Enhanced *In Situ* Bioremediation Progress Report
November 2022
402 North Meridian
Puyallup, Washington

November 16, 2022

Prepared for

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November 2022
402 North Meridian
Puyallup, Washington

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LIST OF ABBREVIATIONS AND ACRONYMS

µg/L .... micrograms per liter
ART .... Accelerated Remediation Technologies, Inc.
bgs .... below ground surface
CaO_2 .... calcium peroxide
CUL .... cleanup level
DO .... dissolved oxygen
Ecology .... Washington State Department of Ecology
EISB .... enhanced *in situ* bioremediation
EPA .... US Environmental Protection Agency
ft .... foot/feet
GAC .... granular-activated carbon
GRO .... gasoline-range organics
ID .... identification
IDW .... investigation-derived waste
in H_2O .... inches of H_2O
Landau .... Landau Associates, Inc.
lbs .... pounds
MTCA .... Model Toxics Control Act
NFA .... No Further Action
ORC® .... oxygen release compound
Property .... 402 North Meridian property
PVC .... polyvinyl chloride
redox .... reduction-oxidation
SVE .... soil vapor extraction
UST .... underground storage tank

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1.0 INTRODUCTION

This document presents a progress report for implementing the site remedy recommended by Landau Associates, Inc. (Landau) at the William and Marian Young property at 402 North Meridian in Puyallup, Washington (Property; Figure 1). The recommended remedy includes enhanced *in situ* bioremediation (EISB) and soil vapor extraction (SVE) to treat gasoline-range organics (GRO) contamination remaining from a historical release of gasoline from an underground storage tank (UST) system that operated at the Property as part of a gasoline service station. GRO contamination extends hydraulically (via groundwater flow) downgradient from the Property to include off-Property parcels. All areas where contamination from the Property has come to be located is referred to as the "site" in this document.

This is the third progress report addressing remedy implementation and covers the period following the fourth round of performance groundwater sampling at the site through the third EISB injection (November 2021 to October 2022). Additional remedy implementation information is available in the first and second progress reports (Landau 2020, 2021). The following remedial activities were completed during this period and are described in this report:

- EISB performance groundwater monitoring
  - Performance monitoring: April 2022
  - Performance monitoring: August 2022
- EISB injection activities
  - Injection well rehabilitation: August 2022
  - Third injection: September 2022.

The SVE system was not operated in 2022. SVE operation is discussed further in Sections 1.3.2 and 2.3.

1.1 Background Information

The UST system was excavated in 2003 along with approximately 165 tons of gasoline-contaminated soil. However, some impacted soils were left in place in areas beneath the foundation along the east side of the on-Property building, under the northern boundary of the Property, and under the sidewalk on the east side of the Property (see Figure 1). Between 2015 and 2017, a remedial action consisting of the installation and operation of four Accelerated Remediation Technologies, Inc. (ART) wells was implemented at the Property. As documented in Robinson Noble, Inc. (2017), this remedial action was not successful in achieving cleanup objectives. The ART infrastructure, consisting of four ART recirculation wells connected to an air sparging and SVE system, remains at the Property (Figure 1) and was partially used for implementation of the SVE remedy described in this report. Additional site background information is available in a remedial investigation/feasibility study report (Robinson Noble 2010).

Based on an SVE pilot test conducted in 2017, and an additional evaluation conducted in 2018 as part of the data gaps investigation, Landau recommended implementing SVE during the dry season at the Property (see Landau 2021 for additional information). The SVE system was operated in 2020 from April to August, and in 2021 from April to October. The SVE system was not operated in 2022 due to blower malfunction and relatively low GRO mass removal in 2020 and 2021.

Landau and the previous environmental consultant working on the cleanup recommended that EISB be considered as the most appropriate next step in remediating the Property (Landau 2017; Robinson Noble 2017). EISB, as applied to this Property, consists of injecting a source of oxygen into the subsurface to promote *in situ* (i.e., in place) bioremediation of GRO that is dissolved in groundwater, sorbed to soil, and as residual non-aqueous phase liquid. The estimated GRO plume from 2017 prior to implementation of the Landau-recommended remedy is shown on Figure 2. The EISB approach at this Property targets the former excavation area and surrounding impacted area, which is the suspected source zone (Figure 2). During the data gaps investigation in 2018, three tap water injection tests were conducted to assess the feasibility of injecting a liquid solution or slurry into the aquifer beneath the Property. Measured injection rates indicated that injection of a liquid solution to stimulate EISB was feasible at this Property.

Prior to proceeding with this EISB remedy, an evaluation was made during the 2018 data gaps investigation to confirm that natural *in situ* biodegradation was limited by a lack of the electron acceptor that would be injected (Landau 2018). This demonstration was made by assessing the reduction-oxidation (redox) conditions of the aquifer at locations upgradient, within, and downgradient of contamination. The results of the redox evaluation showed that electron acceptors such as dissolved oxygen (DO), nitrate, and sulfate were low or absent within and downgradient of the plume relative to conditions in upgradient monitoring well MW-3. This suggested that the natural condition of the upgradient aquifer was aerobic, with anaerobic and reduced conditions occurring within and downgradient of the plume. The results confirmed that natural electron acceptors are quickly consumed within the plume and that further natural biodegradation is limited by the absence of these receptors. Redox conditions within the plume are anaerobic and iron- to sulfate-reducing. These conditions persist as far downgradient as well MW-13. Based on the MW-3 results, the upgradient redox conditions are aerobic, supporting the proposal to implement EISB through addition of oxygen for the treatment of GRO.

1.2 Site Description/Physical Condition

Soil conditions encountered during the data gaps investigation consisted of alternating layers of fine sand and silt. Within the former UST excavation area, approximately 7 feet (ft) of gravelly fill is present at the north end of the excavation, while approximately 1 ft of gravelly fill was encountered at the south end of the UST excavation. The permeability of subsurface materials at the Property is high enough to facilitate efficient injection of electron acceptor material for an EISB remedy.

Although contaminated soil was excavated at the time of tank closure, the Property was found to contain GRO in both soil and groundwater at levels exceeding Model Toxics Control Act (MTCA) Method A cleanup levels (CULs) during site investigations conducted in the 2000s. GRO-contaminated soil was found to extend beneath the restaurant building that occupies the Property, as well as beneath the western portion of North Meridian. GRO mass is most concentrated in soil within the smear zone interval of the Property (roughly 6 to 10 ft below ground surface [bgs]).

GRO-contaminated groundwater coincides with the GRO-contaminated soil and extends beyond this area to the east in the direction of groundwater flow. GRO-contaminated groundwater occurs from the water table to around 20 ft bgs and its spatial distribution appears highly variable due to the heterogeneous nature of the aquifer material (i.e., alternating layers of sands and silts).

1.3 Remedial Approach

Landau recommended an EISB remedy for the Property in 2017 (Landau 2017) and has been implementing this remedy by injecting oxygen release compound (ORC®) into the shallow subsurface, operating the SVE system during the low water-table months between May and October,[1] and conducting baseline and performance groundwater monitoring.

1.3.1 Enhanced *In Situ* Bioremediation Approach

The EISB remedy recommended by Landau consists of multiple injections over a period of several years of an electron acceptor material into the upper 20 ft of subsurface at the Property. To date, three injections have been completed: one in January/February 2020, one in September 2020, and one in September 2022.

Biodegradation of petroleum hydrocarbons occurs via microbially-mediated redox reactions. In these redox reactions, petroleum hydrocarbons are used as the electron donor, while various other compounds are used as electron acceptors when available (e.g., oxygen, nitrate, manganese [IV], iron [III], sulfate, carbon dioxide). Bacteria gain the most energy by using oxygen as an electron acceptor because it is a highly-oxidized compound, meaning it can more readily accept electrons from electron donors, like petroleum hydrocarbons. The results of the data gaps investigation (Landau 2018) showed that electron acceptors DO, nitrate, and sulfate are low or absent within and downgradient of the plume relative to upgradient conditions. These results suggest that the natural condition of the upgradient aquifer is aerobic and confirm that natural electron acceptors are quickly consumed within the plume. Further natural biodegradation is likely limited by the absence of these electron acceptors.

Biodegradation can be enhanced by injecting a solution containing electron acceptors, or containing a source of electron acceptors, into the aquifer via site monitoring and injection wells. Aerobic bioremediation, or aerobic EISB, is accomplished through stimulation of micro-organisms present in

[1] The SVE system was not operated in 2022.

the aquifer that can degrade petroleum hydrocarbons, including GRO. The addition of oxygen via ORC allows native bacteria to use petroleum hydrocarbons as a source of energy. For this site, ORC in the form of calcium peroxide (CaO_2) is combined with water and pumped into wells in the source zone to provide additional oxygen as an electron acceptor for treatment of GRO.

The bioremediation remedy at the site is initially focused on cleanup of the Property where the major source of GRO mass is present and where there are no site access restrictions. Under a best-case scenario, remediation of the source area will generate declining concentration trends in the downgradient plume as the source of the GRO contributing to downgradient contamination is removed, thereby allowing use of a monitored natural attenuation remedy for the offsite properties and allowing a site-wide No Further Action (NFA) determination to be pursued with the Washington State Department of Ecology (Ecology). Such a remedy would likely include the need to establish institutional controls (e.g., restrictive covenants) on the impacted downgradient properties to the east of the Property if GRO concentrations remain above applicable CULs at those properties. If the EISB remedy proves effective in achieving cleanup objectives at the Property, then a Property-specific NFA determination may be pursued with Ecology. The EISB technology could then be expanded to remediate impacted offsite properties once site access agreements are secured for the City of Puyallup road right-of-way and with offsite property owners.

1.3.2 Soil Vapor Extraction Approach

An ART system was installed at the Property in 2015 to address the GRO contamination. Robinson Noble operated the system from 2015 through 2016. The ART system includes four ART extraction wells (ART-1 through ART-4) and a control trailer within a fenced enclosure. Each ART well was retrofitted to allow groundwater extraction and re-injection (within the same well), air sparging, and SVE. ART well locations are shown on Figure 1. ART well construction details, along with construction details of site monitoring wells, are provided in Table 1.

The SVE portion of the ART system consists of a Busch Samos SB 0430 DO regenerative blower connected to 2-inch-diameter polyvinyl chloride (PVC) pipe suction lines. Suction lines connect to each ART extraction well approximately 6 inches below the top of the ART well. An air dilution valve allows outside air to be pulled through the blower along with soil vapor from the ART wells in order to control the overall flow rate and operate the blower within its optimum flow and vacuum operating range. ART well gate valves located in the control trailer can be used to control the individual extraction flow rates from each ART well. The blower discharges extracted soil vapor and dilution air through two 85-gallon granular-activated carbon (GAC) drums, arranged in a parallel configuration, to treat vapors prior to atmospheric discharge. The GAC vessels are located outside of the control trailer.

SVE can be highly effective at removing volatile organics, such as those associated with gasoline, from subsurface soil. The technology targets volatile organic contaminants that are sorbed to soil in the unsaturated zone and the smear zone. Contaminants in the unsaturated zone and smear zone can act as long-term sources of ongoing contamination to groundwater. In addition to physically removing GRO through volatilization, SVE promotes *in situ* bioremediation of the unsaturated zone and smear zone through the introduction of oxygen to these zones.

The objective of operating the SVE system at the Property is to reduce the concentration and mass of GRO in the unsaturated zone and smear zone to reduce the source of GRO to groundwater. In this regard, SVE is complementary to EISB, which primarily targets contamination below the smear zone. SVE also offers the advantage of being less maintenance-intensive to operate compared to more complex remedial approaches such as the ART system. If Property soil is at least moderately permeable, SVE should produce a treatment area that extends beneath the existing restaurant building and North Meridian. The site remedy includes operation of the SVE system during the dry season, approximately May through September. However, due to blower malfunction, the SVE system was not operated in 2022. Given the limited mass removal of GRO measured over the last two dry seasons of SVE operation, the limited observed radius of influence, and the cost to replace the blower, Landau recommended a temporary, and likely permanent, pause in SVE operations.

1.3.3 Groundwater Performance Monitoring

The site remedy recommended by Landau included baseline groundwater monitoring to characterize the initial conditions within and downgradient of the source zone, and performance groundwater monitoring to determine the effectiveness of ORC injections.

Prior to the injection of ORC, baseline groundwater samples were collected from eight site monitoring wells (MW-4, MW-5, MW-6, MW-7R, MW-8, MW-10, MW-12, and MW-13) and analyzed for field and laboratory parameters. Field parameters consist of DO, oxidation-reduction potential, conductivity, pH, and ferrous iron. Groundwater samples were submitted for laboratory analysis for gasoline; benzene, toluene, ethylbenzene, and xylenes; total organic carbon; nitrate; and sulfate. Baseline groundwater monitoring was completed at the site in October 2019.

Performance groundwater monitoring is conducted at the same eight wells used for baseline sampling, and samples are analyzed for the same field and laboratory parameters. Performance groundwater monitoring is planned to be conducted at least annually to determine the effectiveness of ORC injections to treat GRO contamination. To date, performance groundwater monitoring has been completed at the site semiannually (once during the dry season and once during the wet season) for 3 years for a total of six performance groundwater monitoring events. Sampling frequency may be reduced to once per year depending on the results of the performance groundwater monitoring.

2.0 FIELD ACTIVITIES AND RESULTS

This section describes the field activities related to EISB implementation during the period between November 2021 and October 2022, including performance groundwater monitoring, electron acceptor injection, and management of investigation-derived waste (IDW). No SVE operation occurred during this period. Field activities were performed in accordance with the site-specific health and safety plan and the work plan (Landau 2019). Figure 3 presents a timeline of remedial activities completed at the site since October 2019.

2.1 Performance Groundwater Monitoring

Performance groundwater monitoring in 2022 was conducted semiannually—once during the wet season (fifth round; April) and once during the dry season (sixth round; August) to determine the ongoing effectiveness of ORC injections to treat GRO contamination. Both fifth- and sixth-round sampling occurred after the second ORC injection, but before the third ORC injection at the Property. Samples were collected from eight site monitoring wells (MW-4, MW-5, MW-6, MW-7R, MW-8, MW-10, MW-12, and MW-13) for field parameters and laboratory analysis. Monitoring locations are shown on Figure 2. Table 2 presents a summary of EISB performance monitoring results. Figures 4 and 5 present plots of GRO and DO concentrations, respectively, over time. Appendix A presents plots of GRO and DO concentrations for each individual well over time.

The first and second performance groundwater monitoring events were completed in April 2020 and August 2020, respectively, following the first ORC injection. Results from the first round showed that GRO concentrations had decreased across most of the Property, with concentrations exceeding MTCA Method A CULs at four of the eight site wells. DO concentrations at MW-4 and MW-5 had increased substantially as a result of ORC injection but remained low at most other wells. First-round results indicated localized improvement of aerobic redox conditions and treatment of GRO mass. Results from the second round showed that GRO concentrations remained decreased at most wells. An increased concentration of GRO at MW-6 between the first and second round of performance monitoring indicated that remaining contamination at the Property was still predominantly located proximal to the former excavation. DO concentrations remained elevated at MW-4 and MW-5. Additional details for the first two rounds of performance groundwater monitoring are available in the 2020 progress report (Landau 2020).

The third and fourth performance groundwater monitoring events were completed in April 2021 and August/September 2021, respectively. Results from the third round, conducted approximately 6 months after the second ORC injection, showed that GRO concentrations had decreased across the Property compared to the results of the second performance groundwater monitoring event, and for the first time were below the Method A CUL of 800 micrograms per liter (µg/L) for all eight site wells. DO concentrations remained high at MW-4 and MW-5, and increased substantially at MW-6. DO concentrations increased somewhat at MW-7R, MW-8, MW-10, and MW-12, and remained stable at

MW-13. Third-round results indicated continued localized improvements in aerobic redox conditions and improved treatment of GRO mass near the former excavation following the second injection of ORC. Results from the fourth round showed that GRO concentrations remained low at several site wells but increased between third- and fourth-round performance monitoring to concentrations exceeding MTCA Method A CULs at MW-7R and MW-8, both located downgradient of the Property. DO concentrations remained high at MW-4, MW-5, and MW-6, but decreased slightly from concentrations observed during third-round monitoring. Additional details for the third and fourth rounds of performance groundwater monitoring are available in the 2021 progress report (Landau 2021).

The fifth round of performance groundwater monitoring was conducted in April 2022, approximately 18 months after the second ORC injection at the site. GRO concentrations remained stable or decreased at MW-4, MW-6, MW-7R, MW-8, MW-10, and MW-13 between fourth- and fifth-round performance monitoring, and GRO concentrations increased at MW-5 and MW-12. For fifth-round performance groundwater sampling, results exceeded MTCA Method A CULs at MW-5 (on the Property), and MW-8 and MW-12 (located downgradient of the Property). DO concentrations remained high at wells located on the Property, and also remained relatively stable for wells located downgradient from the Property.

The sixth round of performance groundwater monitoring was conducted in August 2022, nearly 2 years after the second ORC injection at the site. GRO concentrations showed slight to moderate increases at most wells, including MW-4, MW-5, MW-7R, MW-8, and MW12. The GRO concentrations at MW-6, MW-10, and MW-13 were not detected above laboratory reporting limits, which is consistent with the previous sampling results. The maximum detected GRO concentration for sixth-round sampling was 2,400 µg/L at MW-8 and MW-12. DO concentrations decreased somewhat at all site wells except for MW-13, where a significant increase in DO was observed. The third ORC injection occurred after sixth-round performance groundwater sampling.

2.2 Electron Acceptor Injection

A third injection of ORC electron acceptor was conducted at the Property in 2022 to stimulate EISB. Descriptions of the first and second injections are included in the first and second progress reports (Landau 2020, 2021). The third injection was conducted September 13 through September 15, 2022, approximately 2 years after the second injection. Electron acceptor solution was prepared and injected into each of the nine targeted wells (ART-1 through ART-4, MW-3, and MW-14 through MW-17; Figure 2) in general accordance with the work plan (Landau 2019) and as described below. An EISB injection volume summary of all three events conducted so far is provided in Table 3.

2.2.1 Third Injection

Prior to the third injection event, well rehabilitation was attempted at five of the targeted wells (MW-3 and MW-14 through MW-17) to remove deposits within the wells that limited injection effectiveness. Well rehabilitation involved applying a 15 percent by weight vinegar solution to the injection wells and removing built-up calcium deposits from previous injection activities via vacuum truck. The purpose of well rehabilitation was to expose as much of the injection well screens as possible to facilitate injection of ORC to the subsurface. Well rehabilitation resulted in exposure of approximately two-thirds to three-quarters of the screen at each injection well, improving the likelihood of successful injection at all five wells.

The third injection event (September 2022) was conducted in general accordance with the work plan (Landau 2019), with slight modifications made to increase the efficiency of implementation and to use remaining electron acceptor product from previous injection events. The injection volume goal was reduced to 5,800 gallons in order to inject the remaining 1,160 pounds (lbs) of CaO_2 at a ratio of approximately 0.2 lbs of CaO_2 per gallon of potable water.

Approximately 5,600 gallons of solution and 1,155 lbs of CaO_2 were successfully injected during the third event. The volume of injected solution represented 98 percent of the design volume. Like the first and second injection events, solution was redistributed to nearby wells as necessary to overcome slow injection rates, surfacing, and short-circuiting to nearby ART well vaults. The volume goal at each well ranged from 100 to 2,000 gallons; the actual volume achieved at each well ranged from 16 to 2,500 gallons (Table 3).

Concretion of ORC in the injection well casings was the primary cause of injection difficulties during this event. Injection wells ART-1, ART-2, ART-3, and MW-16 would not accept any fluid during this event even after rehabilitation with vinegar. Fluid from these wells was redistributed to MW-3 and MW-17.

2.3 Soil Vapor Extraction Operations

The ART system installed by Robinson Noble in 2015 was reconfigured to be strictly an SVE system prior to the first ORC injection. In January 2020, groundwater extraction pumps and associated tubing, electrical components, and wellhead equipment were removed from each of the ART wells and stored within the control trailer. The entire wellhead was replaced with a blank flange (i.e., a heavy metal seal with no openings), so that each ART well now consists of only a 6-inch casing with a 2-inch-diameter PVC pipe suction line connected to the casing approximately 6 inches below the flange. The suction lines are still connected to the regenerative blower in the control trailer to extract and treat soil vapor; the ART wells no longer have groundwater extraction/reinjection or air sparging functionality.

The SVE system was not operated during this reporting period. Data collected in 2020 and 2021 demonstrated that the vacuum radius of influence generated around the four ART wells was limited, especially during periods with higher water levels. The maximum GRO mass removal rates for the SVE system were calculated as 55 and 27 pounds per year for 2020 and 2021, respectively. However, since the system is effectively operated only during the low water table months of August through October, the actual annual GRO mass removal is only about 25 percent of these amounts, which is considered to be a relatively low annual removal mass. For these reasons, and the expense of replacing the broken blower, it was determined that the SVE system would not be operated in 2022. Further details for SVE operation in 2020 and 2021 are included in previous progress reports (Landau 2020, 2021).

2.4 Residual Waste Management

IDW generated during the period between November 2021 and September 2022 consisted of rinsate from tanks and drums used for mixing injection solution, and purge water from sampling of monitoring wells. IDW was stored in 300-gallon totes and 55-gallon steel drums, respectively, on site until it was removed and disposed of by a specialized environmental waste handling company. The IDW disposal was completed by DH Environmental, Inc. on September 28, 2022. Due to the corrosivity of the injection solution rinsate, this IDW was disposed of as hazardous waste, and necessitated updating the US Environmental Protection Agency (EPA)/state identification (ID) number. The update to the EPA/state ID number is currently being coordinated with DH Environmental, Inc. and is expected to be completed before the end of calendar year 2022.

3.0 DISCUSSION AND RECOMMENDATIONS

The results of 2022 remedial activities are discussed and recommendations for future remedial efforts at the site are provided in this section. Additional performance monitoring events and injections are also described.

3.1 Contaminant Reduction

All monitored wells have exhibited an overall decrease in GRO concentrations since baseline sampling was conducted in August 2018. Prior to the first injection, five wells (MW-4, MW-5, MW-6, MW-8, and MW-12) exceeded the MTCA Method A CUL for GRO (800 µg/L with detectable benzene present). After the first injection, concentrations of GRO remained above CULs at four wells (MW-6, MW-7R, MW-8, and MW-12). Wells MW-4, MW-5, and MW-6 near the former excavation showed the most significant decreases in GRO concentration, indicating that emplaced ORC was effective at stimulating aerobic biodegradation of the remaining GRO mass. As expected, the greatest reduction in contamination levels occurred at wells located on the Property and the least reduction occurred in the downgradient off-Property wells. The three wells that had concentrations of GRO above CULs following the first injection (MW-6, MW-8, and MW-7R) had a slight increase in GRO concentrations prior to the second ORC injection; the second injection was well-timed to prevent rebound in GRO concentrations at the other monitoring wells.

Performance groundwater monitoring in April 2021 following the second ORC injection showed that GRO concentrations at all wells had decreased to below MTCA Method A CULs. In August/September 2021, GRO concentrations at two off-Property wells (MW-7R and MW-8) re-established to a level exceeding MTCA Method A CULs. Concentrations of GRO remained relatively stable between August/September 2021 and April 2022, and then GRO concentrations increased slightly in August 2022. GRO concentrations in monitoring wells located within the limits of the Property remained below MTCA Method A CULs at all locations except for MW-5.

Based on 2021 and 2022 performance monitoring results, it was determined that while ORC injections had made significant progress toward achieving treatment goals at the site, additional injections were necessary to sustain GRO concentrations below CULs. A third injection was completed at the Property in September 2022. The effects of the third injection will be evaluated following April 2023 groundwater monitoring.

3.2 Improved Redox Conditions

As discussed in Section 1.3.1, aerobic EISB is accomplished through stimulation of micro-organisms present in the aquifer that can degrade petroleum hydrocarbons, including GRO. The addition of oxygen via ORC allows native bacteria to use petroleum hydrocarbons as a source of energy. Enhancing aerobic redox conditions in the aquifer is the main objective of injecting CaO_2 as ORC. Increased DO concentrations are the primary indicator of improved aerobic conditions at the site.

DO concentrations increased at all monitored wells following the first ORC injection. The most significant increases initially occurred at MW-4 and MW-5 near the former excavation; DO concentrations at these two wells remained high prior to and following the second ORC injection. After the second ORC injection, a significant increase in DO concentration at MW-6 was observed. All other wells showed slight increases in DO concentrations following the second ORC injection. Where DO concentrations did not show a significant increase, this may indicate that DO is being consumed by bacteria as it becomes available for biodegradation. Over the period of 2 years following the second ORC injection, DO concentrations have generally fallen somewhat, but DO concentrations in on-Property wells remain significantly higher than baseline conditions.

Other indicators of aerobic redox conditions include increased nitrate and sulfate concentrations. If more reducing redox conditions are present, these two compounds are being transformed into more reduced forms (nitrogen gas and hydrogen sulfide, respectively). If these reducing conditions are not present, oxygen is being used as the primary electron acceptor and nitrate and sulfate persist in their original forms. At the four wells currently demonstrating the highest DO concentrations (MW-4, MW-5, MW-6, and MW-13), nitrate and sulfate concentrations generally increased following the first and second ORC injections, and then decreased as time from the most recent injection elapsed, with the exception of MW-6, which showed an increase in nitrate and sulfate concentrations in August 2022 (Table 2). This supports the observation of localized improvements in aerobic redox conditions and improved treatment of GRO mass near the former excavation.

3.3 Next Steps

Performance groundwater monitoring in 2023 will again be conducted in April and August to determine the effectiveness of ORC injections to treat GRO contamination. Samples will be collected from the same eight site monitoring wells (MW-4, MW-5, MW-6, MW-7R, MW-8, MW-10, MW-12, and MW-13) for field measurements and laboratory analysis. Monitoring locations are shown on Figure 2.

Monitoring results from the April and August 2023 monitoring events will be evaluated to determine if additional ORC injections, or an injection of an alternative source of electron acceptors, are necessary to achieve CULs. Future injections may be conducted at injection wells according to the work plan (Landau 2019), or via direct-push injection using direct-push drilling methods. This alternative approach allows injection material to be emplaced in areas between monitoring locations where contaminant mass is suspected to remain in the aquifer. This alternative approach may also reduce the amount of surfacing of injection fluid that occurs and reduce time spent on well rehabilitation (e.g., unclogging injection wells). The SVE system will not be operated in 2023.

The next annual progress report will be prepared in November 2023 and will cover results from field activities conducted in calendar year 2023.

4.0 USE OF THIS DOCUMENT

This EISB Progress Report has been prepared for the exclusive use of Davis Law Office, PLLC, its client on this project, and applicable regulatory agencies for specific application to the Property and surrounding site. No other party is entitled to rely on the information, conclusions, and recommendations included in this document without the express written consent of Landau. Further, the reuse of information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by Landau, shall be at the user's sole risk. Landau warrants that within the limitations of scope, schedule, and budget, our services have been provided in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions as this project. Landau makes no other warranty, either express or implied.

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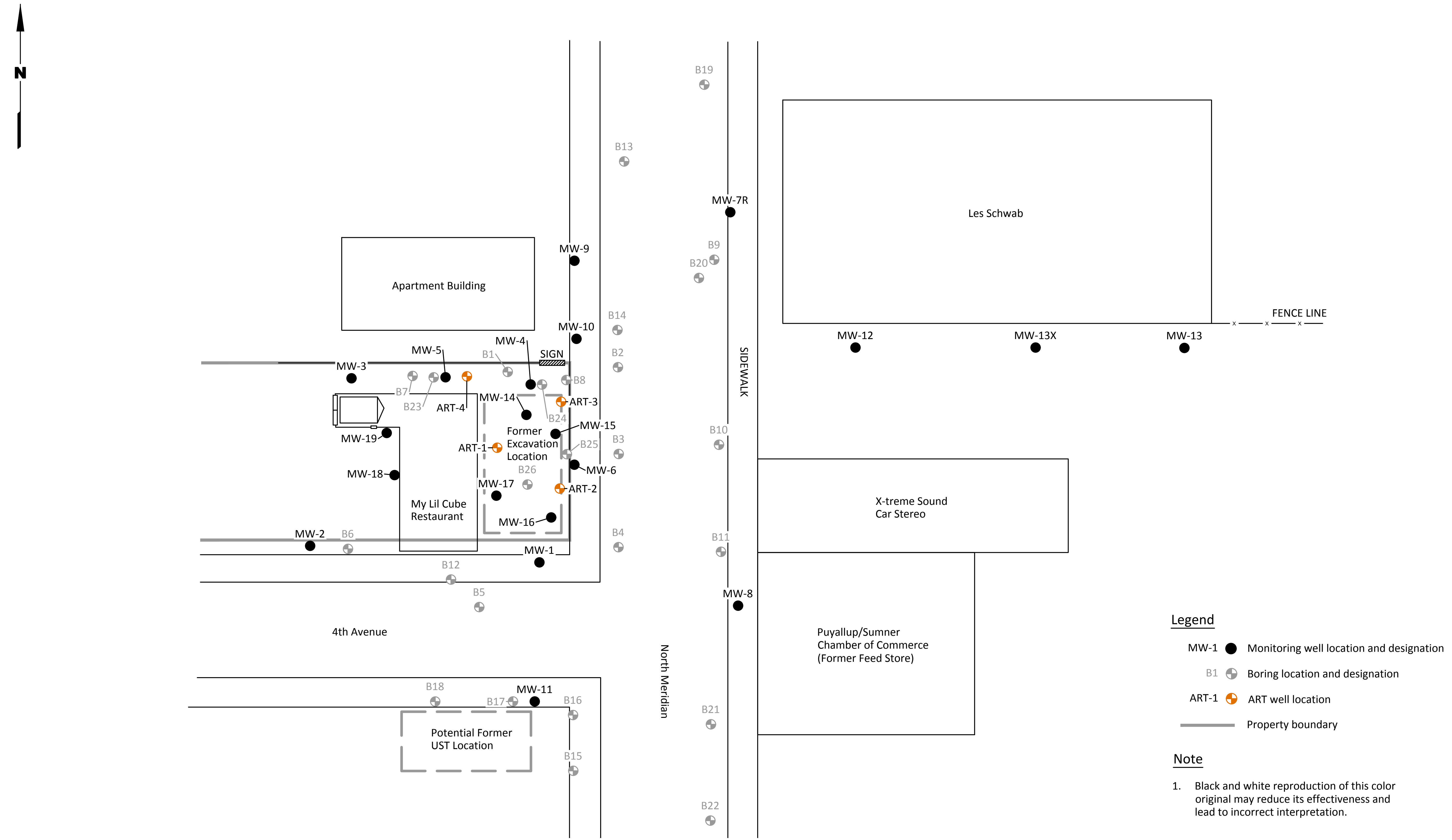

Base Map and Plume Boundary Source: Robinson Noble, 2017

EISB Progress Report 402 North Meridian Puyallup, Washington	**Site Map**	Figure 1

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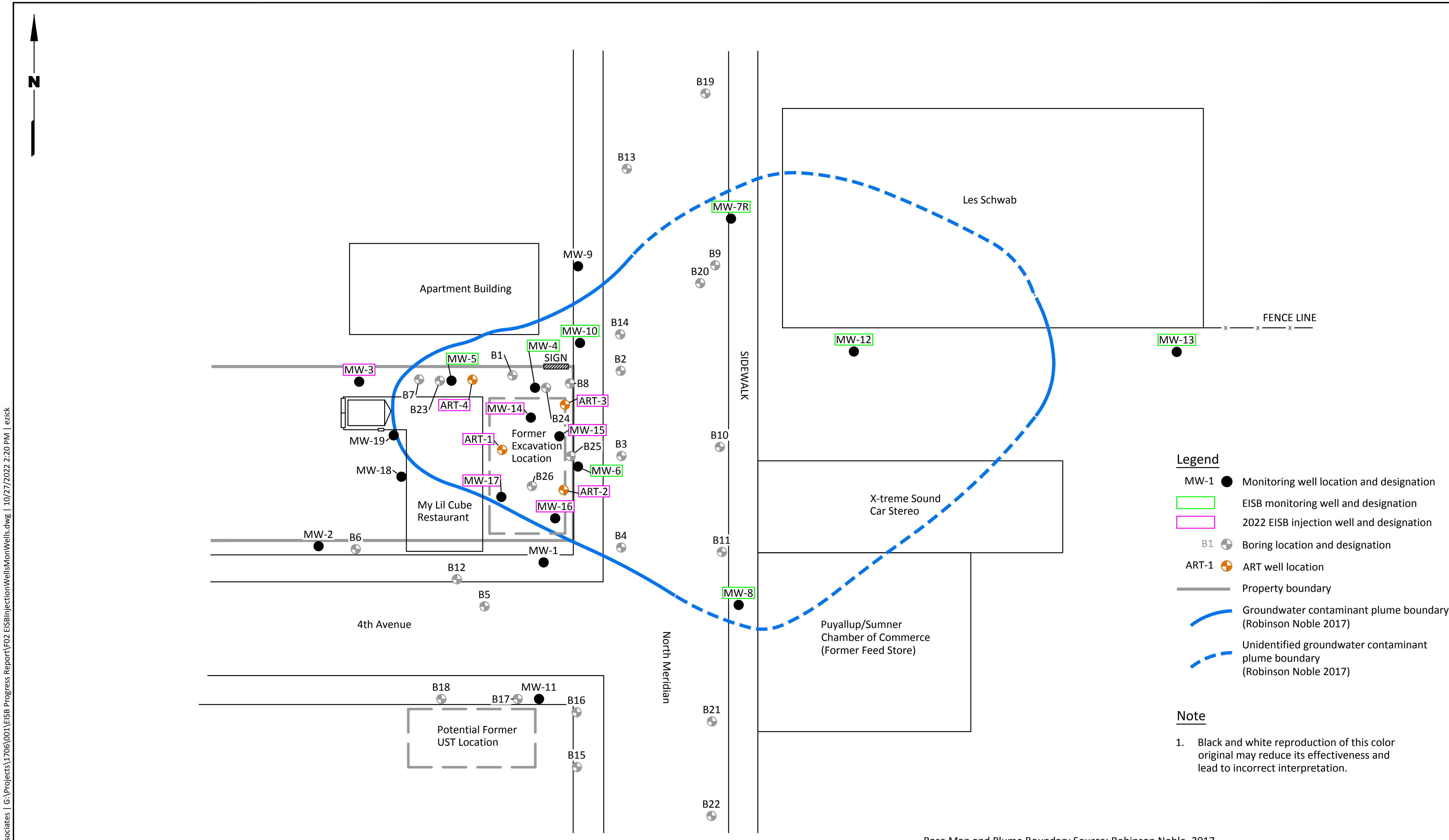

Base Map and Plume Boundary Source: Robinson Noble, 2017

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EISB Injection and Monitoring Wells

Figure 2

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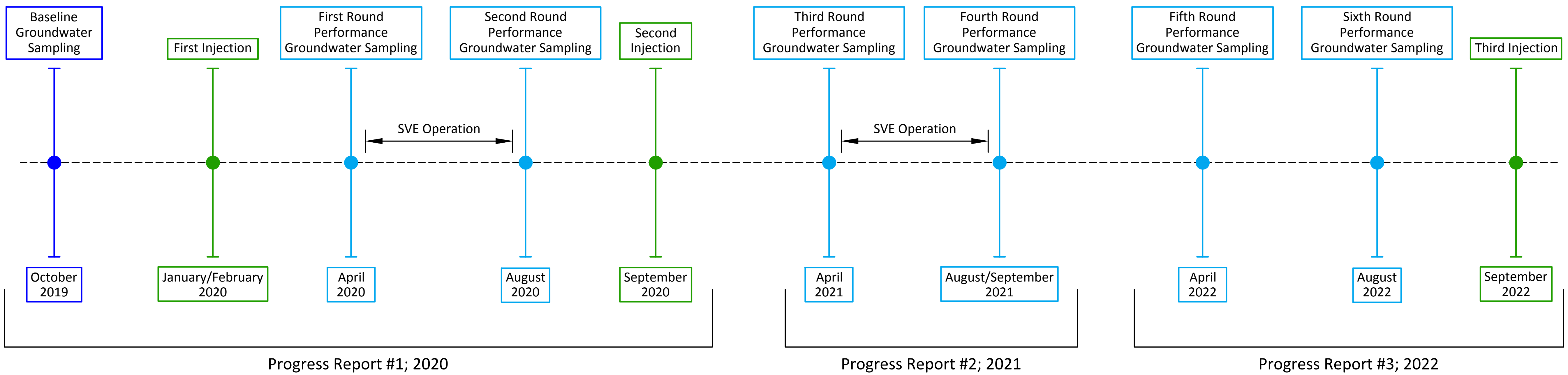

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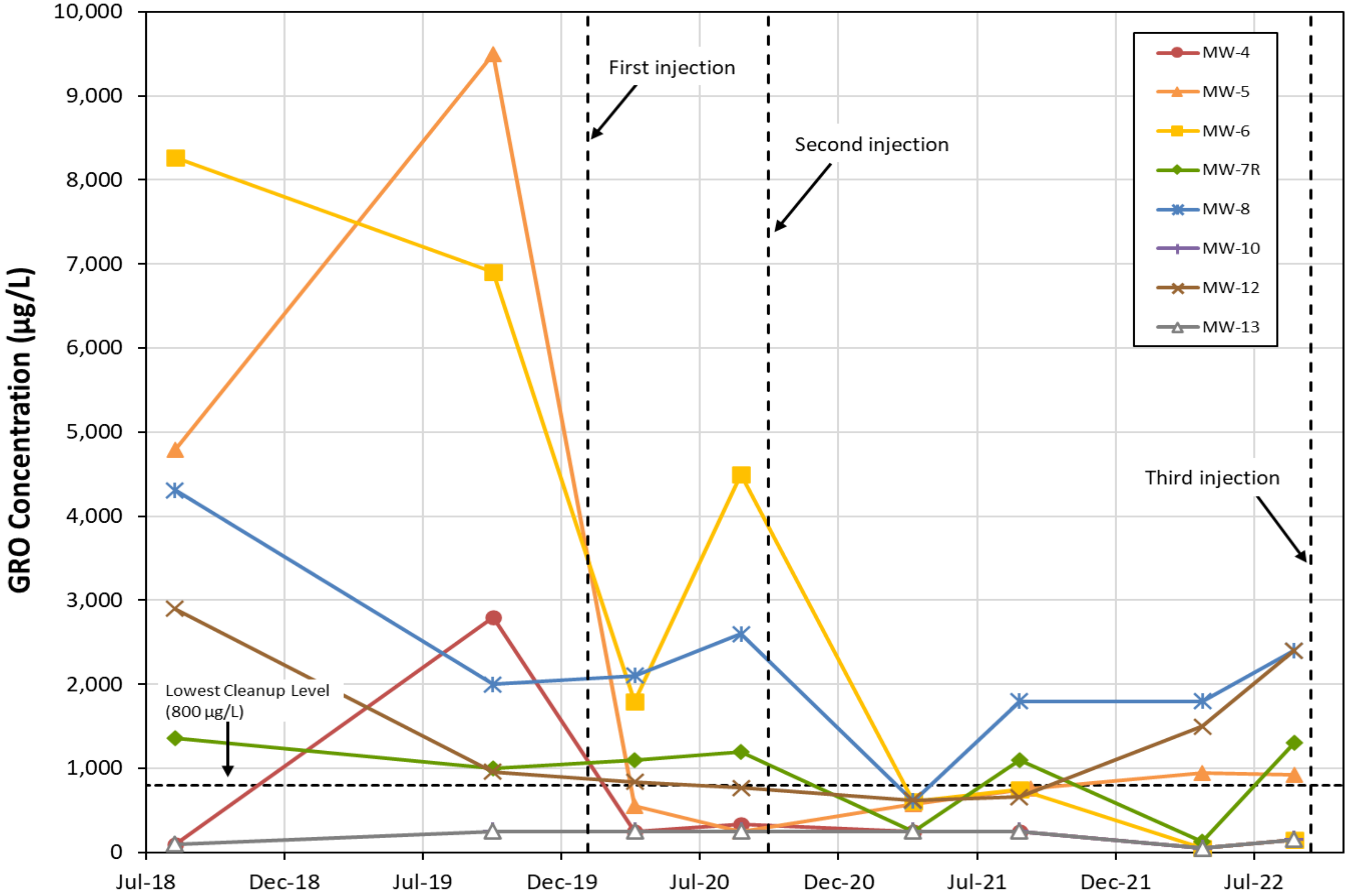
Timeline of Remedial Activities

Figure 3



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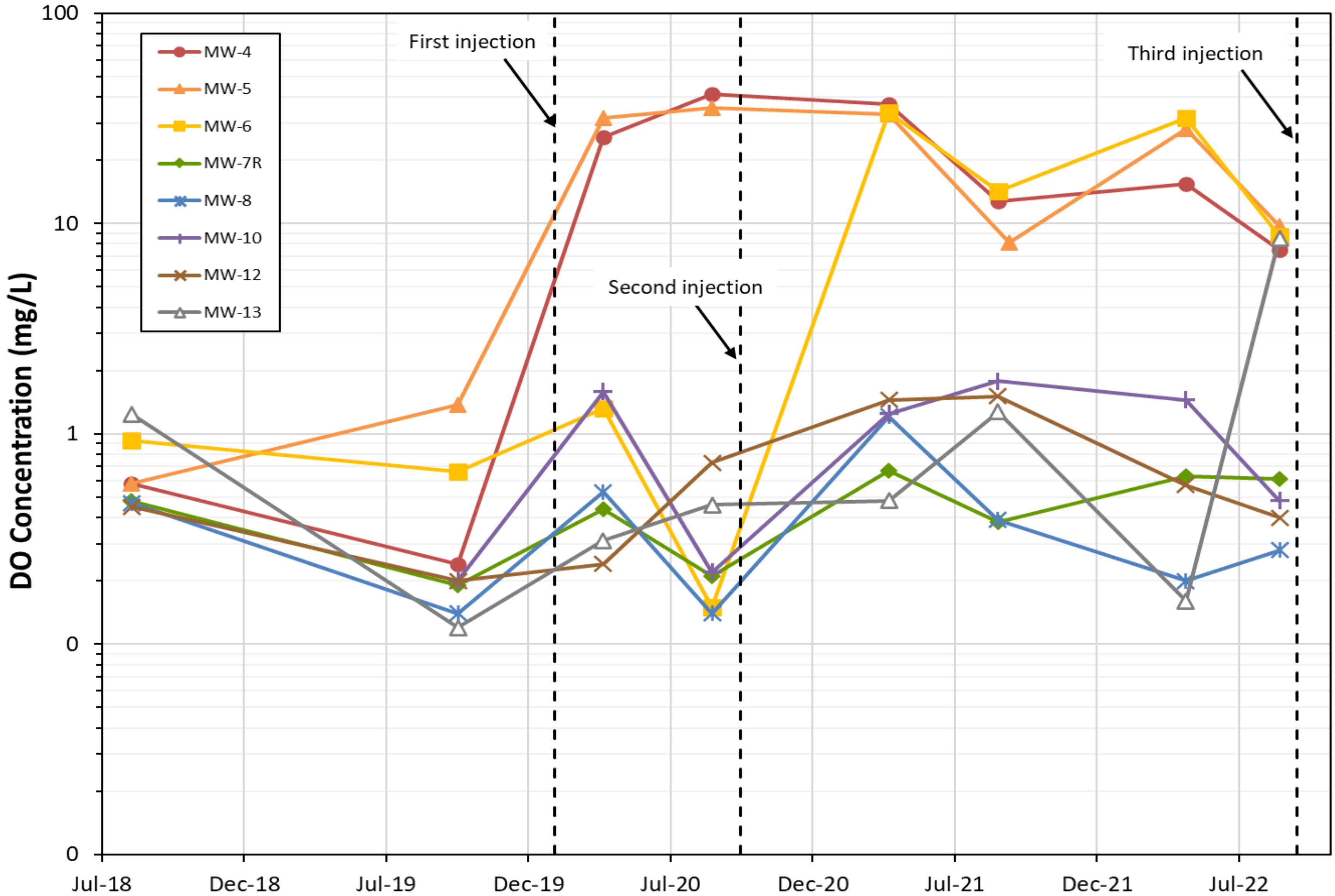
EISB Progress Report
402 North Meridian
Puyallup, Washington

GRO Concentrations Over Time

Figure
4



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EISB Progress Report 402 North Meridian Puyallup, Washington	**Dissolved Oxygen Concentrations Over Time**	Figure 5

Table 1
Well Construction Details
402 North Meridian
Puyallup, Washington

Well	Depth Drilled (ft bgs)	Assembly Length (ft)	Screen Length (ft)	Screen Slot Size/Material	Sand Pack	Casing Diameter (inches)	Monument Type	Installation Date	Status	Driller	Location
MW-1	21	15	10	0.020-in PVC	10/20 Colorado	2	FM	Nov-04	Existing	Holt Drilling	Right-of-way
MW-2	20	16	10	0.020-in PVC	10/20 Colorado	2	FM	Nov-04	Existing	Holt Drilling	Young Property
MW-3	20	20	15	0.020-in PVC	10/20 Colorado	2	FM	Nov-04	Existing	Holt Drilling	Young Property
MW-4	25	20	15	0.020-in PVC	10/20 Colorado	2	FM	Nov-04	Existing	Holt Drilling	Young Property
MW-5	25	22	15	0.020-in PVC	10/20 Colorado	2	FM	Aug-05	Existing	Holt Drilling	Young Property
MW-6	25	22	15	0.020-in PVC	10/20 Colorado	2	FM	Aug-05	Existing	Holt Drilling	Right-of-way
MW-7	21	20	13	0.020-in PVC	10/20 Colorado	2	FM	Aug-05	Redrilled in place	Holt Drilling	Right-of-way
MW-7R	20	20	15	0.020-in PVC	10/20 Colorado	2	FM	Jan-09	Existing	Boart Longyear	Right-of-way
MW-8	25	22	15	0.020-in PVC	10/20 Colorado	2	FM	Aug-05	Existing	Holt Drilling	Right-of-way
MW-9	25	22	15	0.020-in PVC	10/20 Colorado	2	FM	Aug-05	Existing	Holt Drilling	Right-of-way
MW-10	22.5	20	15	0.020-in PVC	10/20 Colorado	2	FM	Jan-08	Existing	Boart Longyear	Right-of-way
MW-11	22.5	20	15	0.020-in PVC	10/20 Colorado	2	FM	Jan-08	Existing	Boart Longyear	Right-of-way
MW-12	20	20	10	0.020-in PVC	10/20 Colorado	2	FM	Jan-08	Existing	Boart Longyear	Right-of-way
MW-13	20	20	10	0.020-in PVC	10/20 Colorado	2	FM	Jan-08	Existing	Boart Longyear	Right-of-way
MW-14	15	7.5	4	0.020-in PVC	20/40 Colorado	2	FM	Aug-18	Existing	ESN Northwest	Young Property
MW-15	20	19.1	10	0.020-in PVC	10/20 Colorado	2	FM	Dec-19	New	Anderson Environmental	Young Property
MW-16	20	18.5	10	0.020-in PVC	10/20 Colorado	2	FM	Dec-19	New	Anderson Environmental	Young Property
MW-17	20	18.5	10	0.020-in PVC	10/20 Colorado	2	FM	Dec-19	New	Anderson Environmental	Young Property
MW-18	20	18.5	10	0.020-in PVC	10/20 Colorado	2	FM	Dec-19	New	Anderson Environmental	Young Property
MW-19	20	18.5	10	0.020-in PVC	10/20 Colorado	2	FM	Dec-19	New	Anderson Environmental	Young Property
ART-1	21	20	15	0.020-in PVC	10/20 Colorado	6	V	Aug-13	Existing	Holt Drilling	Young Property
ART-2	21	20	15	0.020-in PVC	10/20 Colorado	6	V	Aug-13	Existing	Holt Drilling	Young Property
ART-3	21	20	15	0.020-in PVC	10/20 Colorado	6	V	Aug-13	Existing	Holt Drilling	Young Property
ART-4	21	20	15	0.020-in PVC	10/20 Colorado	6	V	Aug-13	Existing	Holt Drilling	Young Property

Abbreviations and Acronyms:

bgs = below ground surface
FM = flush mount
ft = feet
in = inches
PVC = polyvinyl chloride
V = vault

Table 2
Enhanced *In Situ* Bioremediation Data Summary
402 North Meridian UST Site
Puyallup, Washington

Sampling Location	Date Sampled	Elapsed Time from Injection (days)		Northwest Test Method	EPA Test Method						Conventionals				Field Parameters			
				NWTPH-Gx	8021						EPA-300.0		SM 5310	Hach Kit	YSI 556/Pro Plus			
		Injection #1	Injection #2	Gasoline	Benzene	Toluene	Ethylbenzene	m,p-Xylene	o-Xylene	Total Xylenes	Nitrate-Nitrogen	Sulfate	TOC	Fe2+	DO	ORP	pH	Conductivity
				µg/L	µg/L						(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mV)	(pH units)	(uS/cm)
Cleanup Levels (a)				800	5	1,000	700	1,000 (b)	1,000 (b)	1,000 (b)	10	--	--	--	--	--	--	--
Monitoring Wells																		
MW-2	8/8/2018	-545		<100	<1	<2	<1	--	--	<2	<0.05	0.79	7.04	4.5	0.96	55.3	6.54	362
MW-3	8/8/2018	-545		<100	<1	<2	<1	--	--	<2	0.61 J	4.8	3.57	0.5	5.45	71.9	6.09	202
MW-4	8/8/2018	-545		<100	<1	<2	<1	--	--	2.9	<0.05	20.9	20.1	1.0	0.58	58.4	6.75	444
MW-4	10/2/2019	-125		**2,800**	<3.0	14	160	110	11	221	<0.20	13	16	4.5	0.24	-138.1	6.68	702
MW-4	4/6/2020	62		<250	<3.0	<2.0	<3.0	<3.0	<2.0	ND	5.7	23	23	0.5	25.62	24.0	12.06	2,195
MW-4	8/24/2020	202	-37	340	<3.0	<2.0	5.7	7.7	3.1	10.8	1.1	<1.2	21	0.0	41.16	-29.2	12.37	7,168
MW-4	4/8/2021	429	190	<250	<1.0	<1.0	<1.0	<2.0	<1.0	ND	2.7	29	23	1.0	37.08	-192.5	11.39	1,152
MW-4	8/26/2021	569	330	<250	<1.0	<1.0	1.2	<2.0	<1.0	ND	1.7	16	25	0.5	12.69	-32.5	12.67	7,166
MW-4	4/25/2022	811	572	<50	<1.0	<1.0	<1.0	<2.0	<1.0	ND	1.7	23	10	0.5	15.37	71.8	11.31	1,136.3
MW-4	8/24/2022	932	693	150	<0.40	<1.0	<1.0	<2.0	<1.0	<3.0	1.3	25	13	0.0	7.51	34.3	11.75	1,135
MW-5	8/8/2018	-545		**4,790**	<1	2.2	47	--	--	14	<0.05	0.85	12.8	4.0	0.58	51.1	6.39	249
MW-5	10/2/2019	-125		**9,500 J**	<3.0	11	260	290	36	326	<0.20	<1.2	17	5.0	1.37	-127.1	6.29	278.1
MW-5	4/6/2020	62		550	<3.0	<2.0	8.3	3.3	<2.0	3.3	1.8	17	16	1.6	31.83	-324.9	12.81	2,007
MW-5	8/24/2020	202	-37	<250	<3.0	<2.0	<3.0	<3.0	<3.0	ND	<0.20	2.6	12	3.4	35.55	15.7	11.79	1,808
MW-5	4/8/2021	429	190	580	<1.0	<1.0	3.2	5.2	1.7	6.9	3.8	11	20	0.2	33.04	-70.0	12.63	6,499
MW-5	9/10/2021	584	345	760	<1.0	<1.0	5.2	3.1	4.5	7.6	0.2	4.2	20	1.0	8.13	-56.6	12.70	3,552
MW-5	4/25/2022	811	572	**950**	<1.0	<1.0	5.3	3.4	1.3	4.7	2.8	9.0	18	0.5	28.28	58.4	12.01	15,183.3
MW-5	8/24/2022	932	693	**920**	<0.40	<1.0	2.6	2.3	<1.0	3.2	1.9	8.5	19	0.0	9.71	151.1	11.72	1,709.5
MW-6	8/8/2018	-545		**8,270**	**6.4**	10	230	--	--	32	<0.05	2.7	28	5.0	0.93	48.6	6.14	443
MW-6	10/2/2019	-125		**6,900 J**	4.6	10	**710**	39	5.3	44.3	<0.20	<1.2	22	6.5	0.66	-135.8	6.34	396.8
MW-6	4/6/2020	62		**1,800**	<3.0	6.9	50	31	<2.0	31	<0.20	29	25	4.8	1.32	-359.0	8.76	342.4
MW-6	8/24/2020	202	-37	**4,500 J**	<3.0	3.4	240	14	2.2	16.2	<0.20	2.8	29	6.0	0.15	-447.1	6.72	334.7
MW-6	4/8/2021	429	190	610	<1.0	<1.0	28	<2.0	<1.0	ND	0.34	22	13	0.6	33.86	-60.9	12.38	4,120
MW-6	8/26/2021	569	330	750	<1.0	<1.0	39	<2.0	<1.0	ND	0.78	20	12	1.0	14.31	-57.0	12.78	8,705
MW-6	4/25/2022	811	572	<50	<1.0	<1.0	<1.0	<2.0	<1.0	ND	0.21	14	5.9	1.0	31.74	183.9	6.97	841.8
MW-6	8/24/2022	932	693	<150	<0.40	<1.0	<1.0	<2.0	<1.0	<3.0	3.6	39	4.6	0.0	8.67	200.0	8.65	502.0
MW-7R	8/8/2018	-545		**1,360**	<1	<2	<1	--	--	<2	<0.05	4.5	14	1.5	0.48	27.7	6.13	548
MW-7R	10/2/2019	-125		**1,000**	<3.0	<2.0	<3.0	4.0	<2.0	4.0	<0.20	1.3	6.3	3.5	0.19	-95.5	6.21	338.9
MW-7R	4/6/2020	62		**1,100**	<3.0	<2.0	<3.0	4.1	<2.0	4.1	<0.20	<1.2	16	0.6	0.44	-261.0	6.84	470.9
MW-7R	8/24/2020	202	-37	**1,200**	<3.0	2.0	3.1	5.3	<2.0	5.3	<0.20	2.0	8.4	5.0	0.21	-333.9	6.32	447.7
MW-7R	4/8/2021	429	190	<250	<1.0	<1.0	<1.0	<2.0	<1.0	ND	<0.20	13	34.5	3.5	0.67	-63.6	6.43	540.4
MW-7R	8/26/2021	569	330	**1,100**	1.1	1.8	2	4.3	<1.0	4.3	<0.20	3	8.8	6.5	0.38	-130.7	6.67	467
MW-7R	4/25/2022	811	572	130	<1.0	<1.0	<1.0	<2.0	<1.0	ND	1.5	25	8.1	5.0	0.63	66.1	6.20	1,439.0
MW-7R	8/24/2022	932	693	**1,300**	0.52	<1.0	<1.0	<2.0	<1.0	<3.0	<0.20	2.2	76	7.0	0.61	22.2	7.33	640.5

Table 2
Enhanced *In Situ* Bioremediation Data Summary
402 North Meridian UST Site
Puyallup, Washington

		Elapsed Time from Injection (days)		Northwest Test Method	EPA Test Method						Conventionals			Field Parameters				
				NWTPH-Gx	8021						EPA-300.0		SM 5310	Hach Kit	YSI 556/Pro Plus			
Sampling Location	Date Sampled	Injection #1	Injection #2	Gasoline	Benzene	Toluene	Ethylbenzene	m,p-Xylene	o-Xylene	Total Xylenes	Nitrate-Nitrogen	Sulfate	TOC	Fe2+	DO	ORP	pH	Conductivity
				µg/L	µg/L						(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mV)	(pH units)	(uS/cm)
Cleanup Levels (a)				800	5	1,000	700	1,000 (b)	1,000 (b)	1,000 (b)	10	--	--	--	--	--	--	--
MW-8	8/8/2018	-545		**4,310**	<1	<2	<1	--	--	<2	<0.05	0.29	12.7	1.5	0.47	-7.3	6.09	396
MW-8	10/2/2019	-125		**2,000**	<3.0	<2.0	<3.0	<3.0	<2.0	ND	<0.20	<1.2	11	6.0	0.14	-126.0	6.42	377.4
MW-8	4/6/2020	62		**2,100 J**	<3.0	<2.0	<3.0	<3.0	<2.0	ND	<0.20	1.5	14	6.0	0.53	-120.4	6.29	311.5
MW-8	8/24/2020	202	-37	**2,600**	<3.0	<2.0	<3.0	<3.0	<2.0	ND	<0.20	<1.2	10	4.5	0.14	-326.7	6.39	364.1
MW-8	4/8/2021	429	190	610	<1.0	<1.0	<1.0	<2.0	<1.0	ND	1.4	7.1	2.3	3.0	1.21	221.0	6.48	322.3
MW-8	8/26/2021	569	330	**1,800**	<1.0	<1.0	<1.0	<2.0	<1.0	ND	<0.20	<1.5	9.9	6.0	0.39	-105.8	6.61	362.4
MW-8	4/25/2022	811	572	**1,800**	<1.0	<1.0	<1.0	<2.0	<1.0	ND	1.7	11	3	4.0	0.20	-11.3	6.28	674.0
MW-8	8/24/2022	932	693	**2,400**	<0.40	<1.0	<1.0	<2.0	<1.0	<3.0	<0.20	<1.5	6.1	5.0	0.28	44.7	6.43	321.2
MW-10	10/2/2019	-125		<250	<3.0	<2.0	11	<3.0	<2.0	ND	<0.20	5.8	4.0	4.5	0.20	-120.0	6.08	232.6
MW-10	4/6/2020	62		<250	<3.0	<2.0	<3.0	<3.0	<2.0	ND	0.28	4.6	4.9	2.5	1.59	228.0	6.84	95.6
MW-10	8/24/2020	202	-37	<250	<3.0	<2.0	<3.0	<3.0	<2.0	ND	<0.20	2.2	4.1	3.0	0.22	-410.4	6.28	164.2
MW-10	4/8/2021	429	190	<250	<1.0	<1.0	<1.0	<2.0	<1.0	ND	0.28	7.2	1.4	NM	1.25	-225.1	6.11	92.9
MW-10	8/26/2021	569	330	<250	<1.0	<1.0	<1.0	<2.0	<1.0	ND	<0.20	4.2	3.4	6.5	1.78	-1.3	6.51	139.9
MW-10	4/25/2022	811	572	<50	<1.0	<1.0	<1.0	<2.0	<1.0	ND	0.25	3.8	1.2	0.8	1.45	33.8	5.85	152.0
MW-10	8/24/2022	932	693	<150	<0.40	<1.0	<1.0	<2.0	<1.0	<3.0	<0.20	5.6	1.7	0.0	0.48	66.9	7.04	119.7
MW-12	8/8/2018	-545		**2,900**	**5.7**	3.6	<1	--	--	5.8	<0.05	0.33	10.8	1.5	0.45	48.4	5.00	493
MW-12	10/2/2019	-125		**960**	**10**	7.3	<3.0	14	<2.0	14	<0.20	<1.2	10	5.0	0.20	-134.0	6.36	476.0
MW-12	4/6/2020	62		**840**	3.7	3.4	<3.0	8.7	<2.0	8.7	<0.20	<1.2	9.6	1.6	0.24	-352.6	6.81	432.4
MW-12	8/24/2020	202	-37	770	**5.6**	3.7	<3.0	8.4	<2.0	8.4	<0.20	<1.2	9.8	3.8	0.73	-96.5	6.57	469.9
MW-12	4/8/2021	429	190	620	2.1	2.0	1.0	5.6	<1.0	5.6	<0.20	<1.5	7.0	3.0	1.45	-118.6	6.57	466.4
MW-12	8/26/2021	569	330	660	**7.1**	5.3	1.3	10	<1.0	10	<0.20	1.8	9.8	6.5	1.51	-74.6	6.56	467.2
MW-12	4/25/2022	811	572	**1,500**	3.2	2.5	1.5	7.6	<1.0	7.6	<0.20	<1.5	8.1	4.0	0.57	-9.4	6.49	1,054.5
MW-12	8/24/2022	932	693	**2,400**	4.5	3.5	1.6	9.6	<1.0	10	<0.20	<1.5	8.4	6.0	0.40	36.2	6.61	418.5
MW-13	8/8/2018	-545		<100	<1	<2	<1	--	--	<2	<0.05	2.6	6.79	4.0	1.24	73.8	5.54	198
MW-13	10/2/2019	-125		<250	<3.0	<2.0	<3.0	<3.0	<2.0	ND	<0.20	2.5	6.7	4.0	0.12	-131.1	6.43	325.8
MW-13	4/6/2020	62		<250	<3.0	<2.0	<3.0	<3.0	<2.0	ND	<0.20	2.3	9.9	4.0	0.31	-170.6	6.67	292.4
MW-13	8/24/2020	202	-37	<250	<3.0	<2.0	<3.0	<3.0	<2.0	ND	<0.20	3.5	6.8	4.6	0.46	-82.7	6.52	246.3
MW-13	4/8/2021	429	190	<250	<1.0	<1.0	<1.0	<2.0	<1.0	ND	<0.20	3.7	7.5	NM	0.48	-164.4	7.00	224.6
MW-13	8/26/2021	569	330	<250	<1.0	<1.0	<1.0	<2.0	<1.0	ND	<0.20	4.7	5.4	5.5	1.27	-101.2	6.88	225.0
MW-13	4/25/2022	811	572	<50	<1.0	<1.0	<1.0	<2.0	<1.0	ND	<0.20	3.4	5.3	7.0	0.16	-159.5	7.00	373.0
MW-13	8/24/2022	932	693	<150	<0.40	<1.0	<1.0	<2.0	<1.0	<3.0	<0.20	3.9	4.4	3.0	8.52	32.1	7.47	219.3

Injection Events:
First injection: 1/21 - 2/4/2020
Second injection: 9/22 - 9/30/2020

Table 2
Enhanced *In Situ* Bioremediation Data Summary
402 North Meridian
Puyallup, Washington

Notes:

Bolded values exceed the MTCA Method A cleanup level.
J = Data validation flag indicating the analyte was positively identified; the concentration of the analyte in the sample is an estimate
(a) Chapter 173-340 Washington Administrative Code, Model Toxics Control Act Cleanup Regulation, Method A groundwater cleanup level
(b) Total xylenes.
< = analyte not detected at or greater than the listed concentration
-- = not analyzed

Abbreviations and Acronyms:

µg/L = micrograms per liter
µS/cm = microSiemens per centimeter
DO = dissolved oxygen
EPA = US Environmental Protection Agency
mg/L = milligrams per liter
mV = millivolts
ND = not detected
NM = not measured
NWTPH-Gx = Northwest total petroleum hydrocarbon extended-range gasoline analytical method
µS/cm = microsiemens per centimeter
TOC = total organic carbon

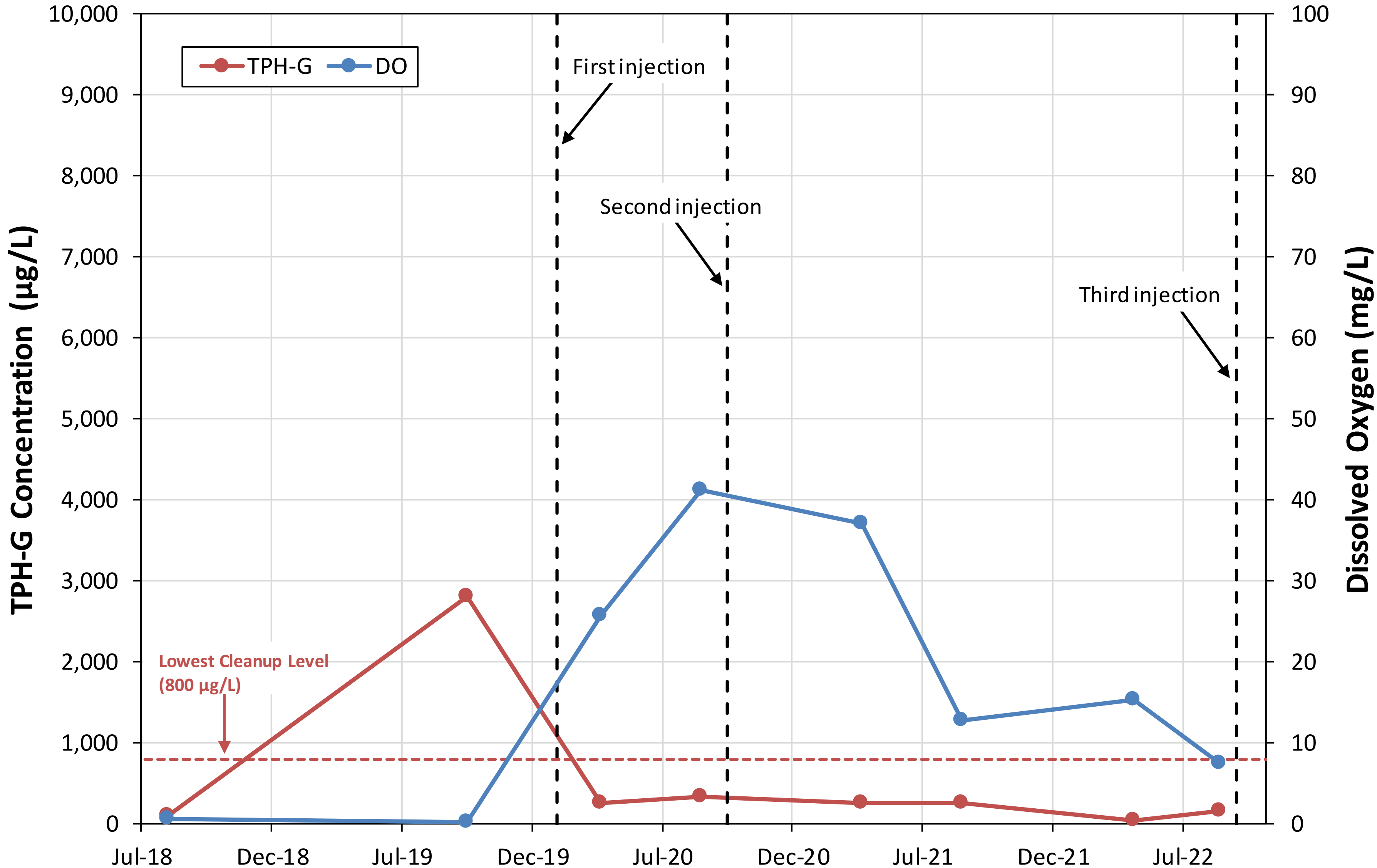
Table 3
Enhanced *In Situ* Bioremediation Injection Summary
402 North Meridian
Puyallup, Washington

Well	Volume (gallons)			
	First Injection Jan. 2020	Second Injection Sept. 2020	Third Injection Sept. 2022	Total
ART-1	989	121	24	1,134
ART-2	45	65	126	236
ART-3	315	93	22	430
ART-4	1,996	1,295	16	3,307
MW-3	1,505	878	852	3,235
MW-14	1,576	183	248	2,007
MW-15	1,306	1,954	1,840	5,100
MW-16	671	84	32	787
MW-17	2,396	2,820	2,504	7,720
MW-18	3,463	4,130	--	7,593
MW-19	200	112	--	312
TOTAL (gal)	**14,462**	**11,735**	**5,664**	**31,861**
ORC (lbs)	**5,995**	**3,520**	**1,155**	**10,670**
Dose (lb/gal)	**0.41**	**0.30**	**0.20**	
Bags	**109**	**64**	**21**	

Abbreviations & Acronyms:
gal = gallons
lbs = pounds

APPENDIX A

Gasoline-Range Organics and Dissolved Oxygen Concentration Plots



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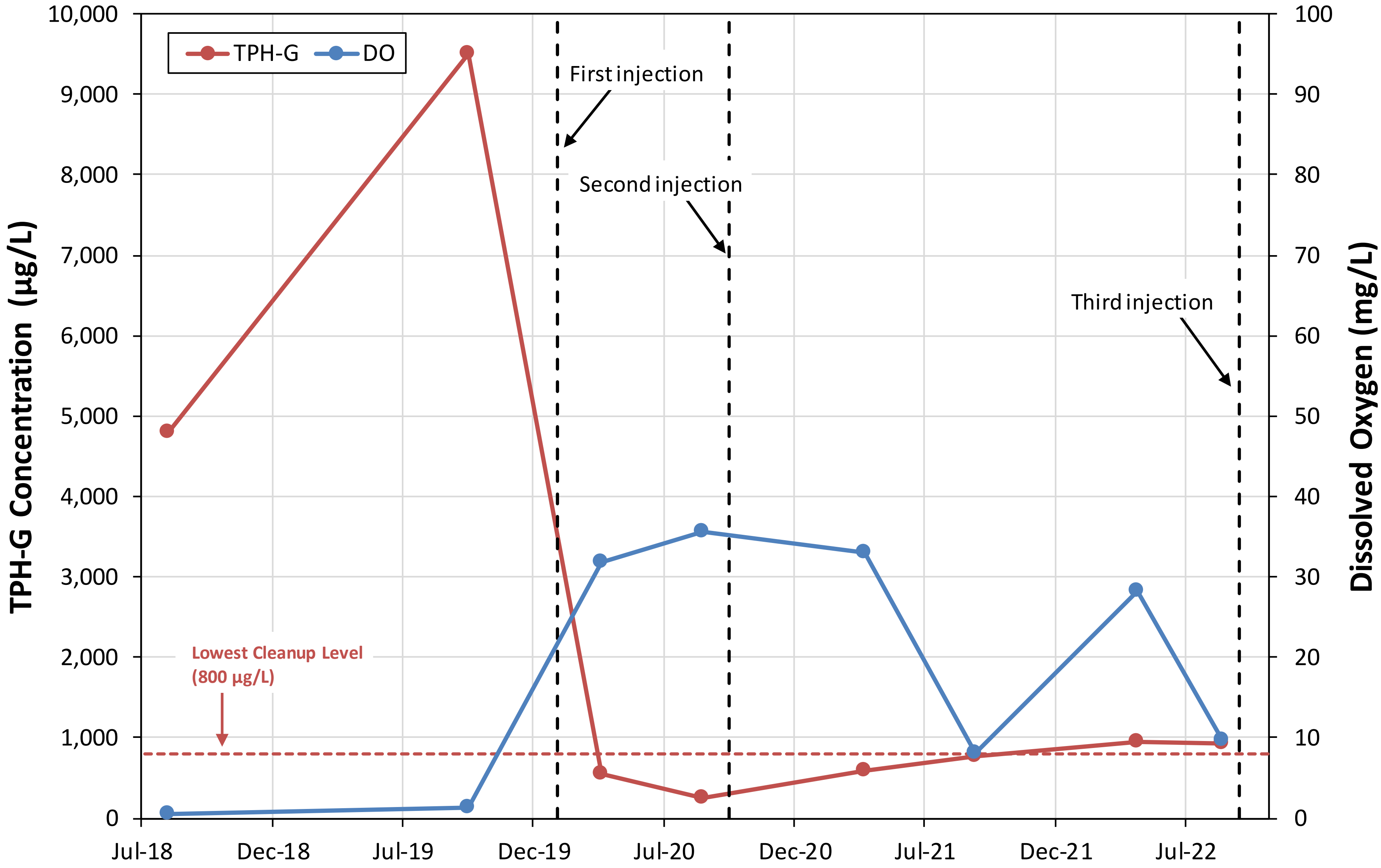
402 North Meridian
Puyallup, Washington

GRO and DO Concentrations – MW-4

Figure
A-1



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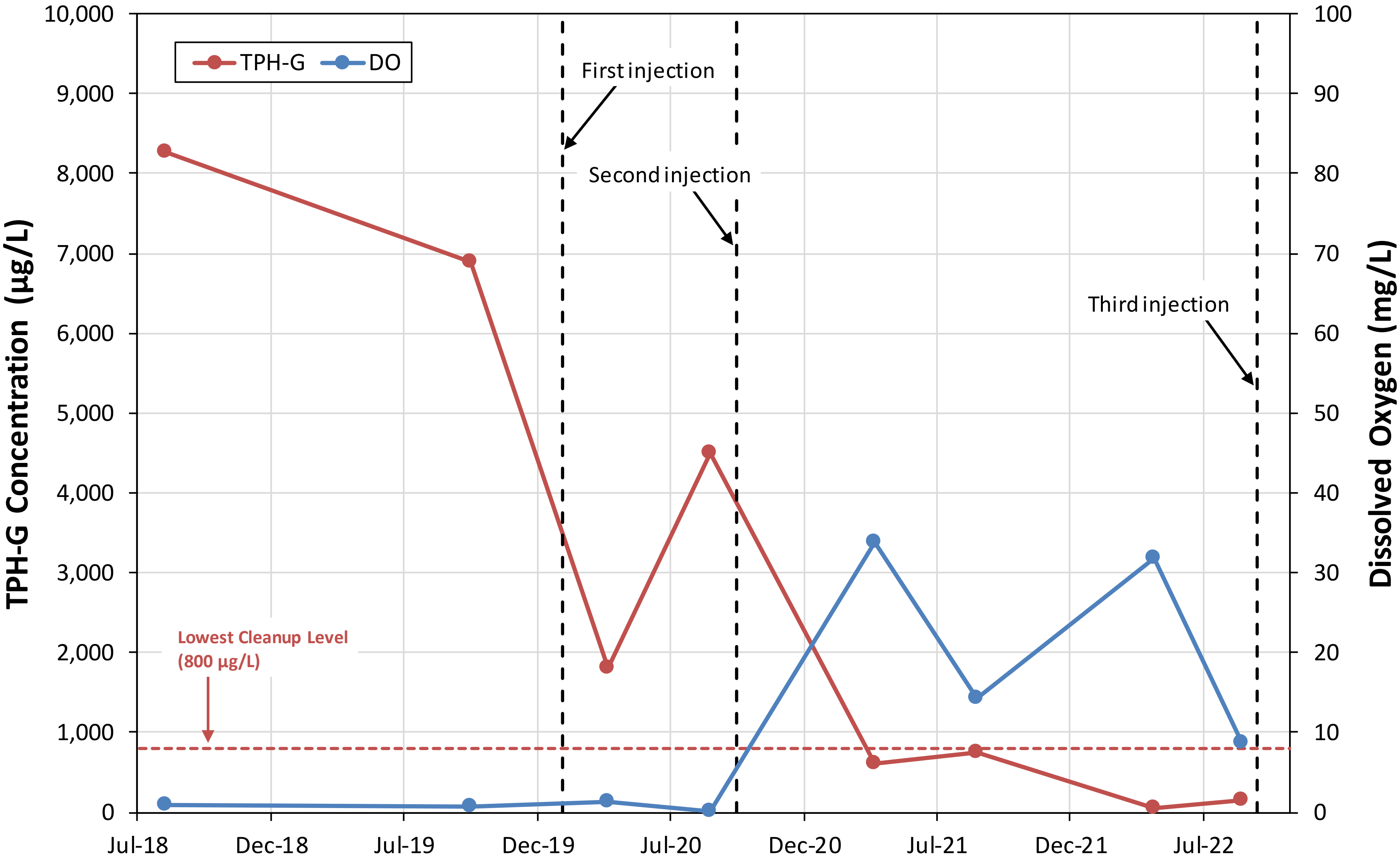
EISB Progress Report 402 North Meridian Puyallup, Washington	**GRO and DO Concentrations – MW-5**	Figure A-2



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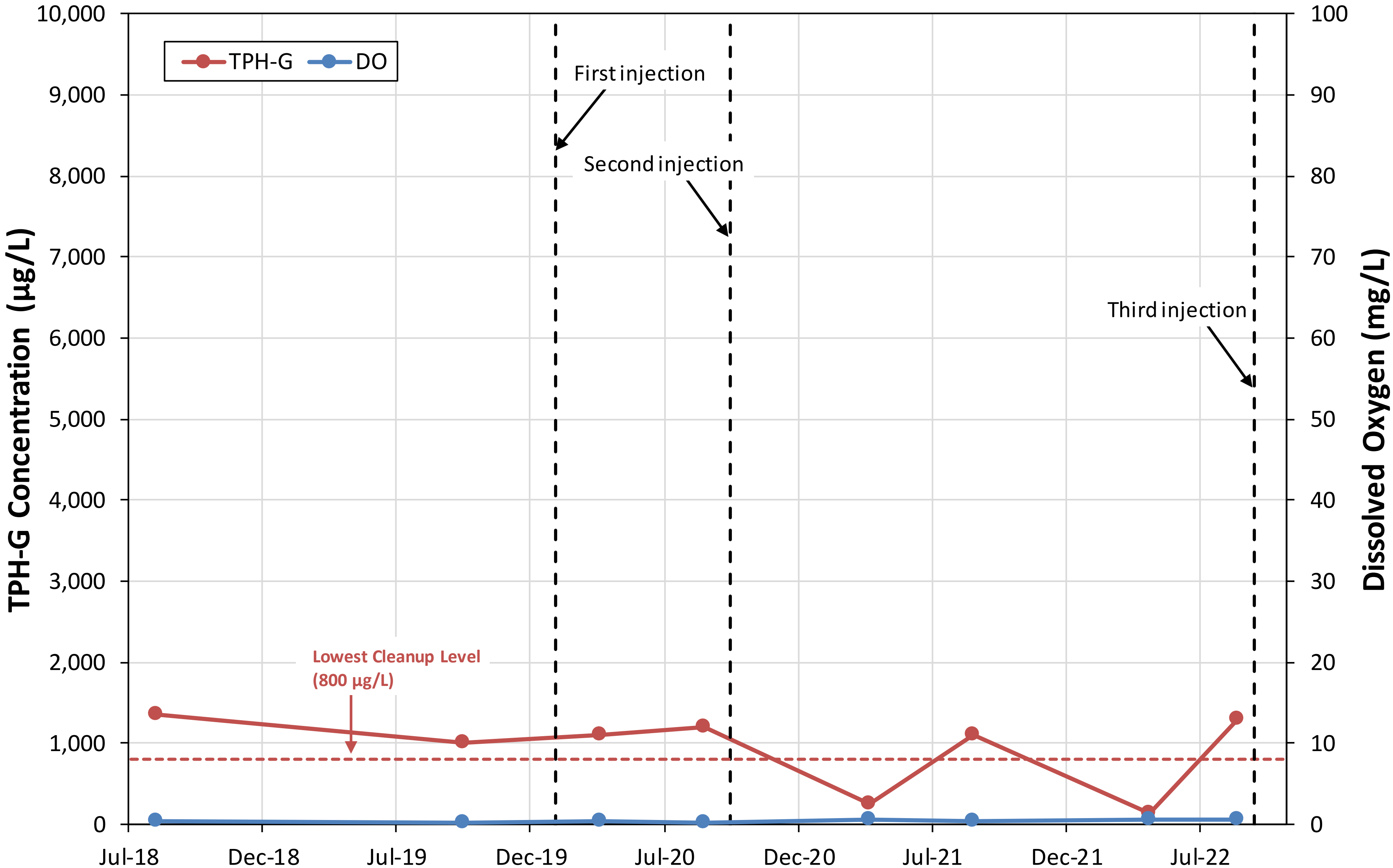
EISB Progress Report 402 North Meridian Puyallup, Washington	**GRO and DO Concentrations – MW-6**	Figure A-3



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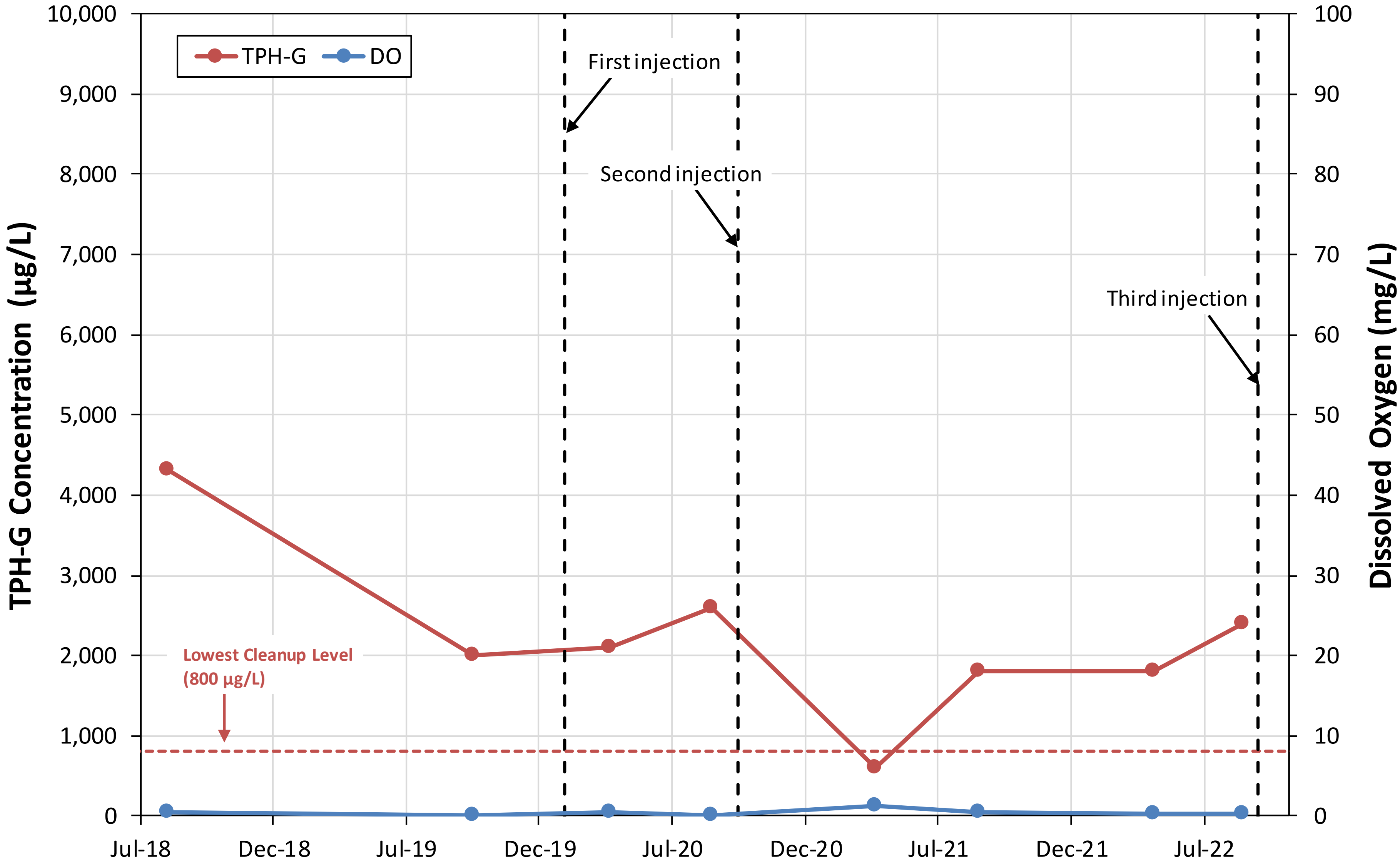
EISB Progress Report 402 North Meridian Puyallup, Washington	**GRO and DO Concentrations – MW-7R**	Figure A-4



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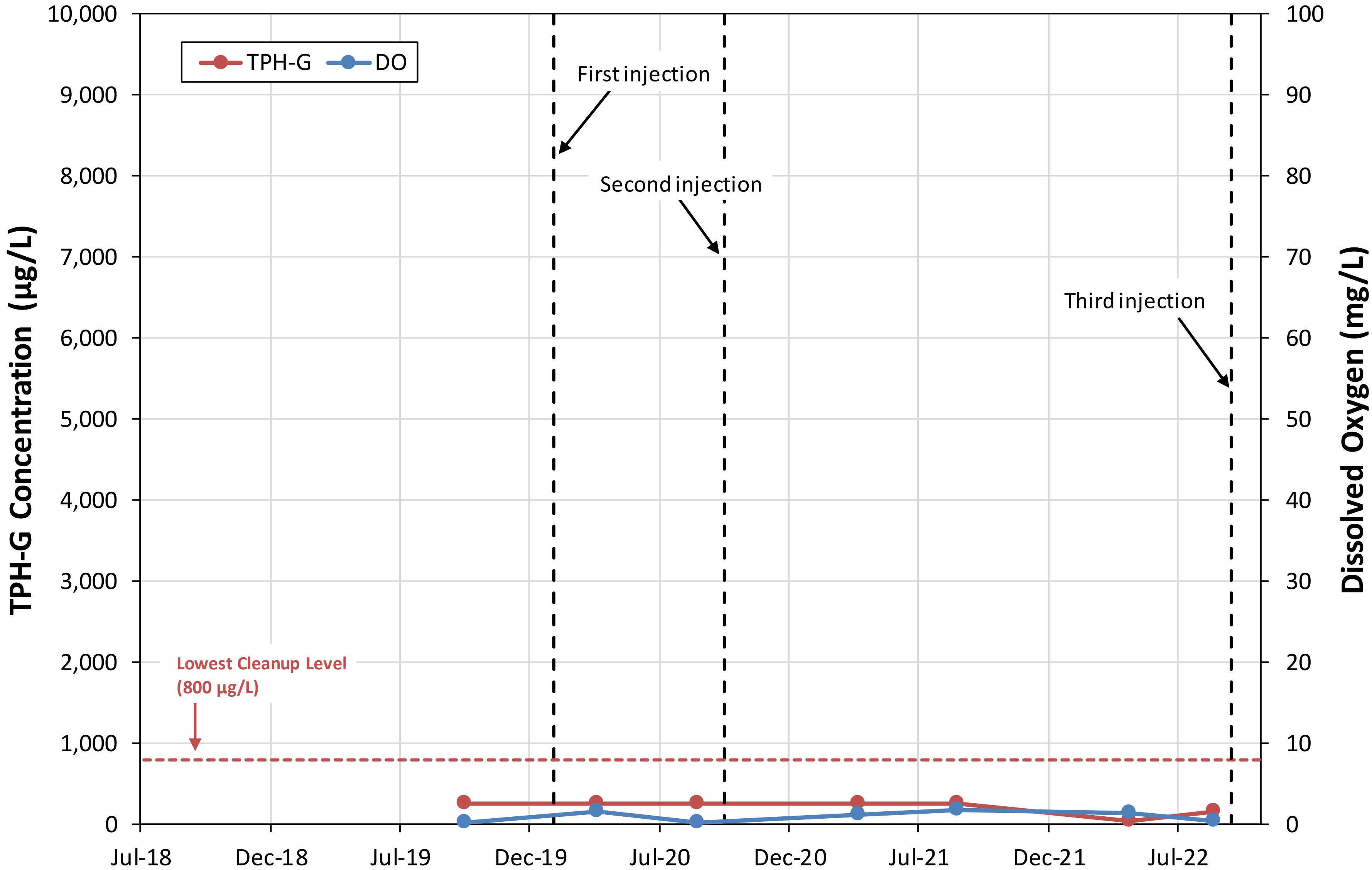
EISB Progress Report 402 North Meridian Puyallup, Washington	**GRO and DO Concentrations – MW-8**	Figure A-5



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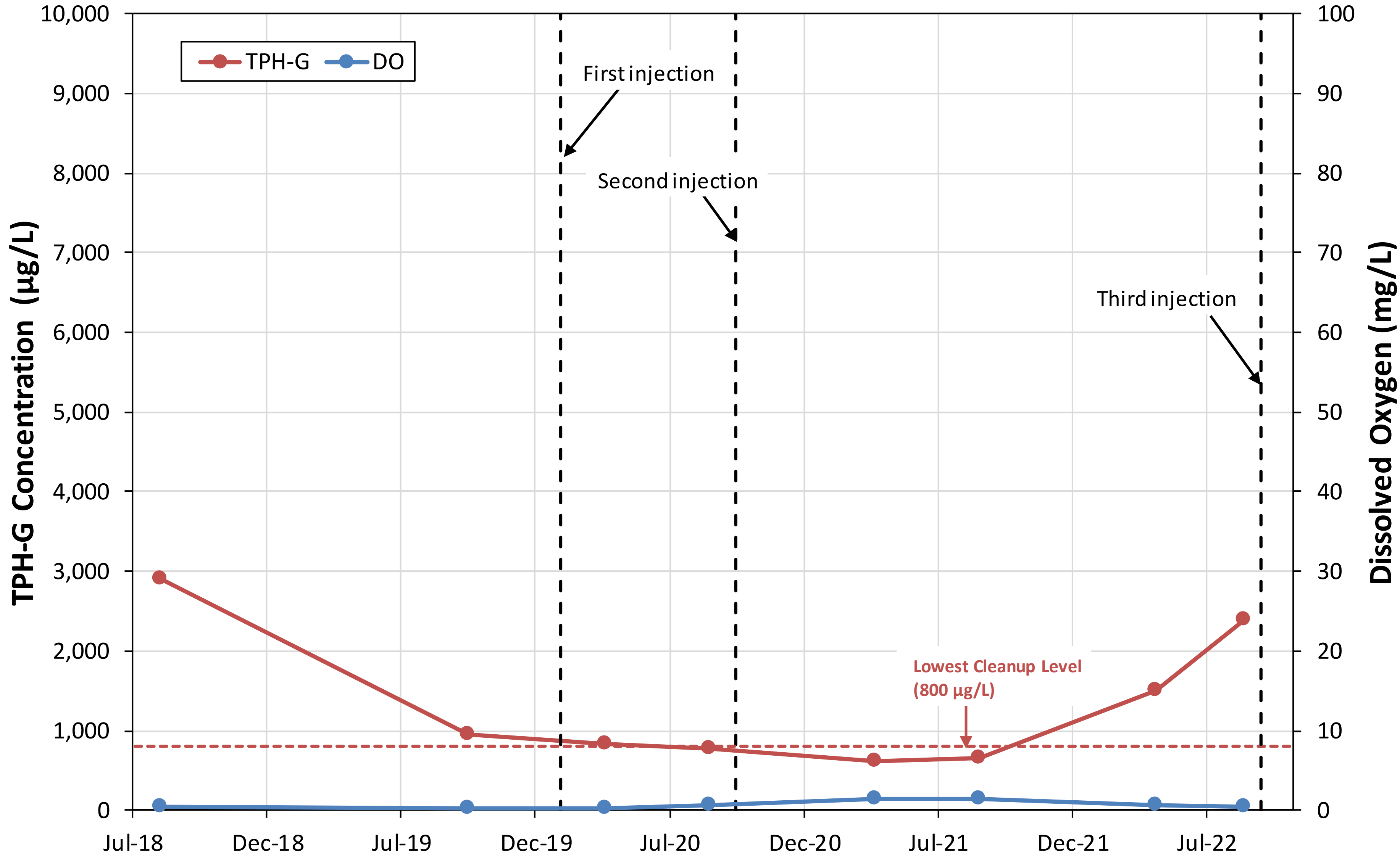
EISB Progress Report 402 North Meridian Puyallup, Washington	**GRO and DO Concentrations – MW-10**	Figure A-6



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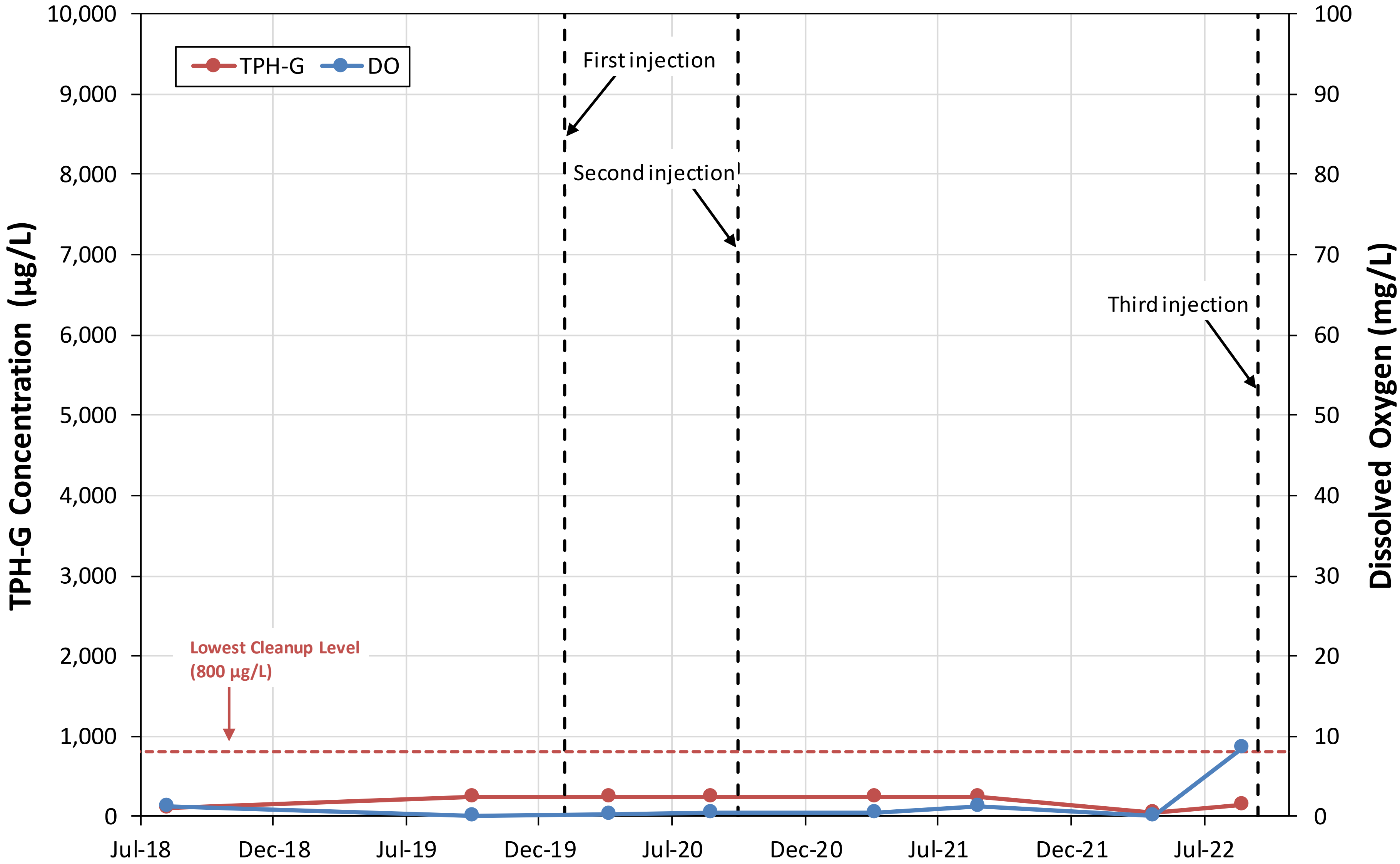
EISB Progress Report 402 North Meridian Puyallup, Washington	**GRO and DO Concentrations – MW-12**	Figure A-7



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EISB Progress Report 402 North Meridian Puyallup, Washington	**GRO and DO Concentrations – MW-13**	Figure A-8