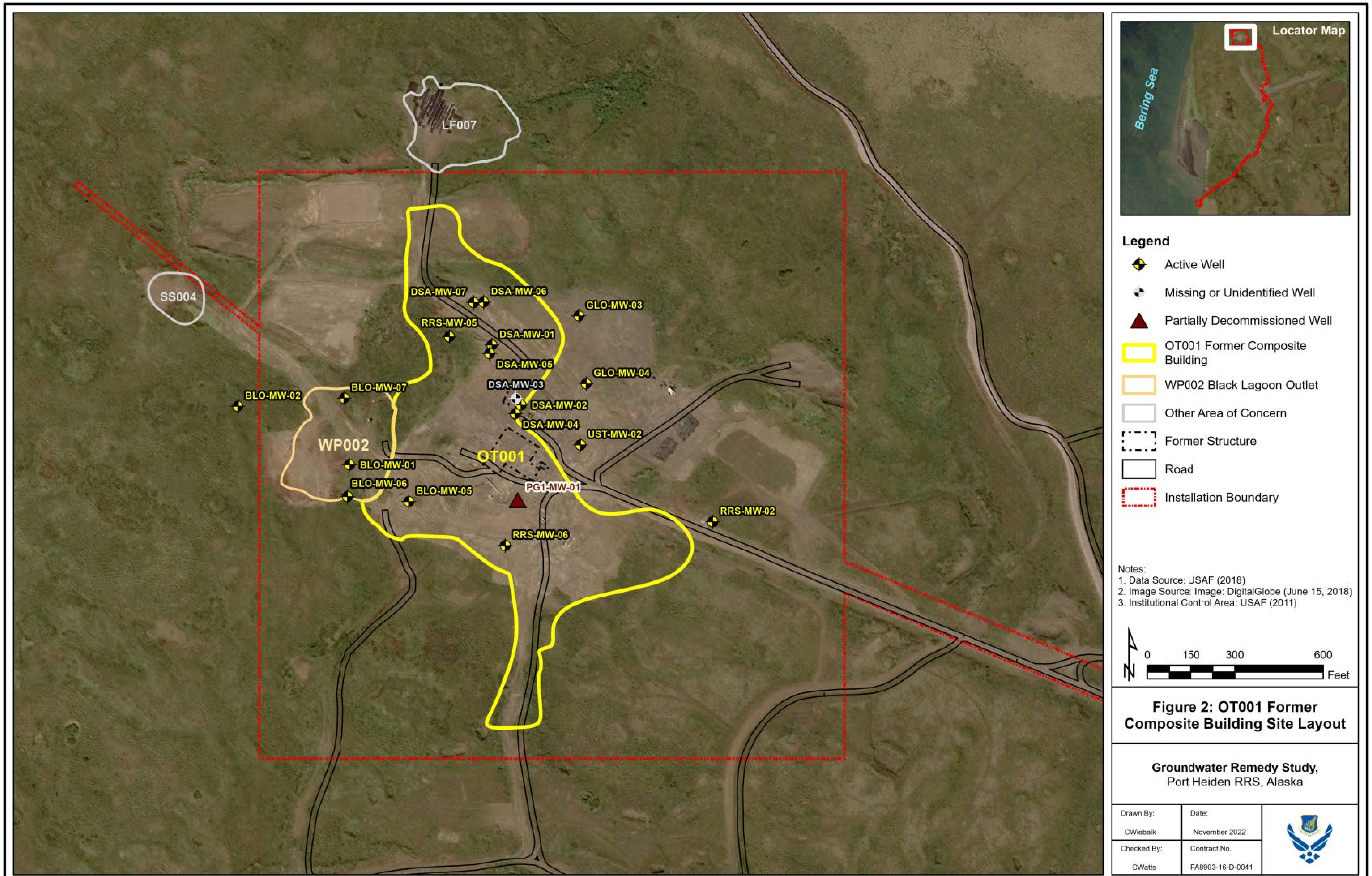

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Figure 3 WP002 Black Lagoon Outfall Site Layout

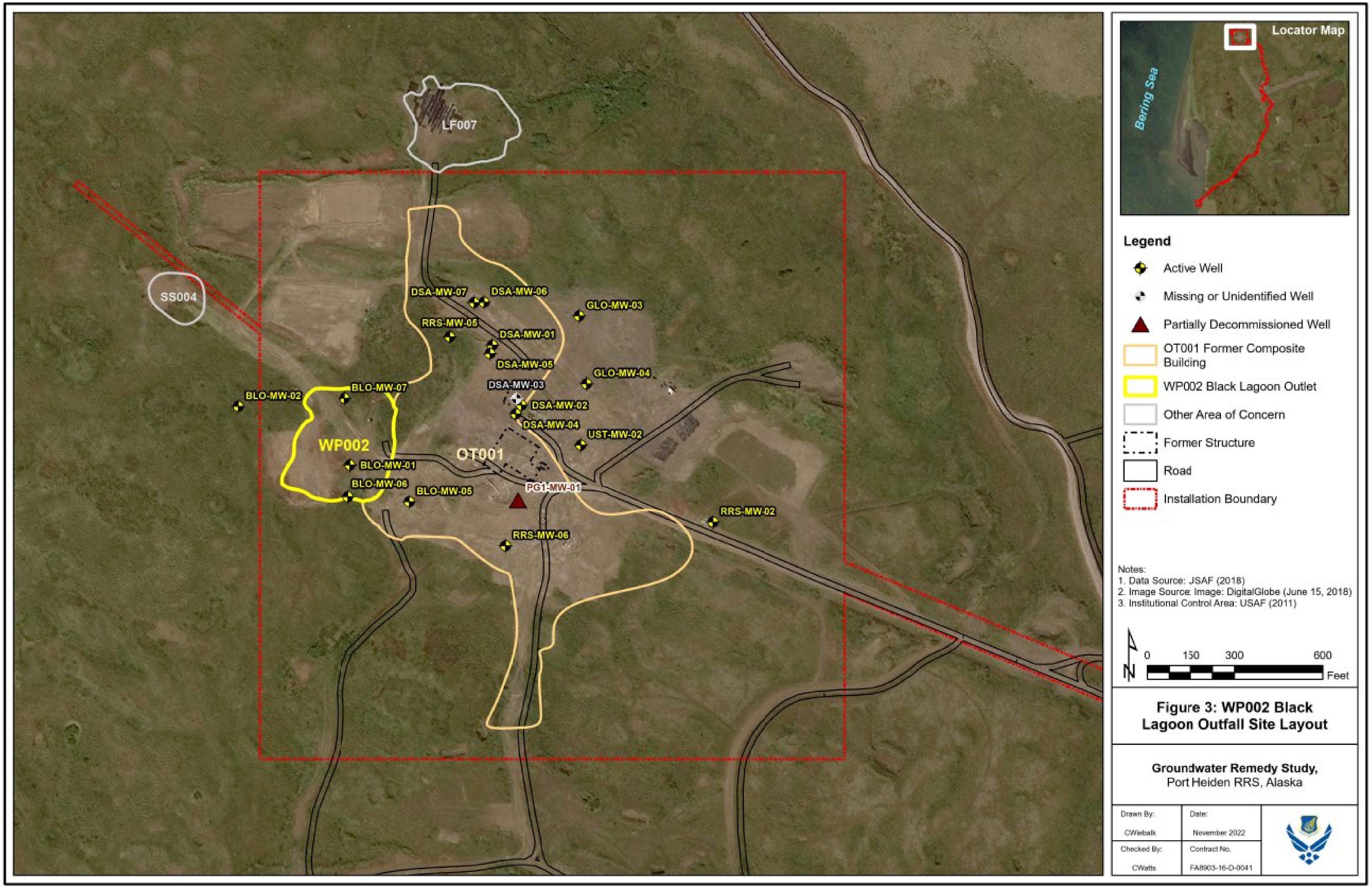

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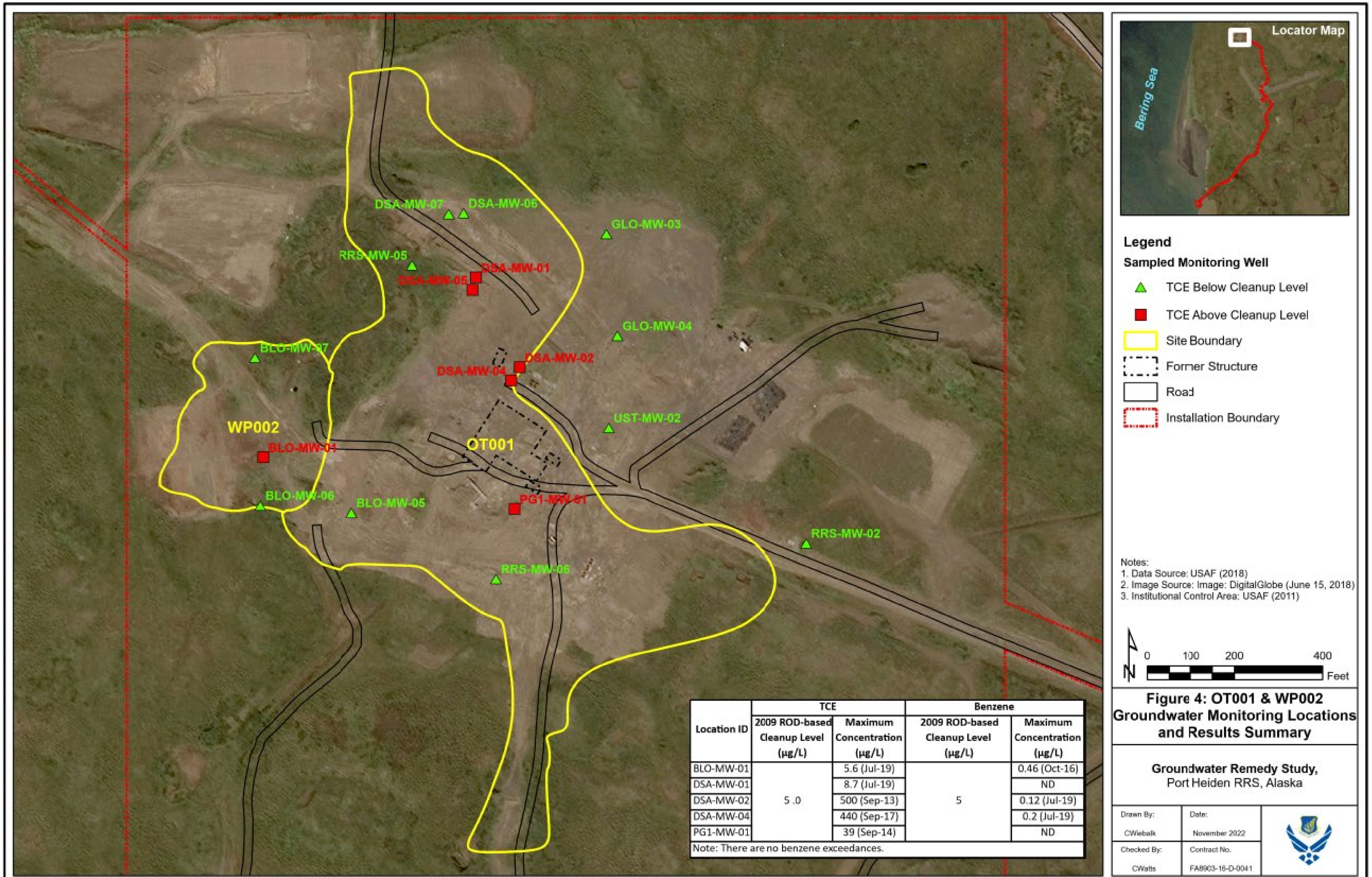
Figure 4 OT001 & WP002 Groundwater Monitoring Locations and Results Summary



Location ID	TCE		Benzene	
	2009 ROD-based Cleanup Level (µg/L)	Maximum Concentration (µg/L)	2009 ROD-based Cleanup Level (µg/L)	Maximum Concentration (µg/L)
BLO-MW-01	5 .0	5.6 (Jul-19)	5	0.46 (Oct-16)
DSA-MW-01		8.7 (Jul-19)		ND
DSA-MW-02		500 (Sep-13)		0.12 (Jul-19)
DSA-MW-04		440 (Sep-17)		0.2 (Jul-19)
PG1-MW-01		39 (Sep-14)		ND

Note: There are no benzene exceedances.

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2.0 GROUNDWATER CONTAMINATION

This section of the Groundwater Remedy Report presents a summary of the analysis of the Site OT001 and Site WP002 groundwater concentrations over time. Concentrations of POL and chlorinated solvent will be highlighted, and their respective increasing, decreasing, or stable trends confirmed through the completion of statistical analysis. Referenced sampling events were performed by the USAF through the implementation of the LTM program at Port Heiden RRS, as documented in prior assessment reports included in **Appendix A**.

The 2009 ROD, which defined the remedy for Port Heiden RRS groundwater, states that after the first five years of groundwater monitoring performed no less than annually during the summer period, the USAF and ADEC may evaluate the MNA progress. At the second of these FYRs, finalized in December 2019, it was determined that the remedy as implemented may not be successful at achieving ARARs including the reduction of TEC concentrations below its respective Table C CUL in the estimated timeframe of 25 years (by 2035). In order to verify the conclusion of the second FYR, site COCs of TCE (plus related breakdown products), benzene, DRO, and RRO were evaluated in the following sections of this remedy analysis report.

Per the 2009 ROD, if results of the FYR indicate parent contaminants TCE and benzene are found to be increasing in concentration or plume aerial/vertical extent, or the estimated cleanup timeframe of 25 years (by 2035) cannot be achieved, the selected remedy may be reconsidered to confirm that human health and the environment remain protected.

2.1 Groundwater Monitoring History

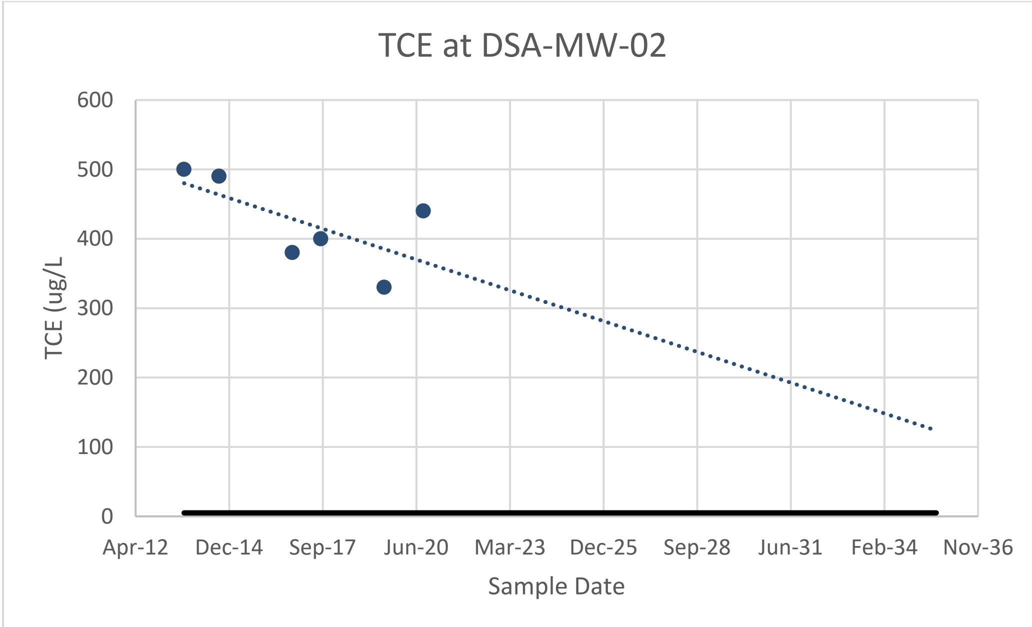
Groundwater monitoring was conducted in 2013, 2014, 2016, 2017, 2019, and 2020 as a component of the annual LTM program at Port Heiden RRS. Groundwater was monitored according to the 2009 ROD, to evaluate the presence of benzene, PCE, TCE and related daughter products (cis-1,2-DCE, trans-1,2-DCE, vinyl chloride, and) (USAF, 2009). Petroleum hydrocarbon components DRO and RRO were also monitored to better evaluate the dissolved POL plume. Analytical results have been compared to 2009 ROD CULs, which were defined for benzene and TCE as 5 micrograms per liter (µg/L), as well as 18 AAC 75 Table C Groundwater CULs (ADEC, 2021) for TCE daughter products, DRO, and RRO. **Appendix B** includes a comprehensive table of analytical results.

2.1.1 TCE & Related Daughter-Products in Groundwater

While the presence of TCE, PCE and/or related daughter products (cis-1,2-DCE, trans-1,2-DCE, vinyl chloride), or have been identified in 15 of the 17 Site WP002 and OT001 monitoring wells, exceedances of their respective 2009 ROD-based or ADEC Table C groundwater CULs are limited to that of TCE in 5 wells, and PCE in 3 wells. Concentrations of cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride have remained below ADEC Table C CULs for the duration of the groundwater monitoring program.

The maximum concentration of TCE reported for OT001 was obtained from monitoring well DSA-MW-02 in September 2013, with a result of 500 µg/L. Since September 2013, dissolved TCE concentrations at this monitoring location have varied between 330 µg/L and 490 µg/L, remaining above the CUL, but demonstrating an overall decreasing trend. **Figure 5** illustrates the decreasing trend in TCE at monitoring well DSA-MW-02, as compared to the 2009 ROD CUL of 5 µg/L.

Figure 5 DSA-MW-02 TCE Trend Estimate



Based upon historic groundwater monitoring results for Sites OT001 and WP002, the five monitoring wells reporting TCE concentrations remaining above the applicable ROD-based CUL include: BLO-MW-01, DSA-MW-01, DSA-MW-02, DSA-MW-04, and PG1-MW-01. Trend estimate graphs projected through 2035 are included for each of these monitoring wells in **Appendix C**. A line of best fit was applied to each set of results to conclude that DSA-MW-02, the monitoring well with the highest reported concentration of TCE in site history, is decreasing in concentration, while the remainder of exceeding wells are following an increasing trend. As illustrated on the trend graphs, none of the five exceeding monitoring wells are estimated to achieve the 5 µg/L cleanup goal for TCE by 2035.

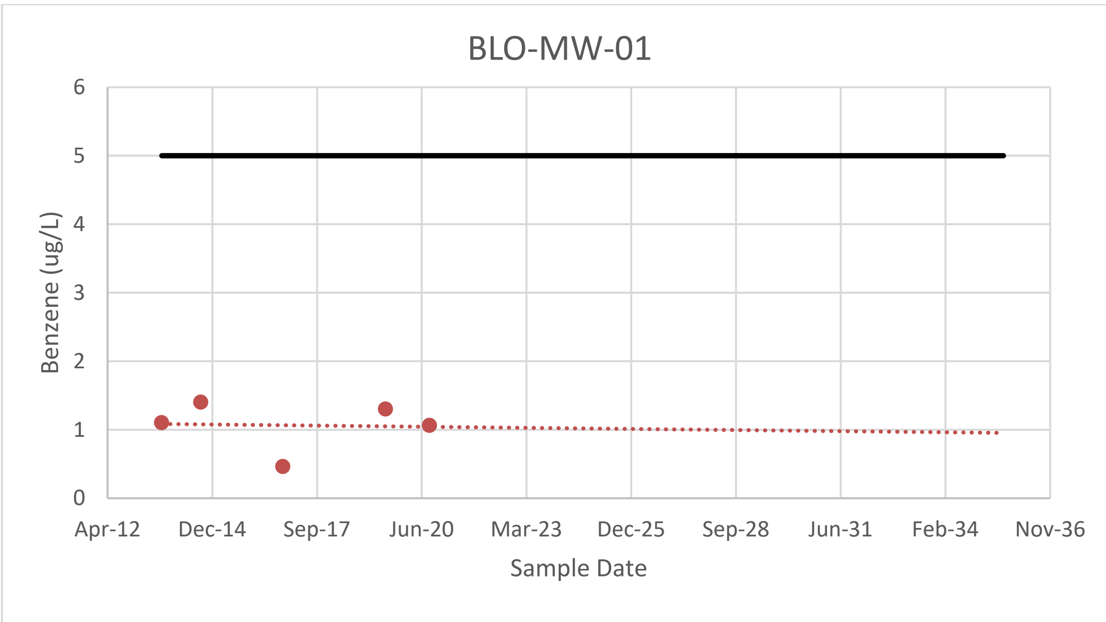
The maximum reported concentration of PCE was reported for WP002 monitoring well BLO-MW-01 in July 2019, with a result of 990 µg/L, which is above the Table C CUL of 41 µg/L. Between 2013-2016, PCE at this monitoring location ranged from non-detect to 0.16 µg/L. The 2019 sampling event identified a large spike to 990 µg/L, then dropping back down in concentration to 0.25 µg/L in 2020. With this magnitude of such a large concentration spike from one year to the next at BLO-MW-01, the 2019 PCE groundwater sample result is suspect for possible cross-contamination.

PCE was identified at concentrations exceeding the applicable ADEC Table C CUL in three monitoring wells during the 2019 and 2020 sampling events: BLO-MW-01, BLO-MW-07, and DSA-MW-02. This marked increase of PCE concentrations in recent years may indicate that a portion of the dense nonaqueous-phase liquid (DNAPL) plume is entering the dissolved phase over time, or that PCE-contaminated soil remaining in the smear zone becomes submerged and mobile in the dissolved phase following seasons of heavy rainfall or snowmelt.

2.1.2 Benzene in Groundwater

Benzene has been reported in less than half (7 of 17) of the monitoring wells evaluated for Sites WP002 and OT001. There have been no exceedances of the applicable 2009 ROD-based groundwater CUL of 5 µg/L during the monitoring period. The maximum reported concentration of benzene was collected from WP002 monitoring well BLO-MW-01 in September 2014 with a result of 1.4 µg/L, that also demonstrates a slight decreasing concentration trend over time. Other than the reported presence in BLO-MW-01, low levels of dissolved benzene have also been reported in six other monitoring wells, but only during the 2019 groundwater sampling event. The ROD cleanup goal of 5 µg/L has been achieved, as evidenced by 5 sampling events reporting concentrations below CUL. **Figure 6** illustrates the dissolved benzene trend at monitoring well BLO-MW-01, which remains in compliance with the 2009 ROD cleanup goal of 5 µg/L.

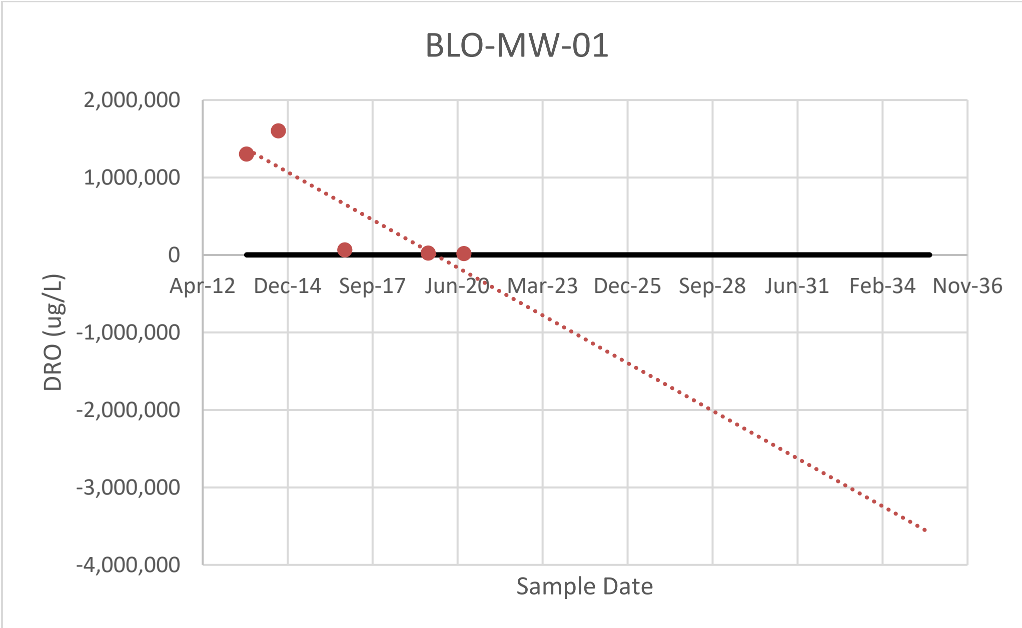
Figure 6 BLO-MW-01 Benzene Trend Estimate



2.1.3 DRO & RRO in Groundwater

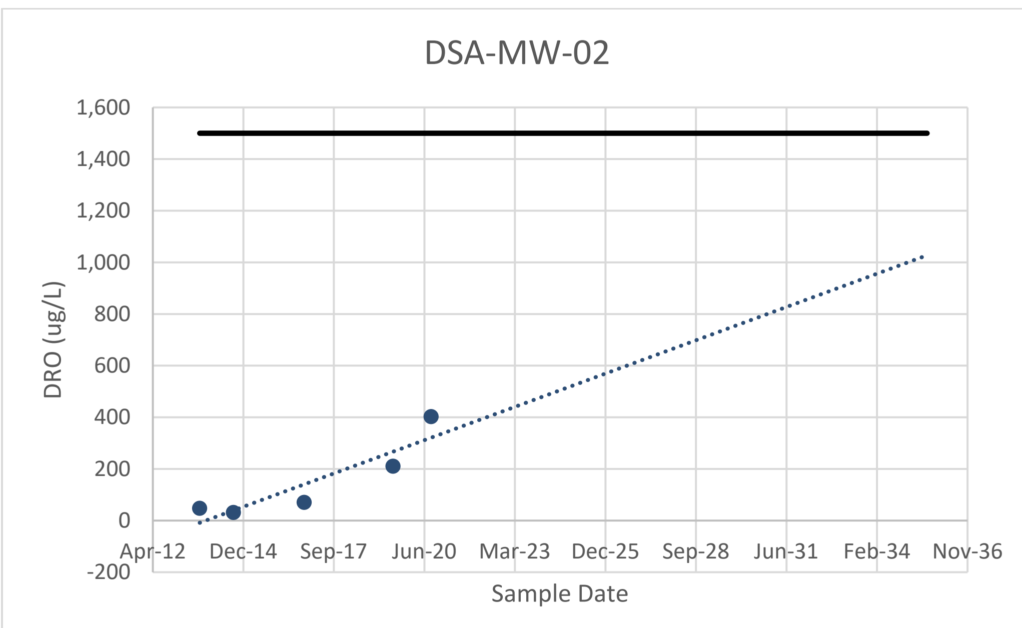
While the presence of DRO and RRO have been identified in about half (8 of 17) of the monitoring wells evaluated for Sites WP002 and OT001, exceedances of applicable ADEC Table C groundwater CULs are limited to that of 1 well (BLO-MW-01) for both DRO and RRO. The maximum reported concentration of DRO is from WP002 monitoring well BLO-MW-01 in September 2014, with a result of 1,600,000 µg/L, which exceeds the CUL of 1,500 µg/L. Since then, DRO concentrations at monitoring well BLO-MW-01 have drastically reduced, ranging between 15,000 µg/L and 63,000 µg/L, demonstrating an overall decreasing trend. **Figure 7** below illustrates this trend in DRO at monitoring well BLO-MW-01, as compared to the 18 AAC 75 Table C CUL of 1,500 µg/L.

Figure 7 BLO-MW-01 DRO Trend Estimate



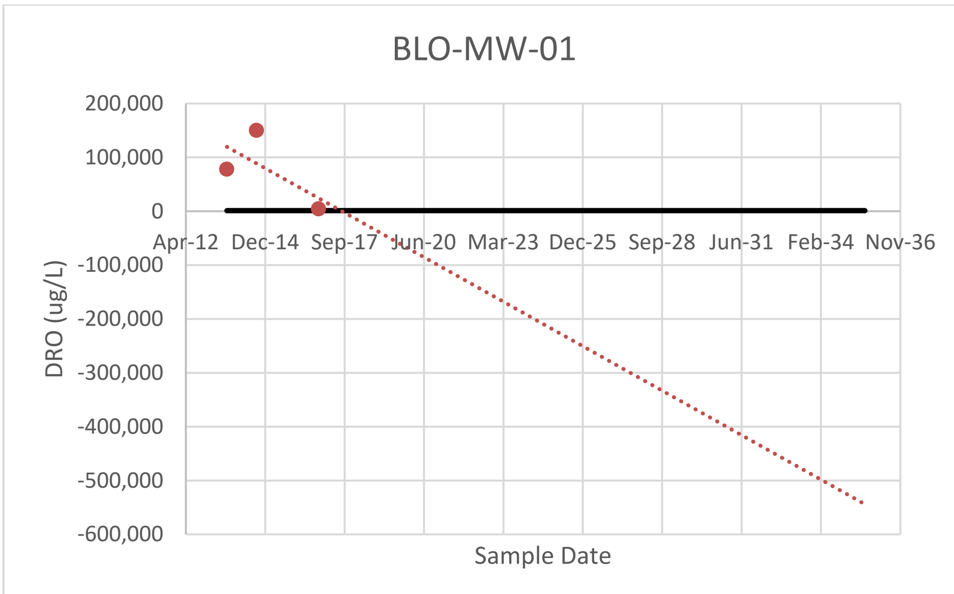
The DRO trend at DSA-MW-02 (downgradient from BLO-MW-01) also stands out, although below the CUL to date, has been doubling in concentration each year, and is anticipated to exceed the CUL in the future if that trend continues. **Figure 8** below illustrates this trend in DRO at monitoring well DSA-MW-02, as compared to the 18 AAC 75 Table C CUL of 1,500 µg/L.

Figure 8 DSA-MW-02 DRO Trend Estimate



The maximum reported concentration of RRO was also reported for WP002 monitoring well BLO-MW-01 during the September 2014 sampling event, with a result of 150,000 µg/L. Since then, RRO at this monitoring location has reduced to 4,200 µg/L in October 2016, remaining above the Table C CUL of 1,100 µg/L. It should be noted that the groundwater samples collected from monitoring well BLO-MW-01 from 2017-2020 did not include analysis for RRO. The current concentration of dissolved RRO in groundwater is unknown, but assuming a continuing decreasing trend since 2016, it is estimated that RRO concentrations in the vicinity of monitoring well BLO-MW-01 would be Assuming a similar degradation as DRO, it is estimated that the dissolved RRO concentration at monitoring well BLO-MW-01 would have achieved concentrations below the Table C CUL of 1,100 µg/L by 2020. **Figure 9** below illustrates this trend in RRO at monitoring well BLO-MW-01, as compared to the 18 AAC 75 Table C CUL of 1,100 µg/L.

Figure 9 BLO-MW-01 RRO Trend Estimate



2.2 Statistical Analysis

In order to further evaluate contaminant trends in groundwater at Sites OT001 and WP002, contaminant plume behavior modeling was conducted for TCE, benzene, and DRO concentrations in 16 monitoring wells within the existing well network. The analysis, monitoring, and evaluation process utilized historic groundwater analytical data obtained from the monitoring well network. The results of the statistical analysis were conducted to assist in updating the conceptual site model (CSM) to evaluate potential groundwater migration through the soil column, into the active layer and toward the tributary stream which feeds into Reindeer Creek (locally known as North River) located approximately one mile to the north of former Port Heiden RRS. This statistical analysis was performed as part of the CERCLA process to evaluate the implemented remedy, and to meet requirements set forth by the 2009 ROD to confirm that the current groundwater remedy is functioning as intended to protect human health and the environment (USAF, 2009).

A Mann-Kendall (M-K) statistical test was implemented, utilizing six years (2013-2020) of groundwater analytical data to determine plume behavior surrounding sample compliance points. M-K is a simple, non-parametric statistical test that provides an end result indicating an increasing or decreasing contaminant trend over a specific period of time. Test requirements are a sample group of at least four rounds of analytical data collected from similar times of year, as the test does not account for seasonal variability.

For this statistical model, the following 14 groundwater monitoring wells were identified as candidate monitoring points, while maintaining test criteria: BLO-MW-01, BLO-MW-05, BLO-MW-06, BLO-MW-07, DSA-MW-01, DSA-MW-02, DSA-MW-04, DSA-MW-05, DSA-MW-06, DSA-MW-07, GLO-MW-03, GLO-MW-04, RRS-MW-05, and RRS-MW-06. Representative groundwater samples have been consistently collected during the late summer to early fall months of July through September 2013, 2014, 2016, 2017, 2019, and 2020. Sample data is also sporadically available between 2004 and 2012, however the more recent 2013-2020 consecutive data was utilized to provide increased statistical confidence of the M-K test. Concentrations of key site contaminants TCE, benzene, and DRO were utilized from available historical data to perform the M-K statistical test. There were two additional wells (PG1-MW-01 and UST-MW-02) considered for inclusion in the test, for a total of 16 monitoring wells, however their data set was insufficient to provide the minimum four rounds of analytical results. Groundwater sampling and analysis for RRO and PCE have not been performed consistently over the monitoring period to support the M-K analysis for these contaminants.

Detailed statistical analysis results for each of the monitoring wells and the data-time plots for those wells reporting COC concentrations above their respective CULs are included in **Appendix C**. A summary of the M-K statistical results and mathematical trend estimates are included below in **Table 2**. The M-K analysis inputs, including historic and recent concentrations of TCE, benzene, and DRO, the analytical mean (average), standard deviation, and coefficient of variation amongst other statistical observations are detailed in **Appendix C**. The test results are indicated by the M-K statistic (S), which suggests an increasing trend for positive values, a decreasing trend for negative values or no determinable trend for values equal to zero. Based upon the S value, the coefficient of variation, and calculated confidence in each data set, the overall concentration trend will be reported as stable, decreasing, increasing, or without trend.

Figure 4 illustrates the maximum reported groundwater concentration for both TCE and benzene, in each monitoring well. **Figure 10** provides the TCE plume extent, based upon available analytical data collected for ROD contaminant TCE, between 2013 and 2020. For the purposes of this figure, and to provide the best visual comparison of contaminant concentrations over time, 2013 and 2020 sample data were utilized. Because there have been no historic concentrations of benzene above the 5 µg/L CUL, only TCE plume extent (5 µg/L contour) is illustrated on **Figure 10**. **Figure 10** also portrays the groundwater flow direction across the site, which was estimated from field measurements supporting the 2006 RI/FS, to indicate the direction of migration to the east and northeast, toward the Reindeer Creek (locally known as North River) tributary located approximately one mile north and downgradient from OT001/WP002 (USAF, 2006).

Table 2 Mann-Kendall Trend Analysis Results Summary

Location	Sample Event	Sample Date	Benzene		TCE		DRO	
			Concentration	M-K Trend & Statistic	Concentration	M-K Trend & Statistic	Concentration	M-K Trend & Statistic
			µg/L	S	µg/L	S	µg/L	S
BLO-MW-01	1	Sept-13	1.1	Stable -2	3.5	No Trend 2	1,300,000	Decreasing -8
	2	Sept-14	1.4		5		1,600,000	
	3	Oct-16	0.46		3.1 J		63,000 J	
	4	Sept-17	NS		NS		NS	
	5	Jul-19	1.3		5.6		20,000 J	

Location	Sample Event	Sample Date	Benzene Concentration	Benzene M-K Trend & Statistic	TCE Concentration	TCE M-K Trend & Statistic	DRO Concentration	DRO M-K Trend & Statistic
			µg/L	S	µg/L	S	µg/L	S
	6	Sept-20	1.06		4.17		15,000	
BLO-MW-05	1	Sept-13	ND	No Trend -4	0.37	Decreasing -9	75 J	No Trend 6
	2	Sept-14	ND		0.15		32 J	
	3	Oct-16	ND		ND		44	
	4	Sept-17	ND		0.16 J		NS	
	5	Jul-19	ND		0.046		ND	
	6	Sept-20	ND		0.032		ND	
BLO-MW-06	1	Sept-13	ND	No Trend -3	0.88	Decreasing -9	74 J	No Trend 5
	2	Sept-14	ND		0.14		42 J	
	3	Oct-16	ND		ND		ND	
	4	Sept-17	ND		ND		37 MJ	
	5	Jul-19	ND		ND		91 J	
	6	Sept-20	ND		ND		ND	
BLO-MW-07	1	Sept-13	ND	Stable -5	NS	Increasing 9	NS	No Trend 6
	2	Sept-14	ND		ND		84 J	
	3	Oct-16	ND		ND		ND	
	4	Sept-17	ND		ND		77 J	
	5	Jul-19	0.052		0.47		240	
	6	Sept-20	ND		0.771		ND	
DSA-MW-01	1	Sept-13	ND	No Trend -4	6.2	No Trend 3	NS	Insufficient Data
	2	Sept-14	ND		7.7		NS	
	3	Oct-16	ND		7.3		NS	
	4	Sept-17	ND		6.4		NS	
	5	Jul-19	ND		8.7		ND	
	6	Sept-20	ND		7.14		ND	
DSA-MW-02	1	Sept-13	ND	No Trend -1	500	Stable -7	47 JD	Increasing 8
	2	Sept-14	ND		490		31 J	
	3	Oct-16	ND		380		70 JM	
	4	Sept-17	ND		400		NS	
	5	Jul-19	0.12		330		210	
	6	Sept-20	ND		440		402	
DSA-MW-04	1	Sept-13	ND	No Trend 4	120	No Trend 4	97 JM	Stable 0
	2	Sept-14	ND		90		80 J	
	3	Oct-16	ND		340		82 JM	
	4	Sept-17	ND		440		NS	
	5	Jul-19	0.2		290		100 J	
	6	Sept-20	NS		NS		NS	
DSA-MW-05	1	Sept-13	ND	No Trend	2.8	Stable	NS	No Trend
	2	Sept-14	ND		2.9		NS	

Location	Sample Event	Sample Date	Benzene Concentration µg/L	Benzene M-K Trend & Statistic S	TCE Concentration µg/L	TCE M-K Trend & Statistic S	DRO Concentration µg/L	DRO M-K Trend & Statistic S
	3	Oct-16	ND	-3	2.2	-7	NS	2
	4	Sept-17	ND		0.58		NS	
	5	Jul-19	0.011		1.2		ND	
	6	Sept-20	ND		1.9		ND	
DSA-MW-06	1	Sept-13	ND	No Trend -4	ND	Stable -4	NS	Insufficient Data
	2	Sept-14	ND		0.15		NS	
	3	Oct-16	ND		ND		NS	
	4	Sept-17	ND		ND		NS	
	5	Jul-19	ND		0.096		ND	
	6	Sept-20	ND		ND		ND	
DSA-MW-07	1	Sept-13	ND	No Trend -4	ND	Stable -3	NS	Insufficient Data
	2	Sept-14	ND		ND		NS	
	3	Oct-16	ND		ND		NS	
	4	Sept-17	ND		ND		NS	
	5	Jul-19	ND		0.047		ND	
	6	Sept-20	ND		0.095		ND	
GLO-MW-03	1	Sept-13	ND	Stable 0	ND	Stable 0	NS	Insufficient Data
	2	Sept-14	ND		ND		NS	
	3	Oct-16	ND		ND		NS	
	4	Sept-17	ND		ND		NS	
	5	Jul-19	NS		NS		NS	
	6	Sept-20	ND		ND		ND	
GLO-MW-04	1	Sept-13	ND	No Trend -4	ND	Stable -5	NS	Insufficient Data
	2	Sept-14	ND		ND		NS	
	3	Oct-16	ND		ND		NS	
	4	Sept-17	ND		ND		NS	
	5	Jul-19	ND		0.094		ND	
	6	Sept-20	ND		ND		ND	
RRS-MW-05	1	Sept-13	ND	No Trend -3	0.11	Stable -1	NS	Insufficient Data
	2	Sept-14	ND		ND		NS	
	3	Oct-16	ND		ND		NS	
	4	Sept-17	ND		ND		NS	
	5	Jul-19	0.01		ND		ND	
	6	Sept-20	ND		0.11		ND	
RRS-MW-06	1	Sept-13	ND	No Trend -3	ND	No Trend -4	NS	Insufficient Data
	2	Sept-14	ND		ND		NS	
	3	Oct-16	ND		ND		NS	
	4	Sept-17	ND		ND		NS	
	5	Jul-19	0.01		ND		ND	

Location	Sample Event	Sample Date	Benzene		TCE		DRO	
			Concentration	M-K Trend & Statistic	Concentration	M-K Trend & Statistic	Concentration	M-K Trend & Statistic
			µg/L	S	µg/L	S	µg/L	S
	6	Sept-20	ND		ND		185 J	

Notes: **All concentrations are in µg/L.**

M-K Statistic: Trend is determined by a combination of the S value, coefficient of variation, and calculated confidence. Trend is generally reported as stable, decreasing (S < 0), increasing (S > 0), or without trend (S= 0). Source of guidance is: J.J. Aziz, 2003; WDNR 2003; EPA 2009.

Source of historic data is historic groundwater reports USAF, 2014c; 2015b; 2019a; 2019b;2020; 2021b.

In the case of a ND result as shown in **Table 2**, the laboratory reporting limit is utilized as the result value for the M-K analysis. For this reason, as reporting limits vary between laboratories or over time as equipment capabilities improve, ND results are not always consistent, and can provide for decreasing or increasing trends where a contaminant is not present.

Previous field studies have positively identified widespread POL and chlorinated solvent contamination in subsurface soil and groundwater surrounding the footprint of the Former Composite Building and adjacent Black Lagoon Outfall area from historic base activities which led to the source areas indicated in **Figure 10,** located about one mile south and upgradient from a tributary stream which feeds into Reindeer Creek (locally known as North River). While approximately 50,000 tons of POL- and PCB-contaminated soil has been removed from the RRS for offsite disposal, or treated onsite through landfarming to date, characterization efforts indicate an estimated 450 tons of PCB-contaminated soil remain above the 1.0 mg/kg CUL across the former Port Heiden RRS, with only an estimated 20% of that contamination remaining within or around the OT001 footprint (USAF, 2021a). With greatly reduced source areas and the ongoing occurrence of natural attenuation over time, TCE, benzene, and DRO concentrations should decrease over time (decreasing trend). However, the results of the M-K analysis indicate only 21 percent (%) of monitoring wells analyzed for benzene, 64% of monitoring wells analyzed for TCE, and 17% of monitoring wells analyzed for DRO resulted in decreasing or stable plume test results. A majority of the remaining single-well trend analysis results indicated no trend and/or lacked the stability or statistical confidence to provide a definitive plume stability result. Increasing contaminant plumes were confirmed only for TCE at monitoring well BLO-MW-07 with a positive M-K statistic of nine, and for DRO at monitoring well DSA-MW-02 with a positive M-K statistic of eight.

As a result of the statistical analysis performed for historic and recent groundwater monitoring events at Sites OT001 and WP002, an overall stable or decreasing trend was observed for TCE in groundwater, and an overall inconclusive trend was observed for benzene and DRO in groundwater. Statistically speaking, in order for a plume to be confidently considered in a declining state, wells must demonstrate decreasing contaminant levels over three or more consecutive sampling rounds. At this time, OT001 and WP002 groundwater quality has not demonstrated three consecutive years of decreasing contaminant trends for ROD COCs benzene and TCE, nor has that decreasing trend been demonstrated for DRO or RRO, and therefore the OT001 and WP002 contaminant plumes cannot be confidently considered in a declining state per the requirements of the statistical model.

2.3 Monitored Natural Attenuation

As a component of the current 2009 ROD groundwater remedy, monitoring and evaluation of natural attenuation parameters was conducted at Sites OT001 and WP002 in 2013, 2014, 2016, 2017, 2019, and 2020, in conjunction with monitoring groundwater for Site COCs, related daughter products, and the presence of petroleum hydrocarbon in diesel and residual ranges. Over time as fuel (benzene and DRO) components break down in groundwater from natural attenuation, the fuel by-products will help break down TCE (USAF, 2009). MNA parameter results have detected reportable concentrations of alkalinity, iron, manganese, Kjeldahl nitrogen, nitrate/nitrite nitrogen, and sulfate for the OT001 and WP002 groundwater quality. With the recent-confirmed presence of dissolved oxygen (i.e., oxidizing conditions) noted during well purge and stabilization procedures (USAF; 2020a, 2020b), aerobic biodegradation can be evaluated for potential in the reduction of benzene and DRO contamination. The fuel breakdown process ultimately uses the available dissolved oxygen, resulting in low dissolved oxygen concentrations in the aquifer. Low dissolved oxygen concentrations and reduced oxidation reduction potential are favorable to TCE breakdown. Over time, the current aerobic conditions actively reducing benzene and DRO concentrations are anticipated to transform to anerobic conditions, and become more effective at reducing TCE, PCE and related chlorinated daughter products.

Evaluation of MNA parameters over time can be used to determine trends amongst the monitoring well network to evaluate the progression of natural attenuation of the dissolved POL and solvent plume. During biodegradation, dissolved oxygen, oxidation reduction potential, nitrate, and sulfate decrease, and iron and alkalinity increase. **Table 3** summarizes the 2013-2020 groundwater analytical results of MNA parameters for Sites OT001 and WP002 for monitoring well sample locations reporting one or more exceeding concentrations of ROD COCs.

Table 3 MNA Parameters of Contaminated Groundwater

Location	Sample Date	Alkalinity	Iron	Manganese	Kjeldahl Nitrogen	Nitrate / Nitrite	Sulfate
		Concentrations in mg/L					
BLO-MW-01	Sept-13	918	21.8	10.7	--	0.017	4.5
	Sept-14	850	35.4	9.4	--	0.031	1.93
	Oct-16	850	5.6	9.7	0.33 J	ND (0.5)	6.5
	Sept-17	--	--	--	--	--	--
	Jul-19	800	4.8	12 J	ND (0.5) J	ND (0.12) J	2.2 J
	Sept-20	902	7.16	11.9	0.75	ND (0.05)	0.8
BLO-MW-07	Sept-13	--	--	--	--	--	--
	Sept-14	--	38.8	0.839	--	0.22	--
	Oct-16	42	1.4	0.026	0.19 J	0.14	3.8 J
	Sept-17	45	2.0	0.036	--	ND (0.5)	3.4
	Jul-19	47	3.4	0.16 J	ND (0.5)	0.07 J	3.6
	Sept-20	42.9	54.7	1.03	ND (0.13)	ND (0.05)	2.37
DSA-MW-01	Sept-13	72.3	1.82	0.073	--	0.12	3.99
	Sept-14	83	0.26	0.01	--	0.33	5.07
	Oct-16	80	0.065	0.002	0.76	0.89	12
	Sept-17	79	0.068	0.002	--	1.4	8.3
	Jul-19	77	0.29 J	0.015 J	ND (0.5)	0.88	7.4

Location	Sample Date	Alkalinity	Iron	Manganese	Kjeldahl Nitrogen	Nitrate / Nitrite	Sulfate
		Concentrations in mg/L					
	Sept-20	87.9	0.18	0.01	0.25	0.7	6.27
DSA-MW-02	Sept-13	131	77.4	1.55	--	1.44	6.93
	Sept-14	136	6.04	0.09	--	1.92	8.89
	Oct-16	120	1.9	0.03	ND (0.5)	1.4	9
	Sept-17	120	1.3	0.029	--	1.7	8.4
	Jul-19	130	9.6	5.3	ND (0.5) J	1.1 DJ	9.5
	Sept-20	119	88.7	1.34	ND (0.15)	1.87	8.5
DSA-MW-04	Sept-13	97.9	4.45	0.17	--	0.027	10.9
	Sept-14	114	21.7	0.57	--	ND (0.02)	11.1
	Oct-16	78	5.2	0.31	0.51 J	ND (0.5)	8.8
	Sept-17	110	2.1	0.067	--	0.32	8.3
	Jul-19	88	4.6	0.22	ND (0.5)	ND (0.12)	8.7
	Sept-20	--	--	--	--	--	--
PG1-MW-01	Sept-13	137	44.2	0.88	--	0.19	4.51
	Sept-14	111	7.63	0.156	--	0.33	6.35
	Oct-16	--	--	--	--	--	--
	Sept-17	--	--	--	--	--	--
	Jul-19	--	--	--	--	--	--
	Sept-20	--	--	--	--	--	--

Notes:

Concentrations are in milligrams per liter (mg/L)
-- = Not Analyzed
Laboratory Qualifiers:
ND = non-detect at the corresponding method detection limit; LOD reported in parenthesis
D = Analyte identified at a primary, secondary, or tertiary dilution
J = Result is an estimated concentration based on data assessment.

Based upon historic observations of dissolved oxygen concentrations in groundwater at the former Port Heiden RRS, aerobic biodegradation of fuels and weathering of TCE (although more slowly than fuels) is possible. However, the trends above do not show a predominant reduction in nitrate and sulfate, or a rise in iron or alkalinity to support positive evidence of passive aerobic degradation.

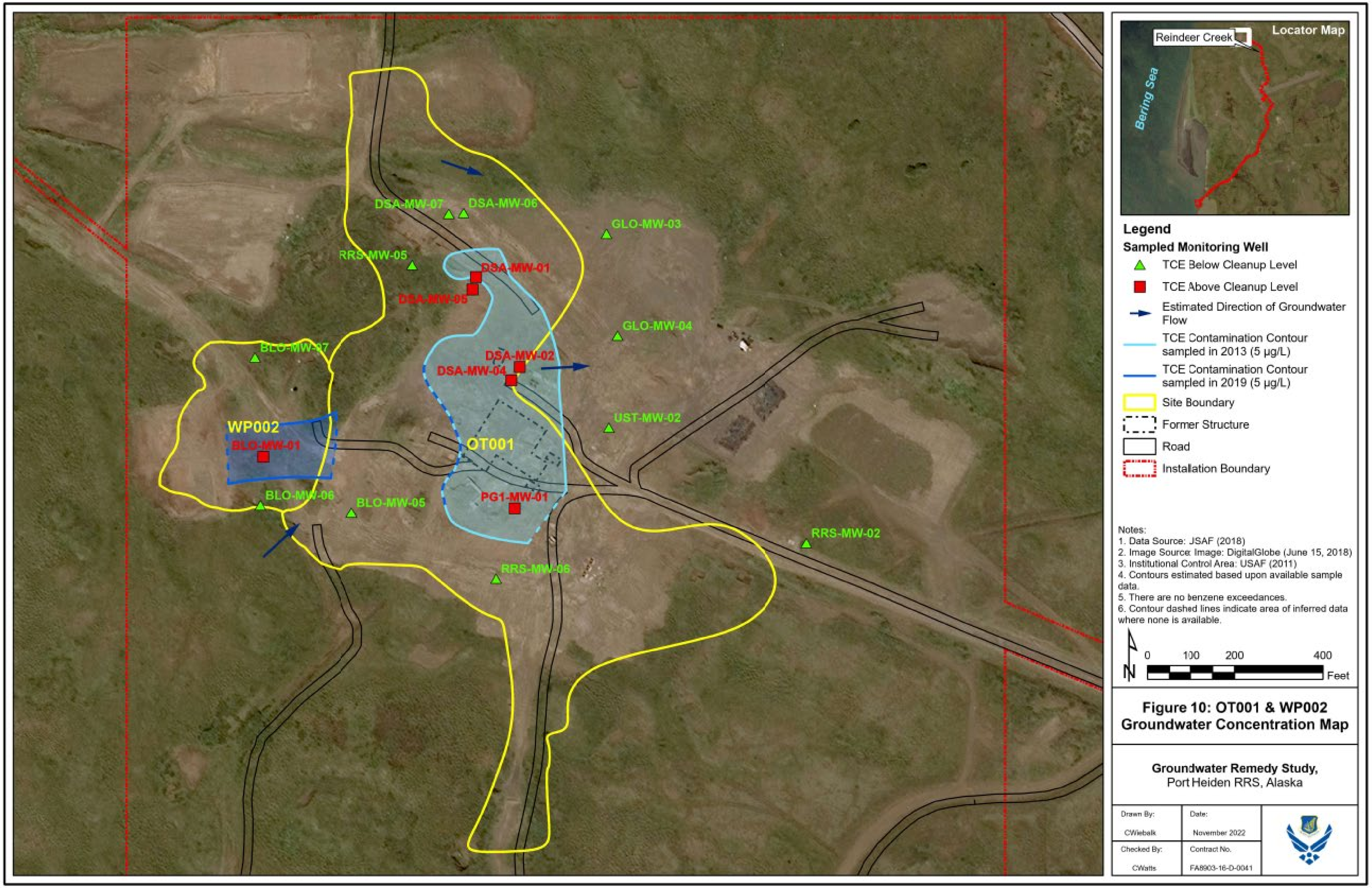
2.4 Protectiveness Statement

The second FYR issued in December 2019 determined the remedy protectiveness to be deferred until further information could be obtained through the completion of a groundwater remedy study (USAF, 2019d). Based upon the conclusions of the groundwater trend estimates and M-K statistical analysis, concentrations of TCE in groundwater remain above the 2009 ROD-based CUL of 5 µg/L in 5 monitoring wells, with an increasing or stable plume confirmed at one of these monitoring locations (DSA-MW-02). TCE trend estimates indicate project cleanup goals will remain unachieved at the Port Heiden RRS for at least 5 of the 16 monitoring wells by 2035.

Dissolved concentrations of benzene have achieved the 2009 ROD-based CUL, however POL contamination remains a concern at Sites OT001 and WP002 given the concentrations of DRO and RRO above applicable 18 AAC 75 Table C CULs. The long-term trend analysis indicates both DRO, and RRO concentrations will reach Table C CULs by 2035.

Although a distinct reduction in dissolved COC contamination has been observed in particular wells, because the chemical-specific RAO for TCE is expected to remain unachieved in 31% of available monitoring wells, the current remedy of LTM with MNA and LUCs is not considered protective of human health and the environment. In accordance with the 2009 ROD, groundwater use restrictions and LUCs will remain in place to prevent exposure of potential receptors to contaminated groundwater until 18 AAC 75 Table C CULs are met. In this way, protectiveness of the remedy is upheld. **Figure 10** provides illustrations of the dissolved TCE plume extent above the 2009 ROD CUL of 5 µg/L for the 2013 and 2019 groundwater monitoring events.

Figure 10 OT001 & WP002 Groundwater Concentration Map



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3.0 PROPOSED & POTENTIAL GROUNDWATER REMEDIES

This Groundwater Remedy Study is an iterative process that relies on the existing analytical findings, CSM, risk evaluation, and exposure scenarios derived from past site investigations to identify and evaluate potential remedial alternatives that will satisfy site RAOs if implemented. Based upon historic sampling performed during the 2004 RI, the findings of the CSM evaluation presented in the 2006 RI/FS, and the evidence collected from ongoing groundwater monitoring implemented by the 2009 ROD groundwater remedy since 2013, a revised remedial alternative is necessary to address the remaining concentrations confirmed the past two years of monitoring (2019-2020) of TCE (up to 440 µg/L), PCE (up to 990 µg/L), DRO (up to 20,000 µg/L) and RRO (up to 4,200 µg/L in 2016; not recently analyzed for) in groundwater at Port Heiden RRS Sites OT001 and WP002. Concentrations of these four parameters remain above the chemical-specific ARARs, leaving the first RAO listed in Section 1.4 (achievement of CULs) unsatisfied, without the possibility of reaching these goals within 25 years of remedy implementation by 2035.

In conjunction with the continued PCB- and POL-contaminated soil removal planned by the USAF to continue in 2022, the employment of a revised remedial alternative for groundwater at Port Heiden RRS Sites OT001 and WP002 is anticipated to reduce or eliminate exposure pathways for potential human and ecological receptors or achieve site cleanup goals in such a manner that will be protective of human health and the environment. Historic sampling data, trend analysis, statistical evaluation outputs, and new and innovative remedial technologies were evaluated to identify potential alternatives and to assist in the selection the preferred revised remedial alternative to address chlorinated solvents and POLs in groundwater at Sites OT001 and WP002. The purpose of the Groundwater Remedy Study, in addition to following the CERCLA process, is to develop a revised list of acceptable remedial alternative options to address TCE, PCE, DRO, and RRO in groundwater, which in this case require treatment/removal of the remaining source term in the soil, as indicated in Section 1.3.1, for the removal of the estimated remaining 450 tons of PCB and POL-contaminated soil at the former RRS. The CERCLA evaluation process provides an effective and standardized method for evaluating potential remedial alternatives and for the selection of the preferred remedial alternative.

This Groundwater Remedy Study includes evaluation of only those remedial alternatives that are implementable in a semi-remote geographic location such as Port Heiden. This criteria includes new and innovative technologies, as well as those that have received USAF and regulatory concurrence as potentially viable remedial options for similar Alaskan chlorinated solvent and POL-contaminated sites. The potential remedial alternatives for the Port Heiden RRS are limited by several factors, including the following:

- The semi-remote location is not road accessible to developed regions of Alaska or to permitted disposal facilities, and requires barge or air transport of materials and staff;
- The cold, damp south Alaskan marine climate provides a moderately short duration between spring and fall when temperatures are above freezing that would allow for implementation of in-situ biological alternatives, or transportation of equipment and materials via barge;
- The limitations of local resources and the significant expense that would be incurred for transport of equipment, supplies, and resources that would be associated with portable treatment facilities.

Remedial alternatives are evaluated on a media-specific basis, focusing on options that respond well to POL and chlorinated solvent contaminants, and the nature and extent of the COCs that have impacted the site. Rough cost estimates were developed for each potential remedial alternative evaluated to allow for a ranked comparison of low, medium, and high implementation costs in comparison with trade-offs for achieving RAOs along with the estimated time-frame to achieve the 2009 ROD CULs.

Under CERCLA, the feasibility to implement the revised remedial alternatives are evaluated using the five principal requirements established by the EPA that include the following objectives:

- Protection of human health and the environment;
- Compliance with site-specific ARARs (chemical, location, and action);
- Cost-effectiveness of implementation;
- Permanence of the selected alternative and potential to implement alternate treatment technologies or resource recovery technologies; and
- Satisfy a preference for treatment as a principal element or provide an explanation in the ROD as to why this preference was not met.

The objective of the revised remedial alternative is to provide protection to human health and the environment based upon the future restoration goals of unrestricted land use, as per the 2009 ROD (USAF, 2009). The proposed revised remedial alternatives selected for further evaluation were based upon the site's geographic location, its future land use, trends monitored through the current remedy to date, and the remedial goals using nine criteria as outlined under the CERCLA FS Guidance. Each of the nine evaluation criteria are described below:

1. **Protection of human health and the environment:** How well does the alternative provide protection to human health and the environment?
2. **Compliance with ARARs:** Does the alternative meet applicable state and federal laws?
3. **Long-term effectiveness and permanence of the alternative:** What is the long-term risk after implementation of the Remedial Action (RA) is complete? Are the COCs permanently removed or destroyed?
4. **Toxicity, mobility, or volume reduction through treatment:** How well does the treatment reduce toxicity, mobility, or volume of the contaminants?
5. **Short-term effectiveness:** Could the health and safety of human and ecological receptors be impacted during the implementation of the alternative?
6. **Implementability:** Is the alternative available and able to be constructed, maintained, and/or enforced? What is the technical and administrative feasibility of this alternative and availability of the required goods and services?
7. **Cost:** Is the alternative cost-effective in terms of both capital and operational and maintenance costs?
8. **State agency acceptance:** What are the State's (or supporting agency's) comments or concerns pertaining to the alternatives considered and the selection of the preferred alternative?
9. **Community acceptance:** What are the community's comments or concerns regarding the alternatives considered and the selection of the preferred alternative?

Under CERCLA, Criteria 1 and 2 are threshold criteria that must be met by statute for a proposed alternative to be considered for implementation. Criteria 3 to 7 are the primary balancing factors on which each alternative is evaluated to identify the selection of the preferred alternative. Criteria 8 and 9 are modifying criteria that will be evaluated upon obtaining regulatory and community comments on a future Proposed Plan or Explanation of Significant Difference. At this Groundwater Remedy Study evaluation stage, neither the State or community have reviewed the findings documented in this study or the revised list of remedial alternatives, therefore, the level of acceptance has yet to be verified. The State will review and comment on the Groundwater Remedy Study, and the State and community will be given the opportunity to review and provide input on the potential and preferred remedial alternatives in a subsequent Proposed Plan or Explanation of Significant Difference prior to development of a ROD Amendment for Sites OT001 and WP002.

3.1 2006 RI/FS Proposed Remedies

This section provides an updated description and summary of the screening process for each of the remedial alternatives considered for groundwater, including the contaminated smear zone soils within the groundwater plumes, as part of the 2006 RI/FS prepared by the USAF (USAF, 2006). Recent groundwater concentrations and site conditions have been incorporated into the re-evaluation of each alternative. The remedial alternatives for Sites OT001 and WP002 groundwater which were developed in 2006 for the Former Facility Area groundwater, included:

1. **No Action** (Alternative No. 1) - The "No Action" alternative was included to provide a baseline, as required by CERCLA, as part of the FS process performed in 2006 and repeated within this Groundwater Remedy Study. This option for which no action is taken, allows for comparison with the other alternatives evaluated. TCE, PCE, DRO, and RRO-contaminated soil and groundwater would remain untreated. Over time, the solvent and fuel concentrations would be reduced by biological processes and weathering. Natural attenuation of contaminants, although unmonitored, would proceed slowly due to the cold subsurface temperatures and nature of TCE and PCE to breakdown into components with their own associated risks to the environment. This alternative requires no action, so it could be implemented immediately, however, due to the long-term liability associated with this alternative and the lack of protection, it is not considered a viable alternative.
2. **Long Term Monitoring, Land Use Controls, and Monitored Natural Attenuation** (Alternative No. 2) – This alternative is the current selected remedy for groundwater, determined by the 2009 ROD (USAF, 2009). Similar to Alternative No. 1, this option is non-invasive, or passive, and would include leaving in place all remaining contaminated soil and groundwater with concentrations above applicable CULs with ongoing natural attenuation occurring slowly over time by natural biological processes and weathering. However, this alternative also includes, annual LTM of progress, enforcement of LUCs, maintenance of implemented LUCs, and a FYR process to evaluate the protectiveness and applicability of the remedial alternative. Periodic groundwater monitoring would be performed at the facility to assess changes in groundwater concentrations over time. In an effort to ensure subsurface contamination remains in the subsurface, and groundwater use is restricted, annual LTM would be performed to inspect the area for evidence of erosion or subsidence, to confirm dig restrictions and groundwater use restrictions have been maintained, and to confirm the LUC signage in place remains intact and legible to warn site visitors of the presence of contaminated material. Property restrictions already in place as LUCs managed within the 2009 ROD would be maintained. As per CERCLA requirements,

a summary of LUCs would be reported to ADEC annually, and the remedy protectiveness would be reviewed every five years (FYR) until the need for LUCs is removed by the reduction in TCE, PCE, DRO, and RRO concentrations to below the ADEC Table C Groundwater CULs.

3. **Long Term Monitoring, Land Use Controls, and Enhanced Bioremediation** (Remedial Alternative No. 3) – This option differs from the first two in that it involves an active, rather than passive response, through enhanced bioremediation efforts. Groundwater at Sites OT001 and WP002 that is contaminated with TCE, PCE, DRO, and RRO would be treated with injection of chemical agents into groundwater via existing monitoring wells to enhance natural biodegradation of the contaminants. An oxygen-releasing compound, specifically designed for slow time-release over up to 12 months, would be used to target DRO and RRO-contaminated areas to enhance aerobic biodegradation, while a hydrogen-releasing compound would be implemented to target TCE and PCE to discretely enhance anaerobic biodegradation. Soil nutrients beneficial to bioremediation would also be incorporated. Alternating, discrete injection treatments repeated in low doses annually, would fuel the naturally-occurring bacteria existing within the groundwater and saturated soil, increase the bacterial rate of contaminant degradation, and result in a decrease of the contaminant concentrations until CULs were achieved within an estimated time frame of 10 years after implementation. Periodic groundwater monitoring would be performed at the facility to assess changes in groundwater concentrations over time and LUCs would be implemented. Notices would be placed on property records to inform current and future property owners of the presence of groundwater contamination. Restrictive covenants would also be implemented to prevent the installation of drinking water wells within the areas of contaminated groundwater. These LUCs would remain in-place until ADEC Table C Groundwater CULs were achieved.

4. **In-situ Treatment by Chemical Oxidation** (Remedial Alternative No. 4) - This option, as with Remedial Alternatives #3, involves an active treatment, however this option provides a more aggressive approach, without the reliance on natural biodegradation to achieve CULs. Groundwater at Sites OT001 and WP002 that is contaminated with TCE, PCE, DRO, and RRO would be treated using a potent dose of chemical oxidant (as compared to Alternative 3) injected into the contaminated groundwater plume and within the remaining soil source term. Reaction with the oxidant would degrade the contaminants in the groundwater to concentrations below CULs within an estimated time frame of two years after implementation. The oxidant would be injected using a Direct-Push Technology rig. Mobile chemical tanks for oxidant transport and storage would be required to support the injection operation. Confirmation groundwater samples would be collected following in-situ treatment to evaluate the reduction in mass flux reduction, and then again within roughly 6 months to ensure TCE, PCE, DRO, and RRO concentrations were reduced below ADEC Table C Groundwater CULs. Re-injection of chemical oxidant could be considered based on results, to advance the response as needed.

3.2 Other New or Potential Remedies to Consider

During the 2006 RI/FS, treatments requiring resources such as an electrical source, heavy equipment or fuel were not considered, given the remote nature of the area, the lack of available infrastructure, and the potential for vandalism and theft of equipment associated with operation and maintenance systems. In an effort to consider a wider range of remedial alternatives for achievement of the groundwater CULs at Port Heiden RRS, these limitations can be overcome with proper logistical planning and temporary site security during implementation, if necessary.

Although in-situ treatment options such as chemical oxidation or reactive barrier containment are widely used in the remediation industry, some of the oldest and most proven technologies to treat petroleum and solvents in groundwater include some form of pump and treat with an above-ground treatment component, prior to reinjection to the aquifer.

Additional groundwater remedial alternatives that were considered as part of this Groundwater Remedy Study with the intent to eliminate, control and reduce project risks, include:

5. **On-Site Treatment by Pump and Treat with Air Stripping and GAC Filtration** (Remedial Alternative No. 5) - This option is a mechanical groundwater treatment which would physically remove the solvent and petroleum fractions from the aquifer by means of operating a traditional pump and treat system, with aboveground treatment units for air stripping and Granular Activated Carbon (GAC) filtration, feeding treated water into a final holding tank to be tested before release back into the aquifer. While the equipment, fuel, and oversight resource demand during on-site implementation would be more extreme than Alternatives #2, 3, or 4, the resulting decrease in groundwater contamination would also be more pronounced. Additional extraction and injection wells may also be required to treat the combined OT001 and WP002 area. A pump and treat system is anticipated to result in CULs being achieved within three to five years of operation. Breakdown and storage of treatment equipment be expected over winter. Confirmation groundwater samples would be collected to assess if/when TCE, PCE, DRO, and RRO concentrations were reduced below ADEC Table C Groundwater CULs before reinjection back into the aquifer, but also, groundwater monitoring would be conducted after treatment was completed to ensure contaminant levels remained below applicable CULs once the aquifer had returned to stable, static conditions.

6. **In-situ Treatment by Thermal Remediation Using Electrodes and/or Steam** (Remedial Alternative No. 6) – Similar to Remedial Alternative #4, this option involves an active treatment process that allows the groundwater to remain in place during implementation. The treatment system would require a large logistical investment to transport, setup, and operate the thermal system. Groundwater would be treated for the duration of the Port Heiden field season (two to three months) using either downhole electrodes or steam injection to heat the plume areas in order to thermally strip the solvent and fuel contamination from groundwater. Additional injection wells may also be required to treat the combined OT001 and WP002 area. Confirmation groundwater samples would be collected to ensure TCE, PCE, DRO, and RRO concentrations were reduced below ADEC Table C Groundwater CULs. Based upon the observed response to treatments by the aquifer, and magnitude of smear-zone contamination, multiple treatment and confirmation events may be required, although CULs are expected to have been achieved within approximately two years of operation. The capture of volatilized fuel components from heated soil and groundwater is also a concern, given the opportunity to mobilize contaminants beyond the current extent of contamination. Downgradient groundwater and soil vapor monitoring may be necessary to confirm mobilization from thermal remediation is not occurring.

7. **In-Situ Treatment and Containment by Permeable Reactive Barrier** (Remedial Alternative No. 7) – As with Remedial Alternatives #4 and 6, groundwater would remain in-place within the subsurface during implementation of this option. Permeable reactive barriers filled with a combination of zero-valent iron granules and organic matter would be used to both remediate and contain the POL and TCE plumes, in-situ. Trenching health and safety procedures would be important to maintain the safety of remedial operators performing the barrier installation at depth. Additional downhole injection of reactive barrier material within the source zone would magnify the reaction and promote degradation of contaminants both within the plume area and downgradient groundwater. Achievement of groundwater CULs is expected within approximately 5 years from implementation. Resource demands would include heavy equipment, fuel, and operators to install the barriers and injection wells. Additional monitoring wells placed precisely up, and downgradient of the plume-barrier interface may also be required to properly monitor the treatment progress of Sites OT001 and WP002 groundwater. Confirmation groundwater samples would be collected to ensure TCE, PCE, DRO, and RRO concentrations downgradient of the permeable reactive barrier were reduced below ADEC Table C Groundwater CULs.

3.3 Evaluation of Select Groundwater Remedies

Following an observed persistence of TCE, PCE, DRO, and RRO groundwater contamination at Port Heiden RRS Sites OT001 and WP002, documented within the second FYR of the current groundwater remedy, and concurred with this Groundwater Remedy Study (Section 2.4), an updated evaluation of the 2006 RI/FS proposed remedies and other new potential remedial alternatives has been performed. A comparative analysis has been performed for each of the three primary criteria – effectiveness, implementability, and cost. **Table 4** summarizes the evaluation of seven possible alternatives in comparison to the seven available CERCLA criteria and provides ranked results. CERCLA criterion 8 and 9, state and community acceptance, will be evaluated at a later date once that feedback on the newly selected remedy has become available.

Each of the remedial alternatives for groundwater at Port Heiden RRS Sites OT001 and WP002 assumes that the USAF will continue to remediate the contaminated soil source term, as indicated in the latest Remedial Action Report (USAF, 2021a) which reported that soil excavation and characterization efforts would continue in 2022. While neither of the passive Alternatives #1 or 2 are able to meet the ARARs within the previously estimated 25-year period, it is estimated that active Alternatives 3, 4, 5, 6, and 7 would be successful in reducing TCE concentrations to below the 5 µg/L CUL by 2035. Prior to implementation, the revised selected remedy will be provided for regulatory review and public consideration in a future Proposed Plan or Explanation of Significant Difference and documented in a ROD amendment.

3.3.1 Effectiveness

Each of the active groundwater treatment Alternatives #3, 4, 5, 6, and 7 could effectively reduce the concentrations of solvents (TCE, PCE) and fuels (DRO, RRO) in groundwater to levels below 18 AAC 75, Table C CULs, involving a physical or chemical treatment process. Left untreated (Alternative 1), or under the current groundwater remedy of LTM with MNA and LUCs as specified by the 2009 ROD (Alternative 2), contamination is shown to persist, and migration of groundwater containing TCE, PCE, DRO, and RRO to a surface water tributary stream which connects to Reindeer Creek is possible. The following sections evaluate various forms and degrees of effectiveness comparatively of the originally proposed and other new or potential remedial alternatives.

3.3.1.1 Overall Protection of Human Health and the Environment

Almost all risk is eliminated through the implementation of Alternatives #3, 4, 5, 6, or 7, while concurrently providing a high level of protection to human health and the environment. With these alternatives, Port Heiden RRS soil and groundwater would be treated to meet RAOs and reduce concentrations of solvents and fuels to below CULs, alleviating the risk for downgradient impact to the surface waters of Reindeer Creek by way of tributaries. Only during well installation, sampling, groundwater treatment operation and maintenance, or waste disposal activities would site workers or remediation contractors potentially be exposed to risk through direct contact, inhalation, or ingestion of groundwater or vapors. However, by maintaining compliance with safety training requirements and utilizing proper PPE, this risk can be safely managed. Alternative #2 provides protection of human health and the environment through maintenance of LUCs, although risk remains for the potential downgradient migration to surface waters given the persistent presence of fuel and solvent-contaminated groundwater despite slowly progressing natural attenuation. Alternative 1 is the only option which does not provide protection to either human health or the environment.

Additional consideration of the protectiveness of human health and the environment should also be given to Alternatives #5 and 6, which would require a large supply of fuel to generate electricity necessary to operate the treatment systems. This fuel demand, in conjunction with the release of vapors from diesel generator operation creates a negative impact to the environment.

3.3.1.2 Compliance with ARARs

Evaluation of the proposed alternatives indicates that all alternatives, except the No Action Alternative 1, and the LTM with LUCs and MNA Alternative 2, meet ARARs outlined in the 2009 ROD. Chemical-specific ARARs for groundwater are met with the implementation of Alternatives #3, 4, 5, 6 and 7 with the treatment of OT001 and WP002 to reduce concentrations of solvents and fuels to achieve CULs. Alternatives #1 and 2 do not comply with chemical-specific ARARs.

Similarly, location-specific ARARs are also met by each of the alternatives other than Alternatives #1 or 2. During implementation of any one of the considered forms of in-situ treatment, the use of contaminated groundwater as a potential drinking water source will be restricted until degradation of the contaminants to acceptable levels has been confirmed. During implementation of the preferred RA, no sensitive or rare plants, threatened or endangered species are expected to be disturbed. Alternative #5 includes an added risk of exposure with contaminated groundwater pumped to the surface and contained prior to treatment. Alternatives #3, 4, 6, and 7 avoid any added risk to the environment during field implementation, as treatment occurs within the subsurface, and groundwater would remain in place within the aquifer until CULs were achieved.

Action-specific ARARs are expected to be met by all alternatives, except the No Action Alternative #1. Requirements for health and safety, stormwater protection, and restrictions on use of groundwater as drinking water will be adhered to with the use of LUCs such as deed notations and signage, and engineering controls such as silt fences and berms, dust suppression, and a strict health and safety protocol will be maintained during monitoring network improvements, groundwater treatment and sampling activities, as necessary.

3.3.1.3 Long-Term Effectiveness and Permanence

To successfully eliminate risk of potential human or ecological receptor exposure to solvents and fuels within the aquifer that underlies Port Heiden RRS Sites OT001 and WP002, Remedial Alternatives #4, 5, 6 and 7 provide the most long-term effectiveness and permanence. While Remedial Alternatives #2 and 3, based upon the 2009 ROD language, were intended to have provided long-term effectiveness and permanence through treatment, based upon the findings of this study, are no longer considered effective at removing risk of exposure through decrease in contaminant concentrations within a practical (within 30 years) timeframe. Remedial Alternative #5 (on-site pump and treat with air stripping and GAC filtration) is ranked the highest in long-term effectiveness, as it provides the most assurance for complete removal of solvent and fuels, as compared to the least long-term effective treatment of Remedial Alternative #2 (LTM with LUCs and MNA).

3.3.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Concentrations of fuels and solvents would be reduced to levels considered safe to human health and the environment through each of the active treatment Alternatives (#3, 4, 5, 6, and 7), meeting the balancing criteria for reduction of toxicity. With Remedial Alternative #7, mobility of solvent and fuels would be controlled by the permeable reactive zero-valent iron / organic matter barrier that would immobilize the groundwater plume to prevent potential offsite migration, while reduction of toxicity would also occur as the in-situ chemical reaction takes place at the source term of the plume. While Alternative #2 (LTM with LUCs and MNA) would continue to result in a slight reduction in toxicity over time, the approach has been shown to be ineffective to achieve contaminant reduction to achieve CULs since its implementation in 2009. Alternative #1 would have no impact to toxicity, mobility, or volume of contaminants in soil or groundwater.

3.3.1.5 Short-Term Effectiveness

Short-term effectiveness, in terms of impact, and necessary time to achieve RAOs, ranks the highest with Remedial Alternative #7 (in-situ treatment and containment by permeable reactive barrier), as implementation could be complete within a week, and an observable affect within a month. The next most effective option in the short-term is Remedial Alternative #4 (in-situ treatment by chemical oxidation), with implementation estimated at one week, and marked contaminant reduction expected within two weeks. Remedial Alternatives #3, 5 and 6 (LTM with enhanced bioremediation, pump and treat, and thermal remediation) are ranked as average with regard to short-term effectiveness, as they are each estimated to take several months to implement.

Protection of the community and the environmental contractors performing the tasks during implementation of the remedy would be addressed within the site-specific health and safety plan procedures for implementation, overseen by an authorized environmental professional and site safety officer, as well as documented in the subsequent after action report. In the short-term, Alternatives 2 – 7 are each capable of remaining protective to the community and site workers during implementation, given appropriate procedures are followed, and personal protective equipment is correctly utilized.

3.3.2 Implementability

Each of the alternatives can be implemented both technically and administratively. Critical construction components such as heavy equipment and materials are either being sourced locally or will be mobilized in a timely manner for implementation and execution of Remedial Alternatives 3, 4, 5, 6, or 7. With equipment mobilization, there is potential for weather delays, particularly with fog in the vicinity of Port Heiden during barging season, or ice early in the field season. Specific to the relatively longer time it would take to implement Remedial Alternatives 4, 5, or 6, weather delays have the potential to affect these alternatives more than Remedial Alternatives 2, 3, or 7.

3.3.3 Cost

Each of the seven remedial alternatives were evaluated to provide a ranked comparison of low, medium, and high, for the level of effort required for their implementation based upon the impacted media and the COC. **Table 4** concisely summarizes the ranked order outcome described below.

The No Action Alternative 1 is the least expensive to implement because no effort nor cost would be expended to address contaminated groundwater at Port Heiden RRS. This alternative is not considered a viable option, as it affords no protection of human health and the environment. Alternative 2, which is the current remedy selected by the 2009 ROD, and implemented at Port Heiden RRS since 2010, is the next least expensive alternative, as no heavy equipment or barging is needed outside of occasional monitoring well network improvements, which may include mobilization of a drill rig. Despite being the second least expensive alternative, the cost is still relatively high, as the annual inspection, sampling, and reporting requirement remains until RAOs are met and LTM is discontinued, which on the current course is estimated to take well over 25 years to achieve, as evidenced by Appendix C trend estimates.

Alternatives 3 and 4 are considered low-cost to implement and are only a small amount more of a financial investment to see through than current Alternative 2. While the LTM with LUCs and enhanced bioremediation (Alternative 3) would be a long-term response requiring annual monitoring and reporting and require at least 10 years to successfully treat the groundwater, it is estimated that in-situ treatment through chemical oxidation (Alternative 4) would treat the groundwater plume within one to two field seasons. Pump and treat (Alternative 5), thermal remediation (Alternative 6) and permeable reactive barriers (Alternative3 7) are estimated to require anywhere between two and five years to implement and achieve CUL goals for TCE, PCE, DRO and RRO in groundwater.

The medium-cost option from this set of alternatives is the in-situ treatment and containment by permeable reactive barrier Alternative 7. Heavy equipment needs would include a tractor or backhoe to excavate the trench, place the barrier, and cover with soil. If not locally available for use, the heavy machinery would be barged in. Installation and treatment would be complete within one to two field seasons and would not require operation or oversight after installation.

Alternatives 5 (pump and treat) and 6 (thermal remediation) represent the high-cost alternatives from the selection, with 5 being estimated as the highest of the two. Both require not only mobilization of the heavy equipment that will be needed for the duration of a full field season, but also a coordinated mobilization of the above ground treatment process equipment including holding tanks, air stripper tower, GAC filter tanks, and a mobile boiler, in addition to generators capable of supplying power for the season, and fuel to operate the equipment.

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Table 4 Comparison of Groundwater Remedies

Groundwater Remedy	Threshold Criteria		Balancing Criteria				
	Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume through Treatment	Short-term Effectiveness (Impacts, Times to Achieve Remedial Action Objectives)	Implement-ability	Cost
2006 RI/FS Proposed Remedies							
No. 1 - No Action	Fail	Fail	0	0	0	0	0
No. 2 - LTM, LUCs and MNA	Fail	Fail	1	1	0	5	5
No. 3 - LTM, LUCs and Enhanced Bioremediation	Pass	Pass	2	2	3	4	4
No. 4 - In-Situ Chemical Oxidation	Pass	Pass	3	4	4	3	4
Other New or Potential Remedies							
No. 5 - On-Site Pump and Treat, Air Stripping and GAC Filtration	Pass	Pass	5	5	3	1	1
No. 6 - In-Situ Thermal Remediation Using Electrodes and/or Steam	Pass	Pass	4	4	3	2	2
No. 7 - In-Situ Permeable Reactive Barrier	Pass	Pass	3	3	5	2	3

Key: 5 – Best 4 – Better than Average 3 – Average 2 – Worse than Average 1 – Worst 0 – Not Applicable

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4.0 GROUNDWATER REMEDY STUDY FINDINGS & CONCLUSIONS

This section presents the conclusion of the Groundwater Remedy Study for Sites OT001 and WP002 at Port Heiden RRS, AK. Based upon the evaluation of existing groundwater data, the statistical analysis performed, and trends in contaminant and natural attenuation parameters, the POL and solvent plume beneath the former RRS, while decreasing in some areas, remains stable or increasing in 4 of the 5 wells with TCE concentrations above the 5 µg/L CUL. Furthermore, Sites OT001 and WP002 groundwater quality is not trending towards achievement of the 2009 ROD RAO of 5 µg/L for TCE by 2035. Exceedances of applicable Table C CULs have also been recorded in recent monitoring events for PCE in 3 monitoring wells, and for DRO and RRO in 1 monitoring well. Site-wide benzene concentrations are below the ROD-based CUL, and cis-2-DCE and trans-2-DCE concentrations have reduced to levels below their respective Table C CULs.

Improvements to the existing groundwater monitoring well network are recommended to facilitate comprehensive annual groundwater monitoring at Sites OT001 and WP002. The following changes to the well network are recommended to optimize (Aziz et. al. 2003) monitoring capabilities:

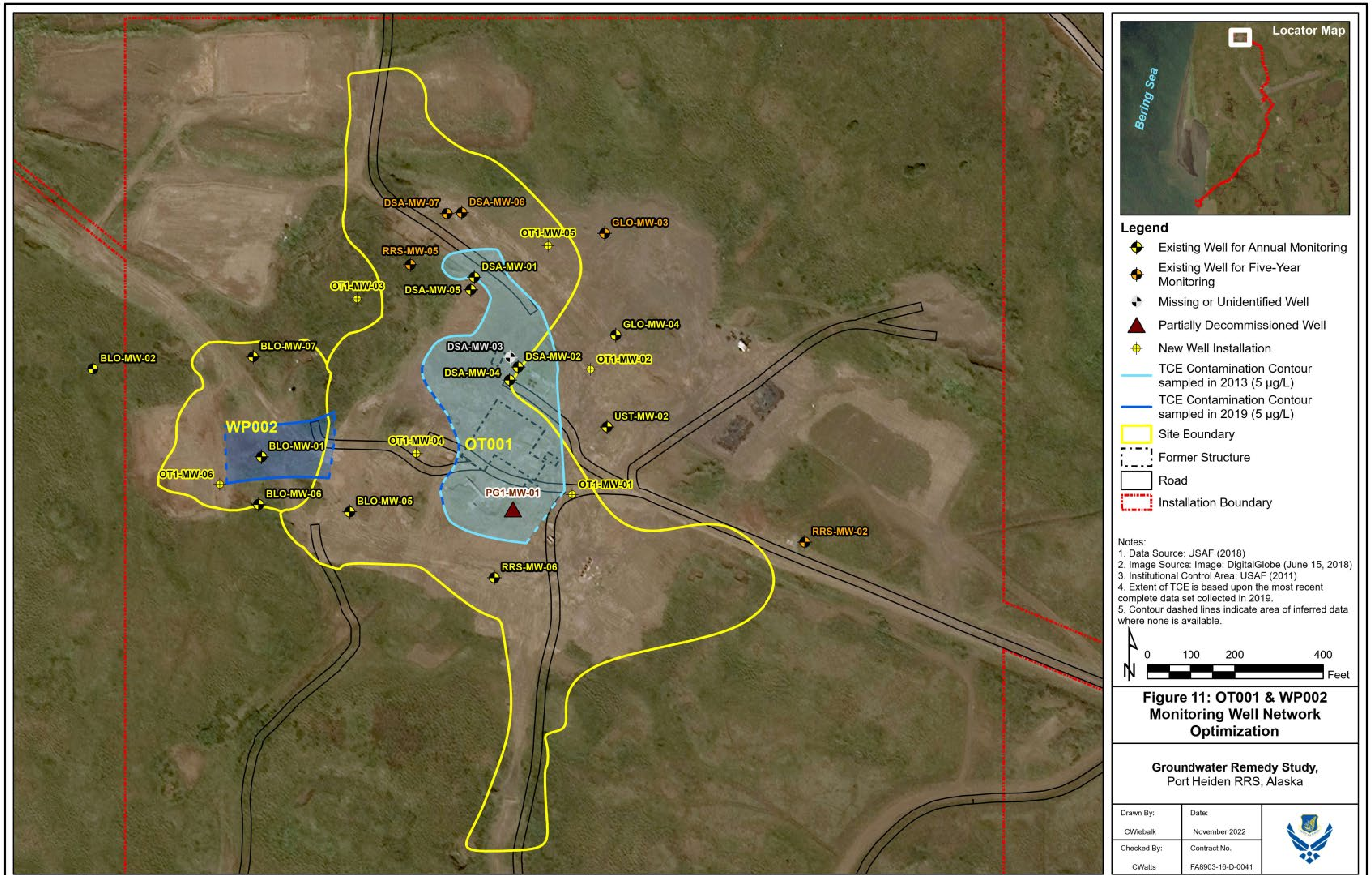
- 1 Well Decommission and Replacement: PG1-MW-01
- 1 Well Locate: DSA-MW-03
- 6 New Well Installations:
  - OT1-MW-01 along the undefined southeast edge and southern half of the OT001 plume
  - OT1-MW-02 at the downgradient edge of the northern half of the OT001 plume
  - OT1-MW-03 at the upgradient edge of the center of the OT001 plume
  - OT1-MW-04 within the southern half of the OT001 plume
  - OT1-MW-05 north of, and cross-gradient from the OT001 plume
  - OT1-MW-06 along the undefined upgradient edge of the WP002 plume
- 11 Existing Wells for Inclusion in Annual Monitoring: BLO-MW-01, BLO-MW-05, BLO-MW-06, BLO-MW-07, DSA-MW-01, DSA-MW-02, DSA-MW-04, DSA-MW-05, GLO-MW-04, RRS-MW-06, UST-MW-02
- 5 Existing Wells for Inclusion in 5-year Monitoring (to be conducted simultaneously with the 11 wells included in the 5th annual monitoring event): DSA-MW-06, DSA-MW-07, GLO-MW-03, RRS-MW-02, RRS-MW-05

Ongoing annual groundwater monitoring from the 11 existing wells, 1 replaced well, 1 located well, and 6 new wells should continue for analysis of TCE, PCE, 1,4-dioxane, DRO, and RRO, until two consecutive monitoring events indicate 18 AAC 75 Table C Groundwater CULs have been achieved at all 19 associated monitoring wells. To confirm no ecological impacts are occurring based upon the applicability of 18 AAC 70 given the potential impact to downgradient surface waters of the Reindeer Creek, Total Aromatic Hydrocarbons (TAH) and Total Aqueous Hydrocarbons (TAQH) should also be analyzed annually. Once analytes are confirmed below CULs for two consecutive monitoring events they may be discontinued. Also, as annual monitoring locations demonstrate a reduction of contaminants for two consecutive monitoring events below their respective CULs, they may be transitioned into the 5-year monitoring list.

PG1-MW-01 was considered decommissioned in 2020 when the subsurface portions of well casing and screen were unidentified (USAF, 2021b), however it represents an area of interest for site groundwater and will need to be replaced. Additional wells (listed above for 5-year monitoring) and parameters are recommended to coincide with the FYR schedule to allow an expanded observation window that should include monitoring all available sites wells for the analytes above, as well as benzene, cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride. While benzene and these common TCE breakdown analytes or predecessors have historically remained either non-detect or below CULs, future spikes in production are possible as weathering continues and biodegradation progresses, and should be monitored at a less-frequent, 5-year interval. **Figure 11** illustrates the recommendations made to improve the existing monitoring well network at Sites OT001 and WP002.

The success of each of the remedial alternatives for treatment of groundwater at Port Heiden RRS Sites OT001 and WP002 is dependent upon the continued remediation by excavation and offsite disposal or onsite landfarming of the contaminated soil source term by the USAF, as indicated in the latest Remedial Action Report (USAF, 2021a) which reported that soil excavation and characterization efforts would continue in 2022. Based upon the findings of this Groundwater Remedy Study, the USAF will reevaluate the 2009 ROD for Sites OT001 and WP002 to ensure the remedy selected for the Sites is protective of human health and the environment. The remedy selected will be reviewed and approved by ADEC prior to implementation.

Figure 11 OT001 & WP002 Monitoring Well Network Optimization



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