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ANCHOR QEA

Memorandum

April 10, 2020

To: Jing Liu, Project Manager
Washington Department of Ecology
Northwest Regional Office
3190 160th Avenue SE
Bellevue, Washington 98008-5452

From: Julia Fitts, LG, Sara Potter, and David Templeton
Anchor QEA, LLC

cc: Kyle McCleary, Duwamish Shipyard, Inc.
Kim Maree Johannessen, Johannessen & Associates, P.S.

Re: Duwamish Shipyard, Inc. Site – Remedial Investigation Addendum
Arsenic Characterization Study Memorandum
Ecology Agreed Order No. DE 6735

Duwamish Shipyard, Inc. (DSI) and Anchor QEA, LLC (Anchor QEA) recently conducted supplemental Remedial Investigation (RI) activities to support completion of the RI for the DSI site (Site). These activities were performed in accordance with the Washington Department of Ecology (Ecology)-approved *Duwamish Shipyard, Inc. Site – Remedial Investigation Addendum Final Arsenic Characterization Study Work Plan* (Work Plan; Anchor QEA 2019a) to address arsenic data gaps. This memorandum provides the results of the supplemental RI sampling and includes an evaluation and discussion of localized elevated groundwater arsenic concentrations. These supplemental RI activities and the forthcoming upland Feasibility Study (FS) are being performed for the Site under Agreed Order No. DE 6735.

Purpose and Background

During review and completion of the *Remedial Investigation Report, Public Review Draft* (RI Report; Anchor QEA 2019b) and following further communications from Ecology (Ecology 2018), Ecology required that, as part of a supplemental RI, additional sampling be conducted to identify the potential source of elevated arsenic concentrations in groundwater in the southwest portion of the Site. Based on follow-up discussions with Ecology in January and March 2019, DSI prepared the Work Plan for additional sampling of soil and groundwater in the southwest portion of the Site as part of a supplemental RI (i.e., the Arsenic Study) (Anchor QEA 2019a). In a letter to Anchor QEA dated May 20, 2019, Ecology approved the RI Report pending completion of this additional Arsenic Study (Ecology 2019). The parties agreed that the Arsenic Study was necessary to better assess the nature and extent of elevated arsenic groundwater concentrations and to support development of a draft upland FS.

The purpose of the Arsenic Study was to further characterize groundwater, soil, and geochemical conditions in the southwest portion of the Site in an effort to identify the source of anomalously high dissolved arsenic groundwater levels measured in well DSIP2-13 during RI sampling (Figure 1). High dissolved arsenic groundwater concentrations were not observed in adjacent wells and were not co-located with high arsenic soil concentrations. Therefore, additional groundwater sampling and soil sampling were performed near DSIP2-13 to understand the extent of localized groundwater impacts, the potential presence of soil sources, and the geochemical conditions that might be impacting arsenic mobility. The results will also inform the development of cleanup levels for soil and groundwater, if appropriate. This memorandum presents the results of the Arsenic Study.

Summary of Investigation Methods

Field investigations for the Arsenic Study were conducted from October 5, 2019 to October 7, 2019 in accordance with the Ecology-approved Work Plan (Anchor QEA 2019a). There were no significant deviations from the Work Plan during field sampling, except for redevelopment and resampling of RI monitoring well DSIP2-16, which eliminated the need to install, develop and sample at proposed location DSIP3-03. Ecology was notified of the intent to deviate from the Work Plan and approved of this change via email on September 26, 2019.

Figure 1 shows the actual locations of direct-push borings for both soil and groundwater sampling and existing Site wells that were decommissioned (or resampled) during this investigation. Field logs, boring and well logs, and photographs are provided in Attachment A.

Soil Sampling

Anchor QEA, with Holt Services, Inc., advanced and collected four (4) soil borings via direct-push drilling techniques at the locations shown in Figures 2a and 2b. The four locations were adjusted in the field based on access considerations and the presence of utilities. After DSIP2-16 was found intact, a fifth planned boring, DSIP3-03, was no longer needed to replace the existing well. Soil borings were used for observation of soil conditions and for collection of soil samples.

Boring locations were field-verified and documented using a differential global positioning system (DGPS). All borings were advanced to a depth of fifteen (15) feet below ground surface (bgs). Soils observed from each boring were logged by the field geologist, including the soil type and the presence of debris, stained soil, or odors. Soil boring logs are included in Attachment A. Boring cuttings were contained, characterized, and disposed of at an appropriate disposal facility.

Discrete soil samples were collected from each boring at the sample intervals listed in Table 1. Soil samples were analyzed for total metals, total solids, total organic carbon (TOC), sulfide, and extractable iron and manganese oxides to investigate the extent of potential arsenic impacts and to characterize subsurface geochemical conditions. All sample containers were kept on ice for transport to the analytical laboratories. Select specialized extractions for iron and manganese oxides were performed at Anchor QEA's Environmental Geochemistry Laboratory (EGL) in Portland, Oregon. All laboratory analyses were performed at Analytical Resources, Inc. (ARI) in Tukwila, Washington.

Monitoring Well Decommissioning

Two damaged RI monitoring wells (DSIP2-13 and DSIP2-02), both of which were installed in 2013, were decommissioned as part of the Arsenic Study. The locations of decommissioned wells are shown in Figure 4 and listed in Table 2. The wells were over-drilled and filled in place. The flush-mounted well monument and lid of each well were removed, and concrete was used to emplace the ground surface flush with the current Site grade at both locations.

The condition of existing well DSIP2-16 was unknown prior to the investigation (and suspected to be damaged) and was therefore scheduled to be decommissioned. During the investigation, the well was found intact and Ecology was notified. In an email dated September 26, 2019, Ecology approved of Anchor QEA's request to resample DSIP2-16 and to remove proposed station DSIP3-03 from the investigation (which was intended to replace DSIP2-16).

Monitoring Well Installation

A total of four monitoring wells—two temporary and two permanent—were installed consistent with the procedures outlined in the Work Plan (Anchor QEA 2019a).

New monitoring well locations were field-verified using a DGPS, and well elevations were surveyed by APS Survey Mapping, Inc. following installation. Groundwater depth at the time of sample collection (below the top of the well casing) was measured by an electronic depth-to-water indicator.

Temporary well points were installed using pre-packed well screens in two locations (DSIP3-01 and DSIP3-02), as shown in Figure 1, to allow sampling of groundwater. Temporary monitoring wells were constructed of approximately 1-inch-inside-diameter polyvinyl chloride (PVC), flush-threaded casing attached to ten (10) feet of flush-threaded, pre-packed well screen. The screens extended 10 feet up from the bottom of the boring (approximately 15 feet bgs), consistent with the well screen depth intervals of neighboring Site wells DSIP2-13, DSIP2-02, and DSIP2-16. Well screen placement was verified in the field based on the observed groundwater level. The well screen and casing were inserted into the open borehole.

Permanent monitoring wells were installed in two of the soil borings, DSIP3-04 and DSIP3-05 (Figure 1). The permanent monitoring wells were constructed of 2-inch Schedule 40 PVC flush–threaded casing attached to 10 feet of flush-threaded, pre-packed well screen. The screens extend 10 feet from the bottom of the boring (approximately 15 feet bgs), consistent with the well screen depth intervals of neighboring Site wells DSIP2-13, DSIP2-02, and DSIP2-16. Well screen placement was verified in the field based on the observed groundwater level. Well materials were inserted into the cased borehole using the drill casing as temporary casing. Approximately 1 to 2 feet of silica sand was placed above the top of the pre-packed screen, and the remainder of the annular space was backfilled with bentonite chips to 1 foot bgs, for each well. A concrete seal and well pad were installed from 1 foot in depth to the surface. The wells are completed with watertight caps inside flush-mounted well monuments. Permanent wells were developed and allowed to re-equilibrate for twelve (12) hours, as prescribed in the Work Plan (Anchor QEA 2019a), prior to sampling.

Groundwater Sampling

Groundwater was sampled from the two temporary wells and from three permanent monitoring wells consistent with the procedures in the Work Plan (Anchor QEA 2019a). Groundwater sampling and well construction details are summarized in Table 2.

Prior to groundwater sampling at the two temporary well points, the depth to water (below the top of casing) was measured at each location using an electronic depth-to-water indicator and recorded. Groundwater was purged with a peristaltic pump equipped with dedicated polyethylene tubing until the water quality parameters (pH, specific conductivity, dissolved oxygen, turbidity, and temperature) stabilized. Once field-measured groundwater quality parameters stabilized, the groundwater was allowed to return to static water level (recharge). Groundwater was then sampled with the peristaltic pump from the approximate middle of the well screen interval using low-flow methodology.

Groundwater samples were collected from the three permanent wells no sooner than 12 hours following development.

All groundwater samples wells were analyzed for dissolved metals and geochemical parameters (sulfate, sulfide, TOC, dissolved organic carbon, total dissolved solids, total suspended solids, ammonia, dissolved iron, dissolved manganese, nitrate, phosphate, and silica). A summary of groundwater testing at each monitoring well, including well details (i.e., well depth and screen interval), is provided in Table 2. All sample containers were kept on ice for transport to the analytical laboratory. Laboratory analyses were performed at ARI.

Data Quality Assessment

Testing was performed by ARI, an Ecology-accredited laboratory that is also accredited under the National Environmental Laboratory Accreditation Program. Specialized extractions for iron and manganese oxides were performed at EGL. Data quality objectives and quality assurance procedures are provided in the Work Plan (Anchor QEA 2019a). Laboratory data packages are provided in Attachment B-1. Data packages were validated by Laboratory Data Consultants in Carlsbad, California. Data validation reports are provided in Attachment B-2. All data qualifiers applied to the data during final validation have been incorporated into the database for this project. Data qualifiers assigned during data validation include the following:

- "J" indicates the associated numerical value is an estimated concentration.
- "U" indicates a reporting limit below which the analyte was not detected.
- "UJ" indicates an approximate reporting limit below which the analyte was not detected.
- "R" indicates data are rejected and not usable for any purpose.

The validation process resulted in the rejection of nine values for antimony due to low recovery in the matrix spike sample. Certain data were qualified as estimated values for a particular analysis based on a method or technical criterion, as stated in the national functional guidelines (EPA 2017a, 2017b). All data were considered usable as reported or as qualified and were deemed acceptable for their intended use by the third-party validator.

Results

Results of the investigation are summarized in the following subsections. Soil boring and groundwater sampling logs are included in Attachment A. Laboratory and data validation reports are included in Attachment B.

Soil Sampling

Soil samples were collected from the locations and intervals shown in Table 1. Final sampling locations were within 15 feet of the proposed locations. Seventeen (17) soil samples from four stations, including one (1) field duplicate, were submitted for analytical testing as shown in Table 1. Documentation of the field sampling is provided in Attachment A.

Results for all stations are summarized below. Soil testing results are provided in Table 3. Maximum soil arsenic concentrations are presented for the Arsenic Study and the existing RI locations in Figures 2a and 2b (0 to 6 feet bgs and 6 to 15 feet bgs, respectively).

- **Arsenic:** The distribution of arsenic in soil within the Arsenic Study area is depicted on cross sections in Figures 3a through 3c. Soil arsenic concentrations range from 1.7 to 32.3 milligrams per kilogram (mg/kg), averaging 7.0 mg/kg. Of the 17 soil samples collected and submitted for analytical testing, five (5) discrete soil samples and a field duplicate from three stations (DSIP3-01, DSIP3-02, and DSIP3-05) are above the soil background level of 7 mg/kg. At DSIP3-01, exceedances of the soil arsenic screening level were measured in the 2 to 4.5 feet bgs interval and the 5 to 7 feet bgs interval (12.6 mg/kg and 13.9 mg/kg [32.3 mg/kg field duplicate], respectively). At DSIP3-02, low level exceedances were measured at 3 to 5 feet bgs and 12 to 14 feet bgs (9.6 mg/kg and 8.3 mg/kg, respectively). At station DSIP3-05 (downgradient of DSIP2-13), only one (1) exceedance of the soil screening level was measured at 12 to 14 feet bgs at 8.67 mg/kg. Soil arsenic concentrations from this study are generally similar to or lower than the arsenic concentrations measured in this area during the RI (see Attachment C for RI data).

- **Lithology:** Detailed soil lithology for all Arsenic Study boring locations is provided in the boring logs in Attachment A-2. The well screen intervals (5 to 15 feet bgs) at stations DSIP3-01 and DSIP3-02 (adjacent to DSIP2-13) consist primarily of high-plasticity silt with varying organic (wood debris) content. At both stations, this silt unit was recorded from approximately 11 feet bgs to the bottom of each boring at approximately 15 feet bgs. At DSIP3-02, similar silt layers were also identified from 2.9 to 4.0 feet bgs, 9.6 to 10.0 feet bgs, and 11.1 to 15.0 feet bgs. The depth and organic content of the silt layers at these stations were similar to those observed at adjacent RI borings, with the exception of DSIP2-13, which consisted of a thicker highly organic silt unit (further described in the Discussion section). These observations are consistent with historical filling activities along the Duwamish Waterway since the early 1900s, prior to DSI's ownership.
- **Total organic carbon:** TOC ranges from 0.03% to 4.0%, averaging 1.1%. At the Arsenic Study stations closest to DSIP2-13 (DSIP3-01 and DSIP3-02), the average TOC is also 1.1%.
- **Extractable iron oxides:** Iron oxide concentrations range from 1,320 to 16,100 mg/kg, averaging 5,540 mg/kg. The minimum and maximum concentrations were both measured at location DSIP3-01, near DSIP2-13. Concentrations are highest at 2 to 4 feet bgs and lowest at 12 to 14 feet bgs.
- **Extractable manganese oxides:** Extractable manganese oxide concentrations range from 3.7 to 39.3 mg/kg, averaging 12.8 mg/kg. The maximum concentration was measured in the 2 to 4.5 feet bgs interval at location DSIP3-01, near DSIP2-13.
- **Total sulfide:** Total sulfide concentrations range from 1.2 to 234 mg/kg, averaging 41.2 mg/kg.

Groundwater Sampling

Groundwater samples were collected in October 2019 from the locations and intervals shown in Table 4. A total of six (6) groundwater samples, including one (1) field duplicate, were collected from five locations and submitted for analytical testing as summarized in Table 2. Documentation of the field sampling is provided in Attachment A.

Results for all Arsenic Study stations are summarized below. Groundwater testing results from the October 2019 sampling event are provided in Table 4. Groundwater dissolved arsenic concentrations detected during that sampling event are presented for the Arsenic Study wells and the existing shallow RI monitoring wells in Figure 4. That figure shows the new Arsenic Study data alongside the maximum RI concentrations for wells that were last sampled during the RI from 2014 to 2015.

- **Arsenic:** Dissolved arsenic concentrations in groundwater at locations within the Arsenic Study area are lower than those observed during the RI. Groundwater arsenic concentrations range from 0.59 to 45.2 micrograms per liter (µg/L), averaging 16.2 µg/L. The two groundwater stations closest to DSIP2-13 measured arsenic concentrations above the groundwater background level of 8 µg/L. DSIP3-01 measured 43.9 µg/L, and a concentration of 45.2 µg/L was measured at DSIP3-02. All other dissolved arsenic concentrations from this study are below the RI screening level.
- **Oxidation-reduction potential (ORP):** Groundwater ORP measurements range from 66.2 to -12.1 millivolts (mV) at all Arsenic Study locations, averaging -29.6 mV. The range of ORP is generally similar for all locations, with the lowest ORP at location DSIP3-02.
- **pH:** Measurement of pH ranged between 6.32 and 6.76, averaging 6.50.
- **Sulfate/sulfide:** Sulfate ranges from 0.16 to 26.8 milligrams per liter (mg/L), averaging 14.7 mg/L. Sulfate is lowest at DSIP3-05, the station furthest downgradient of DSIP2-13. Sulfide was not detected at any location above the reporting limit of 0.05 mg/L.

Discussion

As discussed above, the main objectives of the Arsenic Study were to further characterize groundwater, soil, and geochemical conditions near DSIP2-13, where elevated dissolved arsenic was measured in groundwater during the RI.

Groundwater arsenic concentrations as measured during the Arsenic Study did not replicate the similar elevated concentrations in DSIP2-13, even in nearby temporary wells. This indicates that the elevated groundwater arsenic concentrations observed during the 2014 to 2015 RI sampling are a local anomaly confined to a small area near DSIP2-13. Moreover, the data indicate that the elevated groundwater arsenic concentrations may have attenuated over time. However, because DSIP2-13 was damaged and required abandonment, temporal attenuation cannot be directly verified.

The Arsenic Study did not find high soil arsenic concentrations that could explain the prior elevated groundwater concentrations at DSIP2-13. Further, there appears to be little relationship between soil arsenic concentrations and groundwater arsenic concentrations that would explain the observed trends at the Site. Therefore, soil arsenic data do not indicate a specific soil source area for the elevated dissolved arsenic that was formerly measured in groundwater at the Site.

One possible explanation (out of many) for the prior elevated dissolved arsenic concentration at DSIP2-13 is that local subsurface geochemical conditions are slightly more reducing than surrounding areas, enhancing the partitioning of arsenic from soil to groundwater at higher levels than adjacent areas. Arsenic partitioning between soil and water, as well as mobility, are dependent on the speciation of arsenic (i.e., arsenic[III] and arsenic[V]) and the availability of soil iron oxides, which can adsorb arsenic. Arsenic speciation and iron oxide stability are both functions of ORP and pH, among other factors. Thus, the Arsenic Study included analysis of geochemical parameters (e.g., extractable iron and manganese oxides, and sulfide concentrations) that were not measured during the RI to further understand geochemical conditions that contribute to the arsenic elevation previously detected in the vicinity of DSIP2-13.

An evaluation of those geochemical parameters concluded that conditions at DSIP2-13 are more reducing compared to other samples at the Site. Groundwater ORP at DSIP2-13 was lower (up to -190 mV), as was sulfate (up to 16.3 mg/L), with detectable sulfide levels (up to 0.475 mg/L). This implicates locally enhanced microbial activity as the most likely contributor to the historically elevated groundwater arsenic at this location. It also supports a conclusion that locally sulfate-reducing conditions are present at DSIP2-13, with sulfide as a by-product of those conditions.

The impact of geochemical conditions on arsenic mobility was examined by developing Eh-pH diagrams for arsenic and iron species (Figures 5a and 5b). The diagrams were developed using Site-specific values for temperature, arsenic, iron, and sulfur. Sample Eh (converted from ORP measurements) and pH values measured in the field were plotted on the diagrams and are provided in Table 5. Figure 5a shows that subsurface conditions are situated near the stability boundary between oxidized arsenate species (arsenic[V]) and reduced arsenite species (arsenic[III]). Arsenic(III) adsorbs less strongly to soil and is generally more mobile than arsenic(V) in groundwater. Similarly, Figure 5b shows that groundwater conditions straddle the stability boundary between iron(III) oxides under oxidized conditions and dissolved ferrous iron under more reducing conditions. Iron oxides are a strong adsorbent for arsenic in soil. Iron-reducing bacteria, commonly present in soils, can dissolve the iron oxides under anaerobic conditions, releasing ferrous iron and adsorbed arsenic to groundwater.

Location-specific arsenic soil-water partitioning coefficients (Kd values) were calculated to compare to values that have been cited in literature (Table 6 and Figure 6). Kd values were calculated by averaging the soil concentrations of samples within the well screen interval for each well, and then dividing by the average groundwater concentration for all measurements from in the well. For example, the soil concentration for DSIP2-13 was the average of the samples from the 6- to 8-foot, 9- to 11-foot, and 12- to 14-foot intervals, because all three intervals overlap with the 5- to 15-foot well screen. For wells that had been sampled for groundwater in multiple events, the Kd values from each sampling were averaged to provide a single estimate per well. For wells surrounding DSIP2-13 (i.e., DSIP2-02, DSIP2-16, DSIP3-01, DSIP3-02, DSIP3-04, and DSIP3-05), the empirical Kd values ranged from 107 to 6,949 liters per kilogram (L/kg), all well above the default Model Toxics Control Act (MTCA) value of 29 L/kg. In DSIP2-13, the Kd value was 4.5 L/kg, below the MTCA value, but within range of those observed in studies listed in *Understanding Variation in Partition Coefficient, Kd, Values* (EPA 2004). As emphasized in the U.S. Environmental Protection Agency's 2004 document, "partitioning coefficient values measured as site-specific conditions are absolutely essential."

The reducing conditions and enhanced iron-reducing microbial activity are likely driven by the presence of the organic rich silt layer within the screen interval of DSIP2-13. Based on a review of RI soil boring logs from stations located in the vicinity of the DSIP2-13 and surrounding Site areas, an approximately 7-foot-thick organic silt unit is present across most of the well screen interval (i.e., between approximately 5 and 15 feet bgs) at DSIP2-13. Organic silt in adjacent wells (e.g., DSIP3-01 and DSIP3-02) is present at greater depths than at DSIP2-13, or in thinner layers in the vadose zone, and therefore may not affect shallow groundwater chemistry as strongly.

The overall effect is that localized reducing conditions and associated microbial activity temporarily enhance the mobility of iron and arsenic in groundwater in the vicinity of DSIP2-13. The mobilized iron appears to be reprecipitated downgradient of DSIP2-13, where conditions again become less reducing, and the iron oxides adsorb the previously mobilized arsenic, thereby attenuating the elevation over a relatively short distance.

Summary

A supplemental RI Arsenic Study was performed as required by Ecology under the Agreed Order and the approved Work Plan (Anchor QEA 2019a) to further characterize groundwater, soil, and geochemical conditions near DSIP2-13. Soil arsenic concentrations were within the range of RI levels (i.e., no hot spot was identified). The elevated dissolved arsenic groundwater concentrations observed at DSIP2-13 during the 2014 to 2015 RI sampling were not replicated during the Arsenic Study. Temporary wells near the historical location of DSIP2-13 also had much lower dissolved arsenic concentrations, indicating a highly localized effect. Though other factors may exist, multiple geochemical lines of evidence, including groundwater field parameters, soil lithology, and dissolved iron and sulfate concentrations in groundwater, point to potential localized reducing conditions at DSIP2-13 related to organic rich subsurface soils and enhanced microbial mobilization of iron and arsenic. The results and implications of this study will be evaluated as part of the draft upland FS in coordination with Ecology.

References

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EPA, 2017a. EPA Contract Laboratory Program National Functional Guidelines for Inorganic Superfund Methods Data Review. U.S. Environmental Protection Agency, Office of Superfund Remediation and Technology Innovation. EPA-540-R-2017-001. January 2017.

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Attachments

Tables

Figures

Attachment A

Attachment B

Attachment C

Tables

Table 1
Soil Sampling Summary

Station ID	Date Sampled	Location		Soil Sample ID	Sample Interval (feet)		Elevation (feet MLLW)		Soil Testing
		Easting (feet)	Northing (feet)		Start	End	Start	End	
DSIP3-01	10/5/2019	1267443.1	204400.8	DSIP3-01-2.5-4.5	2.5	4.5	13.9	11.9	Metals, Total Sulfide, Extractable Iron and Manganese Oxides, TS, TOC
				DSIP3-01-5-7	5.0	7.0	11.4	9.4	
				DSIP3-01-D-5-7	5.0	7.0	11.4	9.4	
				DSIP3-01-8-10	8.0	10.0	8.4	6.4	
				DSIP3-01-12-14	12.0	14.0	4.4	2.4	
DSIP3-02	10/6/2019	1267422.2	204362.1	DSIP3-02-3-5	3.0	5.0	14.1	12.1	
				DSIP3-02-6-8	6.0	8.0	11.1	9.1	
				DSIP3-02-9-11	9.0	11.0	8.1	6.1	
				DSIP3-02-12-14	12.0	14.0	5.1	3.1	
DSIP3-04	10/5/2019	1267334.6	204372.2	DSIP3-04-2.5-5.0	2.5	5.0	14.5	12.0	
				DSIP3-04-5.0-7.5	5.0	7.5	12.0	9.5	
				DSIP3-04-7.5-10	7.5	10.0	9.5	7.0	
				DSIP3-04-11.5-14	11.5	14.0	5.5	3.0	
DSIP3-05	10/5/2019	1267601.2	204493.7	DSIP3-05-5-7	5.0	7.0	13.0	11.0	
				DSIP3-05-7-9	7.0	9.0	11.0	9.0	
				DSIP3-05-9-11	9.0	11.0	9.0	7.0	
				DSIP3-05-12-14	12.0	14.0	6.0	4.0	

Notes:
Horizontal datum is Washington State Plane North, U.S. Survey feet.
Vertical datum is feet MLLW. Elevations were collected in the field using differential geographic positioning system. Sample elevation was calculated by subtracting depth below ground surface from ground surface elevation.
Metals: 13 priority pollutant metals [antimony (Sb), arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), silver (Ag), thallium (Tl), zinc (Zn)] and barium (Ba).
MLLW: mean lower low water
TOC: total organic carbon
TS: total solids

Table 2
Monitoring Well Installation, Decommissioning, and Groundwater Sampling Summary

	Activity Completed			Location							Groundwater Testing	
Station ID	Monitoring Well Decommissioned	Monitoring Well Installed	Groundwater Sampled	Easting (feet)	Northing (feet)	Well Screen Interval (feet bgs)	Date Sampled	Groundwater Sample ID	Depth to Groundwater (feet btoc)	Groundwater Elevation (feet MLLW)	Chemistry	Field Parameters
DSIP2-02	X			1267562.4	204456.8	--	--	--	--	--	--	--
DSIP2-13	X			1267446.2	204365.5	--	--	--	--	--		
DSIP2-16			X	1267562.8	204360.2	5.2-15.2	10/7/2019	DSIP2-16-191007	4.39	13.63	Dissolved Metals, TOC, DOC, Sulfide, Sulfate, Nitrate, Total Phosphorous, TDS, TSS, NH_3, Total Silicon	Temperature, DO, specific conductivity, pH, ORP, turbidity
DSIP3-01		X (temporary)	X	1267443.1	204400.8	5.0-15.0	10/5/2019	DSIP3-01-191005	5.35	11.00		
DSIP3-02		X (temporary)	X	1267422.2	204362.1	5.0-15.0	10/6/2019	DSIP3-02-191006	5.33	11.75		
DSIP3-04		X (permanent)	X	1267334.6	204372.2	5.1-15.1	10/7/2019	DSIP3-04-191007	4.95	12.03		
DSIP3-05		X (permanent)	X	1267601.2	204493.7	5.0-15.0	10/7/2019	DSIP3-05-191007	5.95	11.44		

Notes:
Horizontal datum is Washington State Plane North, U.S. Survey feet.
Vertical datum is NAVD 88. Elevations were surveyed in to the height of well casing. Groundwater elevation was calculated by subtracting depth below the top of the well casing.
Water depth presented is at the time of sample collection and measured by electronic depth-to-water indicator. Water levels in the Duwamish River are tidally and seasonally influenced.
--: not applicable
bgs: below ground surface
btoc: below top of casing
DO: dissolved oxygen
DOC: dissolved organic carbon
EPA: United States Environmental Protection Agency
Metals: 13 priority pollutant metals [antimony (Sb), arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), silver (Ag), thallium (Tl), zinc (Zn)] plus barium (Ba), manganese (Mn) and iron (Fe).
MLLW: mean lower low water
NH_3: ammonia
ORP: oxidation reduction potential
TDS: total dissolved solids
TOC: total organic carbon
TS: total solids
TSS: total suspended solids

Table 3

Soil Testing Results

	Location ID	**DSIP3-01**					**DSIP3-02**			
	Location Description	**Near DSIP2-13**					**Near DSIP2-13**			
	Sample ID	**DSIP3-01-2-4.5**	**DSIP3-01-5-7**	**DSIP3-01-D-5-7**	**DSIP3-01-8-10**	**DSIP3-01-12-14**	**DSIP3-02-3-5**	**DSIP3-02-6-8**	**DSIP3-02-9-11**	**DSIP3-02-12-14**
	Sample Date	**10/5/2019**	**10/5/2019**	**10/5/2019**	**10/5/2019**	**10/5/2019**	**10/6/2019**	**10/6/2019**	**10/6/2019**	**10/6/2019**
	Depth	**2 - 4.5 ft**	**5 - 7 ft**	**5 - 7 ft**	**8 - 10 ft**	**12 - 14 ft**	**3 - 5 ft**	**6 - 8 ft**	**9 - 11 ft**	**12 - 14 ft**
	Sample Type	**Normal**	**Normal**	**Field Duplicate**	**Normal**	**Normal**	**Normal**	**Normal**	**Normal**	**Normal**
	Matrix	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
	Easting (feet)	**1267443.1**	**1267443.1**	**1267443.1**	**1267443.1**	**1267443.1**	**1267422.2**	**1267422.2**	**1267422.2**	**1267422.2**
	Northing (feet)	**204400.8**	**204400.8**	**204400.8**	**204400.8**	**204400.8**	**204362.1**	**204362.1**	**204362.1**	**204362.1**
Analyte	**Soil Screening Level**									
Conventional Parameters (pct)										
Total organic carbon	--	**1.3 J**	**0.31 J**	**0.07 J**	**0.73 J**	**0.82 J**	**2.5**	**0.04**	**0.93**	**3.26**
Total solids	--	**78.01**	**80.08**	**80.09**	**70.63**	**69.11**	**81.23**	**81.69**	**70.09**	**56.36**
Metals (mg/kg)										
Antimony	--	0.25 UJ	0.25 UJ	0.23 UJ	**-- R**	**-- R**	0.24 U	0.22 U	0.28 U	0.33 U
Arsenic	7.0	**12.6**	**13.9**	**32.3**	**2.86**	**5.46**	**9.56**	**2.37**	**3.86**	**8.31**
Barium	--	**71.9**	**16.2**	**15.0**	**26.4**	**21.6**	**26.2**	**12.0**	**23.1**	**28.1**
Beryllium	--	**0.22 J**	**0.1 J**	**0.12 J**	**0.17 J**	**0.16 J**	**0.14 J**	**0.1 J**	**0.19 J**	**0.26 J**
Cadmium	0.77	**0.72**	**0.07 J**	**0.07 J**	**0.09 J**	**0.09 J**	**0.14**	0.11 U	0.14 U	**0.08 J**
Chromium	260	**19.2**	**7.98**	**7.53**	**10.3**	**12.9**	**11.2**	**7.11**	**11.5**	**15.2**
Copper	36	**52.3**	**41.0**	**92.1**	**15.5**	**22.7**	**18.7**	**6.87**	**39.2**	**24.6**
Lead	81	**56.9**	**2.3**	**3.45**	**2.4**	**2.68**	**24.9**	**0.82**	**3.27**	**3.38**
Mercury	0.07	**0.136 J**	0.0225 U	0.0229 U	**0.0358 J**	**0.0275 J**	**0.0501**	0.0256 U	**0.0341**	**0.0283 J**
Nickel	38	**25.4 J**	**50.6 J**	**49.1 J**	**8.51 J**	**8.98 J**	**8.73**	**5.69**	**8.07**	**12.6**
Selenium	0.5	**0.15 J**	**0.08 J**	**0.07 J**	**0.11 J**	**0.24 J**	**0.54 J**	**0.53 J**	**0.89**	**1.26**
Silver	0.2	**0.21 J**	**0.07 J**	**0.1 J**	**0.04 J**	**0.05 J**	**0.13 J**	**0.02 J**	**0.04 J**	**0.08 J**
Thallium	--	**0.08 J**	**0.04 J**	**0.03 J**	**0.05 J**	**0.05 J**	0.24 U	0.22 U	0.28 U	0.33 U
Zinc	85	**145**	**23.5**	**23.3**	**27.9**	**28.6**	**33.1**	**18.8**	**27.9**	**32.4**
Geochemical Parameters (mg/kg)										
Extractable iron oxides	--	**16100**	**3340**	**3703**	**6170**	**1330**	**6210**	**3130**	**3760**	**6102**
Extractable manganese oxides	--	**39.29**	**4.46**	**6.15**	**22.1**	**12.86**	**18.66**	**3.7**	**14.78**	**9.41**
Sulfide	--	**62**	1.27 U	1.23 U	**2.4**	**22.7**	**71.4**	**1.79**	**82.9**	**81.4**

Notes:

🟨 Detected concentration is greater than the RI soil screening level

🟧 Non-detected concentration is greater than the RI soil screening level

Bold: Detected result

--: not applicable

µg/kg: micrograms per kilogram

ft: feet

J: estimated value

mg/kg: milligrams per kilogram

pct: percent

R: rejected

U: compound analyzed, but not detected above detection limit

UJ: compound analyzed, but not detected above estimated detection limit

Table 3
Soil Testing Results

	Location ID	**DSIP3-04**				**DSIP3-05**			
	Location Description	**Upgradient**				**Downgradient**			
	Sample ID	**DSIP3-04-2.5-5.0**	**DSIP3-04-5.0-7.5**	**DSIP3-04-7.5-10**	**DSIP3-04-11.5-14**	**DSIP3-05-5-7**	**DSIP3-05-7-9**	**DSIP3-05-9-11**	**DSIP3-05-12-14**
	Sample Date	**10/5/2019**	**10/5/2019**	**10/5/2019**	**10/5/2019**	**10/5/2019**	**10/5/2019**	**10/5/2019**	**10/5/2019**
	Depth	**2.5 - 5 ft**	**5 - 7.5 ft**	**7.5 - 10 ft**	**11.5 - 14 ft**	**5 - 7 ft**	**7 - 9 ft**	**9 - 11 ft**	**12 - 14 ft**
	Sample Type	**Normal**	**Normal**	**Normal**	**Normal**	**Normal**	**Normal**	**Normal**	**Normal**
	Matrix	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
	Easting (feet)	**1267334.6**	**1267334.6**	**1267334.6**	**1267334.6**	**1267601.2**	**1267601.2**	**1267601.2**	**1267601.2**
	Northing (feet)	**204372.2**	**204372.2**	**204372.2**	**204372.2**	**204493.7**	**204493.7**	**204493.7**	**204493.7**
Analyte	**Soil Screening Level**								
Conventional Parameters (pct)									
Total organic carbon	--	**0.11 J**	**0.21 J**	**0.28 J**	**4 J**	**0.03 J**	**0.04 J**	**0.66 J**	**2.83 J**
Total solids	--	**81.9**	**78.06**	**73.12**	**58.88**	**84.2**	**80.16**	**76.99**	**64.92**
Metals (mg/kg)									
Antimony	--	**-- R**	0.24 UJ	**-- R**	**-- R**	**-- R**	**-- R**	**-- R**	**-- R**
Arsenic	7.0	**2.23**	**2.69**	**2.4**	**6.11**	**2**	**1.91**	**1.65**	**8.67**
Barium	--	**22.1**	**21.5**	**25.0**	**32.5**	**17.0**	**18.9**	**19.4**	**36.1**
Beryllium	--	**0.13 J**	**0.13 J**	**0.15 J**	**0.25 J**	**0.09 J**	**0.14 J**	**0.13 J**	**0.28 J**
Cadmium	0.77	**0.07 J**	**0.09 J**	**0.07 J**	**0.18**	**0.05 J**	**0.06 J**	**0.06 J**	**0.14 J**
Chromium	260	**8.27**	**10.3**	**9.06**	**15.6**	**8.85**	**8.78**	**11.4**	**14.3**
Copper	36	**10.6**	**16.4**	**12.5**	**28.9**	**8.29**	**8.73**	**11.4**	**27.8**
Lead	81	**2.19**	**3.87**	**1.66**	**4.1**	**1.1**	**1.09**	**1.19**	**6.42**
Mercury	0.07	**0.0127 J**	**0.013 J**	**0.0175 J**	**0.0376 J**	0.0223 U	0.0233 U	**0.0148 J**	**0.0256 J**
Nickel	38	**7.85 J**	**7.45 J**	**7.51 J**	**14.1 J**	**6.05 J**	**7.87 J**	**6.69 J**	**10.8 J**
Selenium	0.5	**0.08 J**	**0.13 J**	**0.12 J**	**0.36 J**	0.57 U	**0.08 J**	**0.12 J**	**0.39 J**
Silver	0.2	**0.03 J**	**0.04 J**	**0.03 J**	**0.08 J**	**0.02 J**	**0.03 J**	**0.03 J**	**0.07 J**
Thallium	--	**0.04 J**	**0.04 J**	**0.04 J**	**0.08 J**	**0.03 J**	**0.03 J**	**0.03 J**	**0.08 J**
Zinc	85	**24.8**	**40.5**	**21.0**	**34.1**	**32.6**	**22.6**	**20.5**	**32.4**
Geochemical Parameters (mg/kg)									
Extractable iron oxides	--	**4890**	**3410**	**4410**	**3830**	**3370**	**3620**	**4570**	**7850**
Extractable manganese oxides	--	**11.25**	**7.93**	**8.39**	**10.01**	**6.47**	**5.72**	**14.3**	**21.94**
Sulfide	--	1.27 U	**1.71**	**37.6**	**17.3**	1.22 U	**1.96**	**19.1**	**234**

Notes:

🟨	Detected concentration is greater than the RI soil screening level
🟧	Non-detected concentration is greater than the RI soil screening level

Bold: Detected result

--: not applicable

µg/kg: micrograms per kilogram

ft: feet

J: estimated value

mg/kg: milligrams per kilogram

pct: percent

R: rejected

U: compound analyzed, but not detected above detection limit

UJ: compound analyzed, but not detected above estimated detection limit

Table 4

Groundwater Testing Results

	Location ID	**DSIP3-01**	**DSIP3-02**	**DSIP3-04**		**DSIP3-05**	**DSIP2-16**
	Sample ID	**DSIP3-01-191005**	**DSIP3-02-191006**	**DSIP3-04-191007**	**DSIP3-04-D-191007**	**DSIP3-05-191007**	**DSIP2-16-191007**
	Sample Date	**10/5/2019**	**10/6/2019**	**10/7/2019**	**10/7/2019**	**10/7/2019**	**10/7/2019**
	Well Screen Interval (bgs)	**5 - 15 ft**	**5 - 15 ft**	**5 - 15 ft**	**5 - 15 ft**	**5 - 15 ft**	**5.2 - 15.2 ft**
	Sample Type	**Normal**	**Normal**	**Normal**	**Field Duplicate**	**Normal**	**Normal**
	Matrix	**Groundwater**	**Groundwater**	**Groundwater**	**Groundwater**	**Groundwater**	**Groundwater**
	Easting (feet)	**1267443.1**	**1267422.2**	**1267334.6**	**1267334.6**	**1267601.2**	**1267562.8**
	Northing (feet)	**204400.8**	**204362.1**	**204372.2**	**204372.2**	**204493.7**	**204360.2**
Analyte	**Groundwater Screening Level**						
Metals, Dissolved (µg/L)							
Antimony	90	**8.76**	**0.319**	**0.145 J**	**0.155 J**	**0.198 J**	0.4 U
Arsenic	8	**43.9**	**45.2**	**1.87**	**2.06**	**0.587**	**3.34**
Barium	--	**14.3**	**10.5**	**21.8**	**21.8**	**21.7**	**17.5**
Beryllium	--	0.2 U	0.2 U	1 U	1 U	0.4 U	0.4 U
Cadmium	7.9	0.1 U	0.1 U	0.5 U	0.5 U	0.2 U	0.2 U
Chromium	260	**0.896**	**1.16**	**1.17**	**1.09**	**1.17**	**0.324 J**
Copper	2.4	**1.66**	**0.419 J**	**0.949**	**0.942**	0.5 U	0.5 U
Iron	--	**9060**	**7140**	**8350**	**8280**	**25800**	**25300**
Lead	8.1	**0.086 J**	**0.07 J**	**0.365 J**	**0.355 J**	**0.14 J**	0.2 U
Manganese	--	**366**	**309**	**308**	**310**	**924**	**656**
Mercury	0.1	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Nickel	8.2	**8.49**	**0.946**	**1.1**	**1.18**	0.5 U	0.5 U
Selenium	71	0.5 U	**0.472 J**	2.5 U	2.5 U	1 U	1 U
Silver	1.9	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Thallium	--	0.2 U	0.2 U	1 U	1 U	0.4 U	0.4 U
Zinc	81	4 U	5.38 U	4 U	4 U	4 U	4 U
Field Parameters							
Conductivity (µmhos/cm)	--	**2076**	**2573**	**8111**		**4000**	**4508**
Dissolved oxygen (mg/L)	--	**0.2**	**0.12**	**0.09**		**0.14**	**0.08**
pH (su)	--	**6.47**	**6.76**	**6.6**		**6.32**	**6.33**
Oxidation reduction potential (EH) (mV)	--	**-23.8**	**-66.2**	**-12.1**		**-23.2**	**-22.7**
Temperature (deg C)	--	**17**	**18.5**	**18**		**16.2**	**16.5**
Turbidity (NTU)	--	**71**	**35.1**	**5.93**		**3.03**	**2.03**
Geochemical Parameters (mg/L)							
Ammonia as nitrogen	--	**0.519**	**0.92**	**0.46**	**0.488**	**5.54**	**1.36**
Nitrate as nitrogen	--	0.1 UJ	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Phosphorus	--	**0.398**	**1.18**	**0.328**	**0.316**	**0.96**	**0.324**
Sulfate	--	**26.8**	**2.78**	**23.1**	**24.2**	**0.164**	**10.9**
Sulfide	--	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Total organic carbon	--	**10.67**	**11.14**	**11.73**	**11.67**	**10.42**	**2.21**
Total suspended solids	--	**78**	**24**	**3**	**16**	**65**	**33**
Geochemical Parameters, Dissolved (mg/L)							
Dissolved organic carbon	--	**8.4**	**10.39**	**11.57**	**11.39**	**10.2**	**2.19**
Total dissolved solids	--	**1250**	**1380**	**3980**	**4150**	**2170**	**2390**
Metals, Total (µg/L)							
Silicon	--	**25700**	**22200**	**13300**	**16000**	**17800**	**14900**

Table 4
Groundwater Testing Results

Notes:

🟨 Detected concentration is greater than the RI groundwater screening level

🟧 Non-detected concentration is greater than the RI groundwater screening level

Bold = Detected result

--: not analyzed

µg/L: micrograms per liter

µmhos/cm: micromhos per centimeter

bgs: below ground surface

deg C: degrees Celsius

EH: oxidation potential

ft: feet

J: estimated value

mg/L: milligrams per liter

mV: millivolt

NTU: Nephelometric Turbidity Unit

R: rejected

su: standard unit

U: compound analyzed, but not detected above detection limit

UJ: compound analyzed, but not detected above estimated detection limit

Table 5
pH and Eh Values in Groundwater

Station ID	Sample ID	pH	ORP (mV)	Eh (v)
DSIP2-13	DSIP2-13-MW-010614	6.76	-190	0.01
	DSIP2-13-MW-041514	6.73	-55	0.145
	DSIP2-13-MW-070814	6.38	-55	0.146
	DSIP2-13-MW-012815	6.73	-85	0.115
Upgradient	DSIP3-04-191007	6.6	-12	0.188
	DSIP3-02-191006	6.76	-66	0.134
	DSIP3-01-191005	6.47	-24	0.176
Downgradient	DSIP2-16-MW-010614	6.97	-38	0.162
	DSIP2-16-MW-041514	7.11	-125	0.075
	DSIP2-16-MW-070814	6.94	-116	0.084
	DSIP2-16-MW-013015	6.33	-113	0.087
	DSIP2-16-191007	6.33	-23	0.177
	DSIP2-02-MW-010714	6.27	-82	0.118
	DSIP2-02-MW-041614	6.59	-86	0.114
	DSIP2-02-MW-070914	6.44	-90	0.11
	DSIP2-02-MW-012815	6.33	-83	0.117
	DSIP3-05-191007	6.32	-23	0.177

Notes:
Eh: oxidation potential
mV: millivolt
ORP: oxidation reduction potential
v: volt

Table 6
Soil Arsenic, Groundwater Arsenic, and Calculated Kd Values

Station ID	Location Description	Well Screen Depth (feet bgs)	Average Arsenic Concentration in Soil (mg/kg)	Average Dissolved Arsenic Concentration in Groundwater (µg/L)	Kd (L/kg)
DSIP3-04	Upgradient	5-15	3.7	2.0	1900
DSIP3-02	Near DSIP2-13	5-15	4.8	45	107
DSIP3-01	Near DSIP2-13	5-15	10	44	239
DSIP2-13	Elevated Arsenic Groundwater	5.3-15.3	5.4	1345	4.0
DSIP2-16	Downgradient	5.2-15.2	6.3	6.9	913
DSIP2-02	Downgradient	5.7-15.7	4.5	35	127
DSIP3-05	Downgradient	5-15	4.1	0.6	6945

Notes:
Soil arsenic concentrations are based on the average of all samples from the well-screen interval.
Groundwater arsenic concentrations are based on the average of all sampling events.
bgs: below ground surface
mg/kg: milligrams per kilogram
µg/L: micrograms per liter

Figures

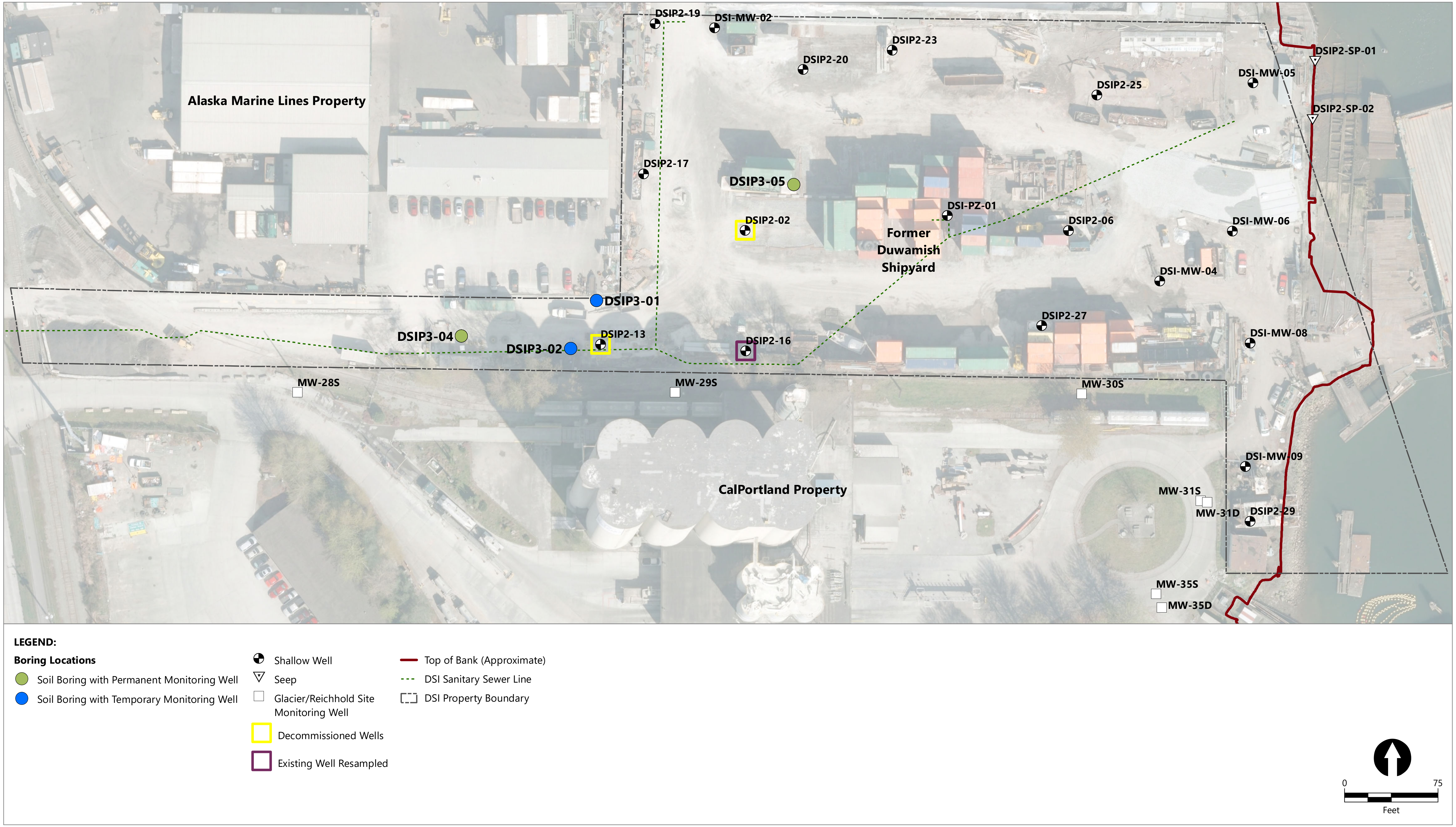

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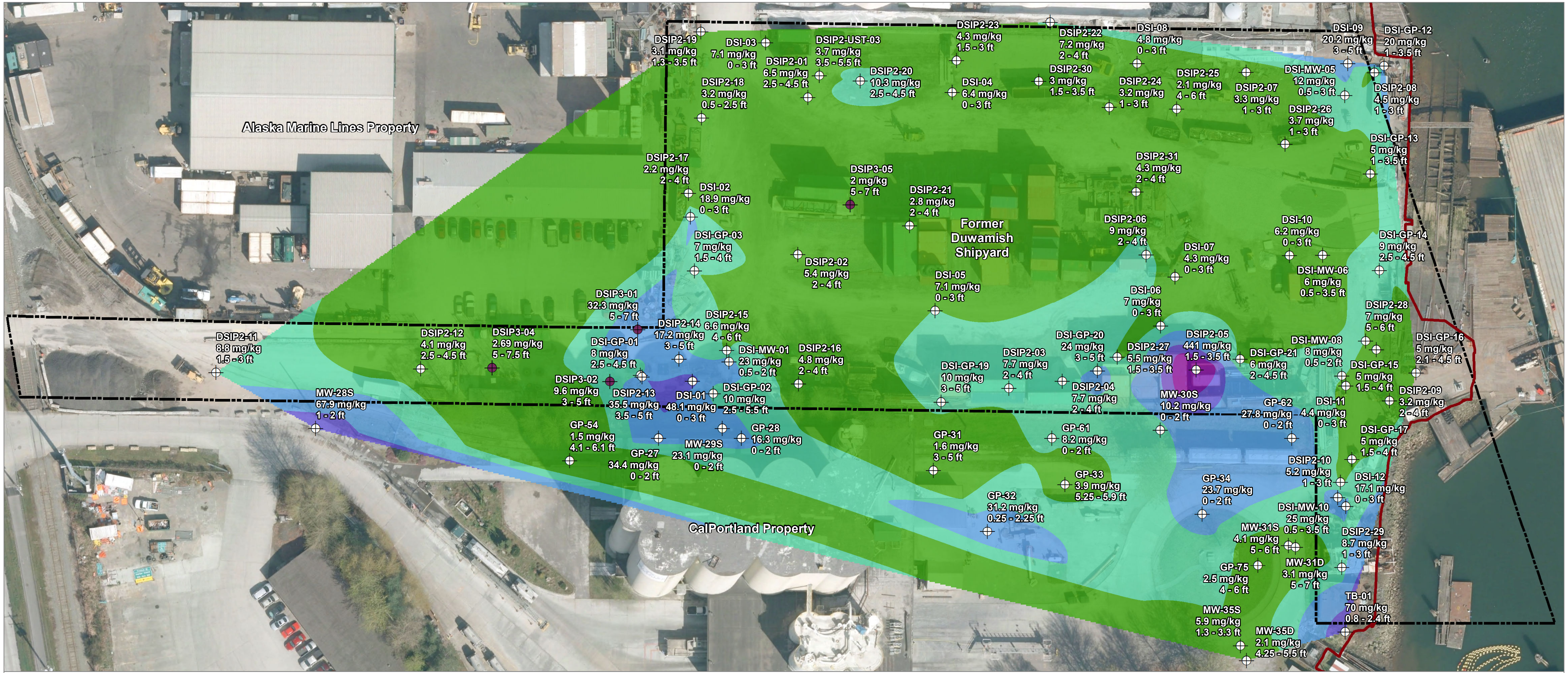
Figure 1
Arsenic Study Sampling Locations
Remedial Investigation Addendum: Arsenic Characterization Study Memorandum
Duwamish Shipyard, Inc. Arsenic Characterization Study



LEGEND:

Arsenic (mg/kg)

🟩 < 7 (< SL)
🟩 7 - 14 (SL - 2x)
🟦 14 - 35 (2x - 5x)
🟪 35 - 70 (5x - 10x)
🟪 > 70 (> 10x)

Soil Sampling Location

⊕ Location ID
Maximum Concentration
Depth of Sample Interval

● Location with 2019 Sample Concentration

— Top of Bank (Approximate)

⬚ DSI Property Boundary

NOTES:

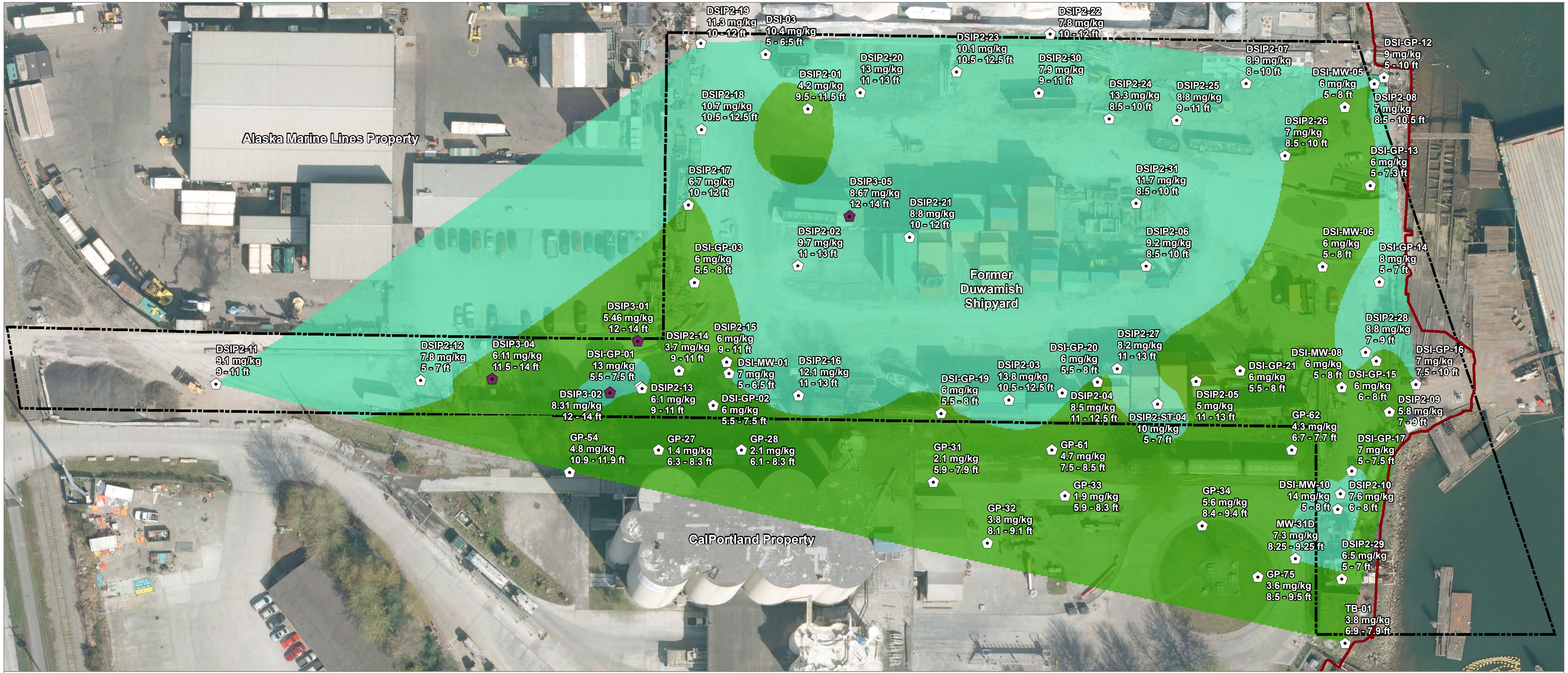
1. The maximum concentration at each soil location was used for contouring at a depth of 0 to 6 feet.
2. The full reporting limit for non-detects (identified with U qualifier) was used for data contouring purposes.

SL = Screening Level

Publish Date: 2020/03/30, 3:56 PM | User: jsfox
Filepath: \\orcas\GIS\Jobs\DuwamishShipyardInc_0111\DSI_Ecology_RI\Maps\As_StudyMemo\DSI_NN_Soils_0to6bgs.mxd

ANCHOR QEA

Figure 2a
Updated Maximum Concentrations of Arsenic in Soil 2014-2019, 0 to 6 feet
Remedial Investigation Addendum: Arsenic Characterization Study Memorandum
Duwamish Shipyard, Inc. Arsenic Characterization Study



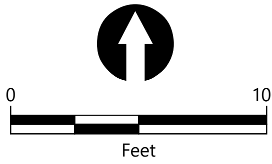
LEGEND:

Arsenic (mg/kg)
- 🟩 < 7 (< SL)
- 🟩 7 - 14 (SL - 2x)
- 🟦 14 - 35 (2x - 5x)
- 🟪 35 - 70 (5x - 10x)
- 🟪 > 70 (> 10x)

Soil Sampling Location
- ⬠ Location ID
  Maximum Concentration
  Depth of Sample Interval
- ⬟ Locations with 2019 Sample Concentrations

- — Top of Bank (Approximate)
- ⬚ DSI Property Boundary

NOTES:
1. The maximum concentration at each soil location was used for contouring at a depth of 6 to 15 feet.
2. The full reporting limit for non-detects (identified with U qualifier) was used for data contouring purposes.
SL = Screening Level



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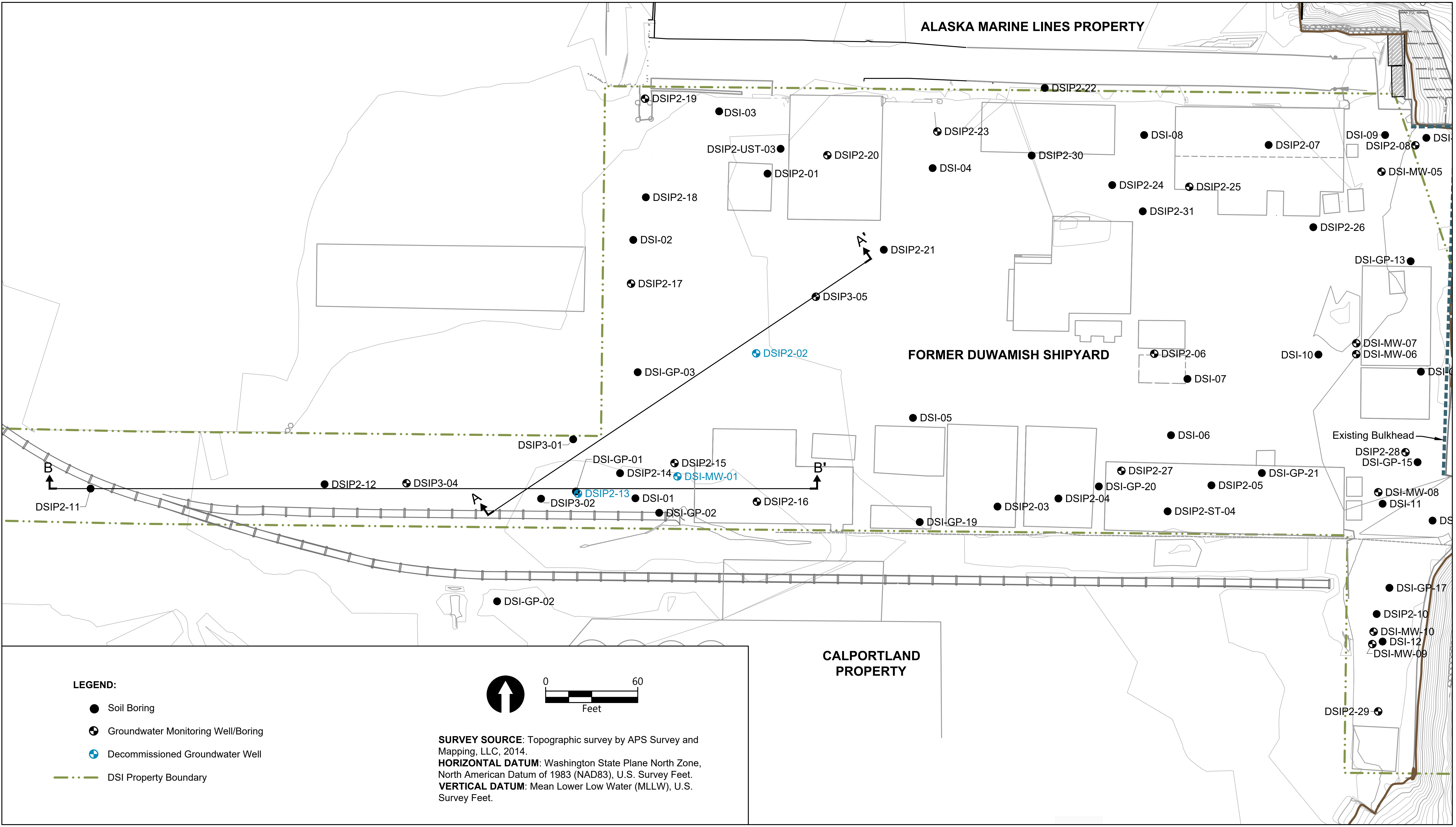
ANCHOR QEA

Figure 2b
Updated Maximum Concentrations of Arsenic in Soil 2014-2019, 6 to 15 feet bgs

Remedial Investigation Addendum: Arsenic Characterization Study Memorandum
Duwamish Shipyard, Inc. Arsenic Characterization Study



LEGEND:

● Soil Boring

⊗ Groundwater Monitoring Well/Boring

⊗ Decommissioned Groundwater Well

-·-·- DSI Property Boundary

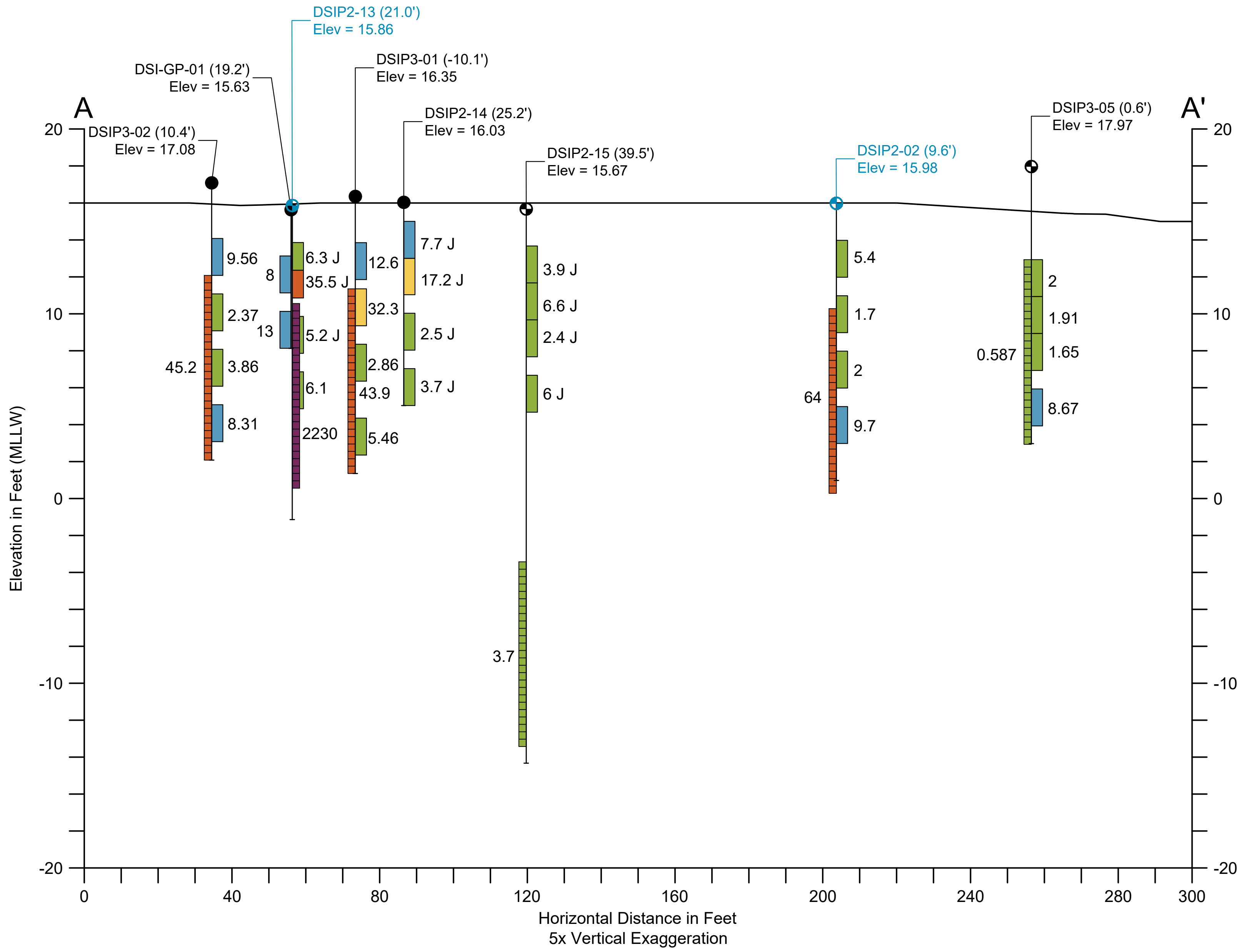
SURVEY SOURCE: Topographic survey by APS Survey and Mapping, LLC, 2014.
HORIZONTAL DATUM: Washington State Plane North Zone, North American Datum of 1983 (NAD83), U.S. Survey Feet.
VERTICAL DATUM: Mean Lower Low Water (MLLW), U.S. Survey Feet.

D:\Users\hmerrick\appdata\local\temp\AcPublish_15952\1101-RI-000 (Upland Arsenic).dwg 3a

Apr 01, 2020 8:33am hmerrick

ANCHOR QEA

Figure 3a
Cross Section Location Map
Remedial Investigation Addendum: Arsenic Characterization Study Memorandum
Duwamish Shipyard, Inc.: Arsenic Characterization Study



LEGEND:

● Soil Boring
(Line represents extent of available RI sample data)

Groundwater Monitoring Well/Boring

Decommissioned Groundwater Well

Soil Screening Level
Arsenic (mg/kg)

- 🟩 <7 (Screening Level)
- 🟦 7-14 (Screening Level-2x)
- 🟨 14-35 (2-5x)
- 🟧 35-70 (5-10x)
- 🟪 >70 (>10x)

Groundwater Screening Level
Dissolved Arsenic (μg/L)

- 🟩 <8 (Screening Level)
- 🟦 8-16 (Screening Level-2x)
- 🟨 16-40 (2-5x)
- 🟧 40-80 (5-10x)
- 🟪 >80 (>10x)

DSIP2-02 — Exploration Identification
(9.6') — Offset Distance from Cross Section (in feet)
Elev = 15.98 — Elevation (in feet)

Location and Depth of Exploration
Sample Location
Well Screen Interval
Bottom of Exploration

SURVEY SOURCE: Topographic survey by APS Survey and Mapping, LLC, 2014.
HORIZONTAL DATUM: Washington State Plane North Zone, North American Datum of 1983 (NAD83), U.S. Survey Feet.
VERTICAL DATUM: Mean Lower Low Water (MLLW), U.S. Survey Feet.

NOTES:

1. Cross section locations are shown on Figure 3a.
2. Soil and groundwater screening levels used are shown in Table 3 and 4.
3. The maximum soil arsenic concentration at each location was plotted for each depth.
4. The maximum groundwater dissolved arsenic concentration for the 2014-2015 quarterly sampling at each location was plotted, together with 2019 data for arsenic study wells.
5. DSIP3-## locations were surveyed by APS Survey and Mapping, LLC on October 7, 2019.

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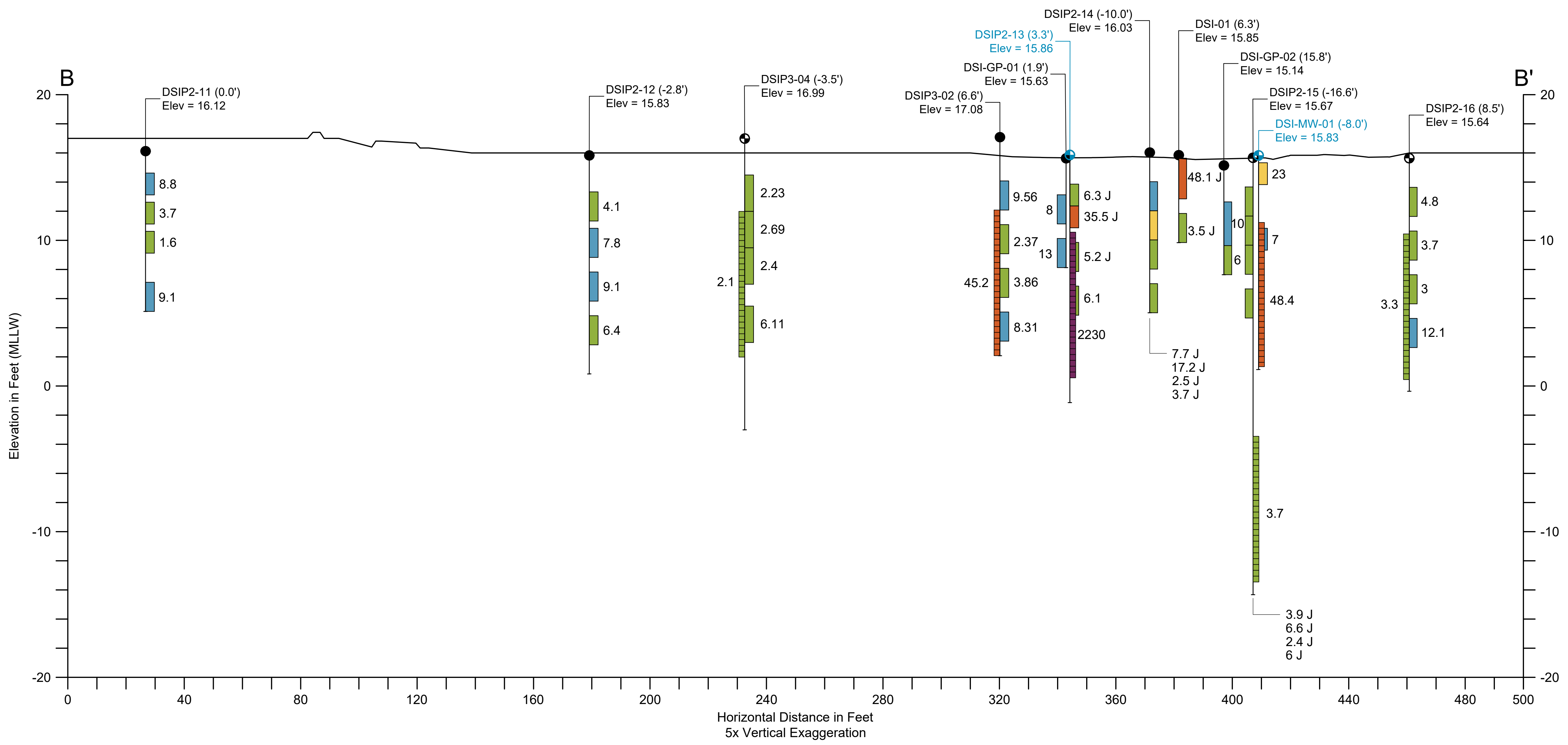
Figure 3b
Cross Section A-A' – Arsenic
Remedial Investigation Addendum: Arsenic Characterization Study Memorandum
Duwamish Shipyard, Inc.: Arsenic Characterization Study



SURVEY SOURCE: Topographic survey by APS Survey and Mapping, LLC, 2014.
HORIZONTAL DATUM: Washington State Plane North Zone, North American Datum of 1983 (NAD83), U.S. Survey Feet.
VERTICAL DATUM: Mean Lower Low Water (MLLW), U.S. Survey Feet.

LEGEND:

- ● Soil Boring (Line represents extent of available RI sample data)
- ◐ Groundwater Monitoring Well/Boring
- ◐ Decommissioned Groundwater Well

	Soil Screening Level Arsenic (mg/kg)		Groundwater Screening Level Dissolved Arsenic (μg/L)
🟩	<7 (Screening Level)	🟩	<8 (Screening Level)
🟦	7-14 (Screening Level-2x)	🟦	8-16 (Screening Level-2x)
🟨	14-35 (2-5x)	🟨	16-40 (2-5x)
🟧	35-70 (5-10x)	🟧	40-80 (5-10x)
🟪	>70 (>10x)	🟪	>80 (>10x)

DSIP2-02 — Exploration Identification
(9.6') — Offset Distance from Cross Section (in feet)
Elev = 15.98 — Elevation (in feet)
— Location and Depth of Exploration
— Sample Location
— Well Screen Interval
— Bottom of Exploration

NOTES:

1. Cross section locations are shown on Figure 3a.
2. Soil and groundwater screening levels used are shown in Table 3 and 4.
3. The maximum soil arsenic concentration at each location was plotted for each depth.
4. The maximum groundwater dissolved arsenic concentration for the 2014-2015 quarterly sampling at each location was plotted, together with 2019 data for arsenic study wells.
5. DSIP3-## locations were surveyed by APS Survey and Mapping, LLC on October 7, 2019.

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Figure 3c
Cross Section B-B' – Arsenic
Remedial Investigation Addendum: Arsenic Characterization Study Memorandum
Duwamish Shipyard, Inc.: Arsenic Characterization Study

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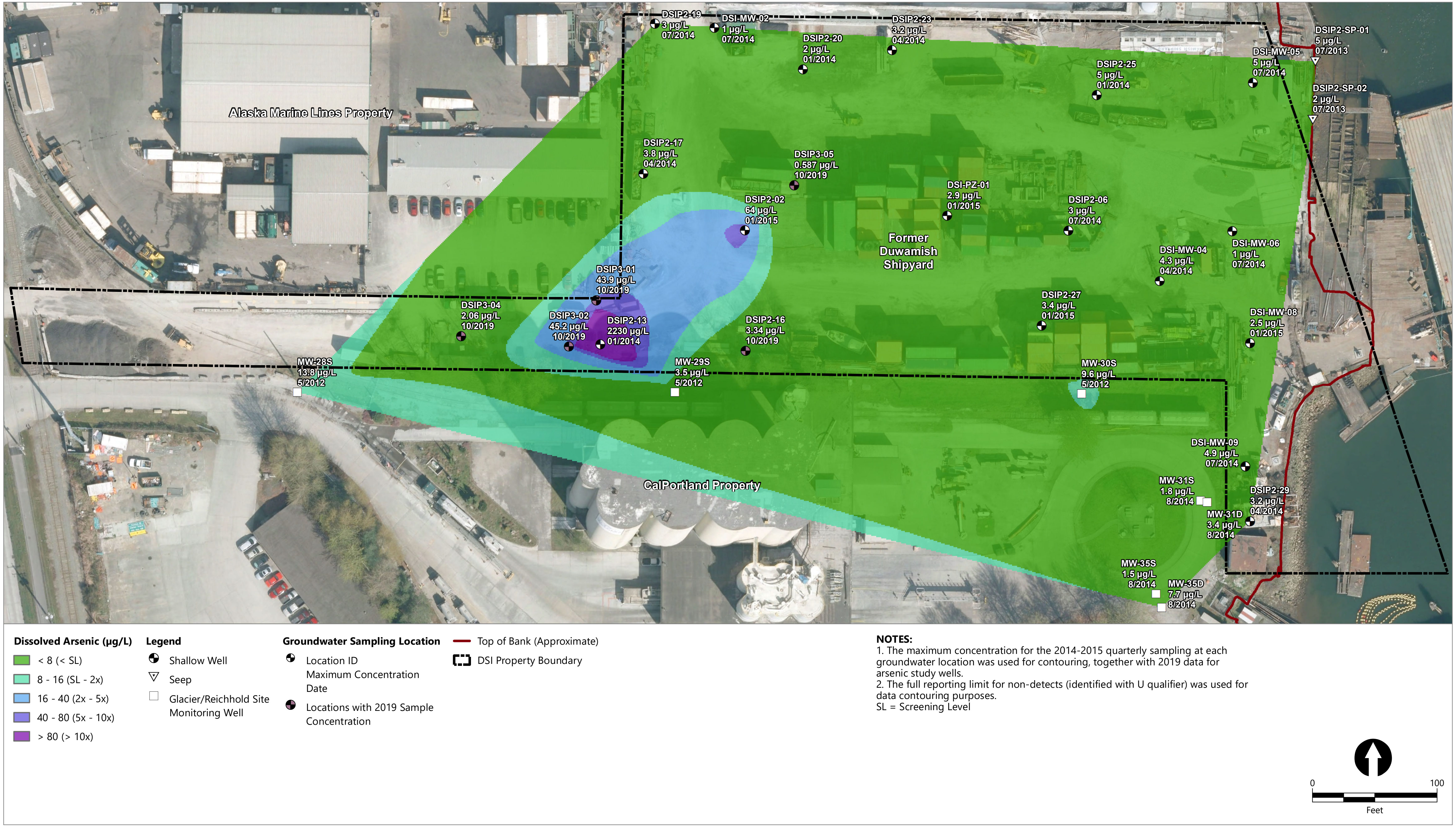

Dissolved Arsenic (µg/L)

- 🟩 < 8 (< SL)
- 🟩 8 - 16 (SL - 2x)
- 🟦 16 - 40 (2x - 5x)
- 🟪 40 - 80 (5x - 10x)
- 🟪 > 80 (> 10x)

Legend

- ⊕ Shallow Well
- ▽ Seep
- ☐ Glacier/Reichhold Site Monitoring Well

Groundwater Sampling Location

- ⊕ Location ID
Maximum Concentration
Date
- ⊕ Locations with 2019 Sample Concentration

- — Top of Bank (Approximate)
- ⬚ DSI Property Boundary

NOTES:
1. The maximum concentration for the 2014-2015 quarterly sampling at each groundwater location was used for contouring, together with 2019 data for arsenic study wells.
2. The full reporting limit for non-detects (identified with U qualifier) was used for data contouring purposes.

SL = Screening Level

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Figure 4

Updated Concentrations of Dissolved Arsenic in Groundwater, 2014-2019

Remedial Investigation Addendum: Arsenic Characterization Study Memorandum
Duwamish Shipyard, Inc. Arsenic Characterization Study

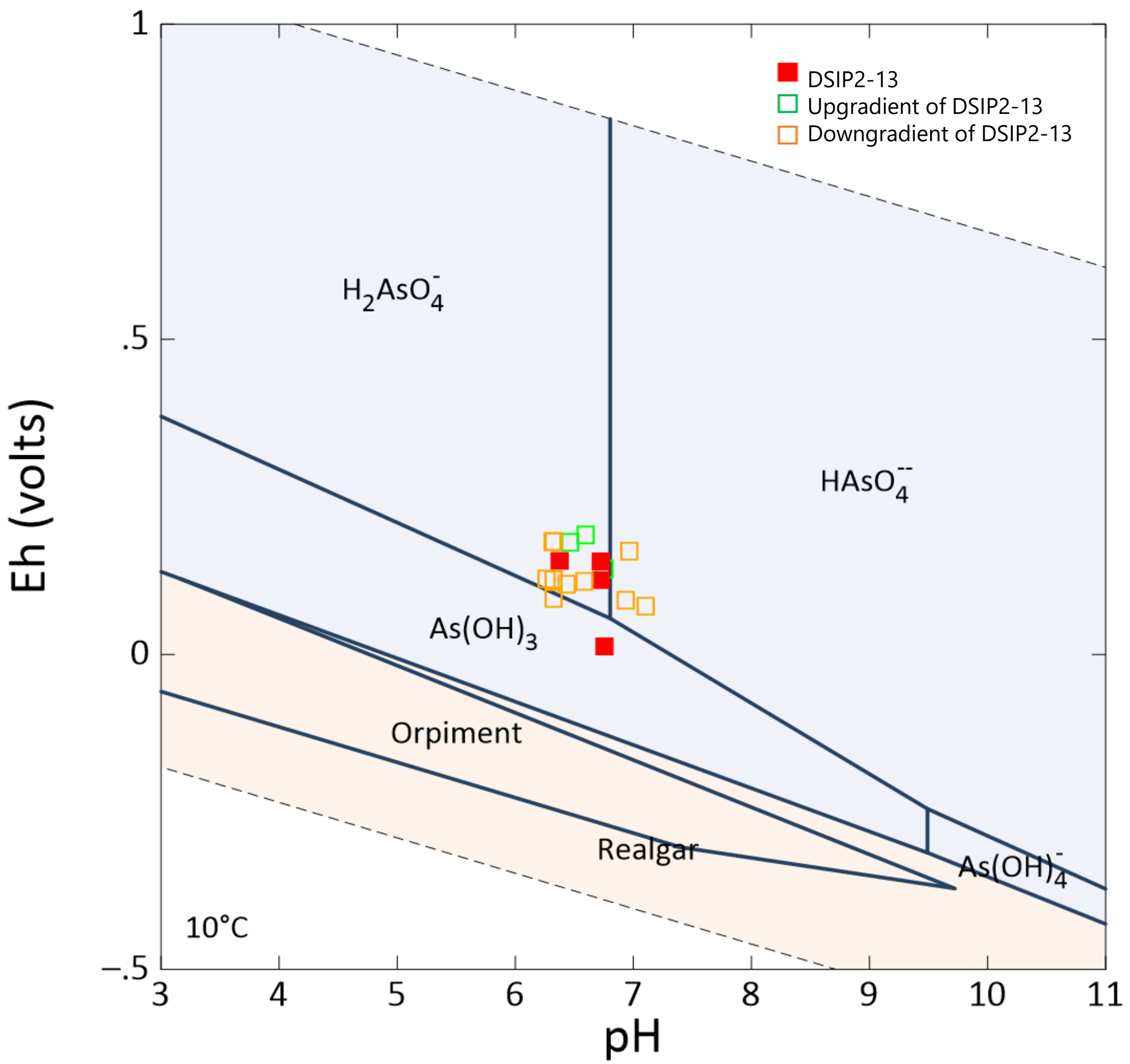

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Figure 5a
Eh-pH Diagram for Arsenic
Remedial Investigation Addendum: Arsenic Characterization Study Memorandum
Duwamish Shipyard, Inc. Arsenic Characterization Study

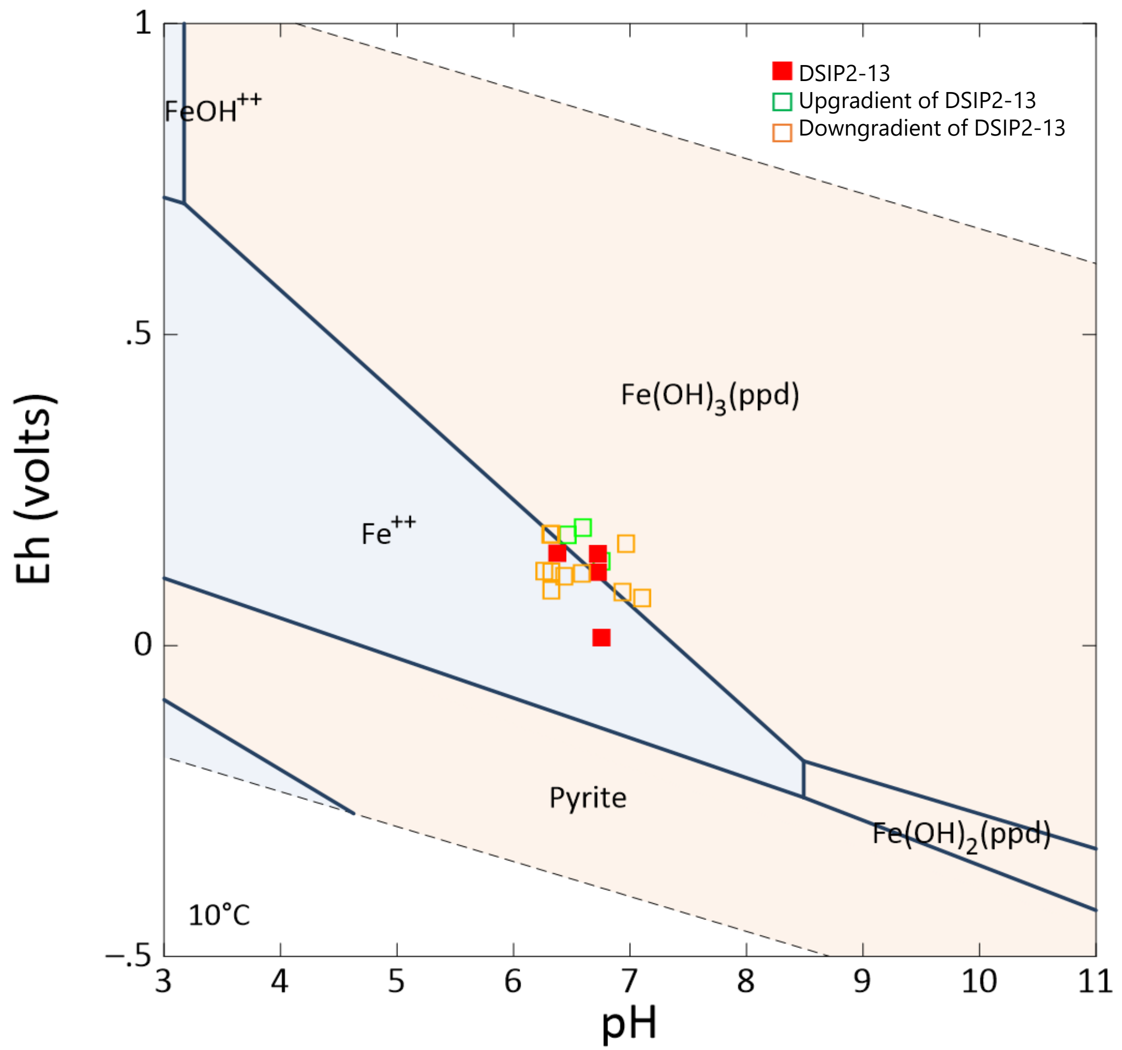

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Figure 5b
Eh-pH Diagram for Iron
Remedial Investigation Addendum: Arsenic Characterization Study Memorandum
Duwamish Shipyard, Inc. Arsenic Characterization Study

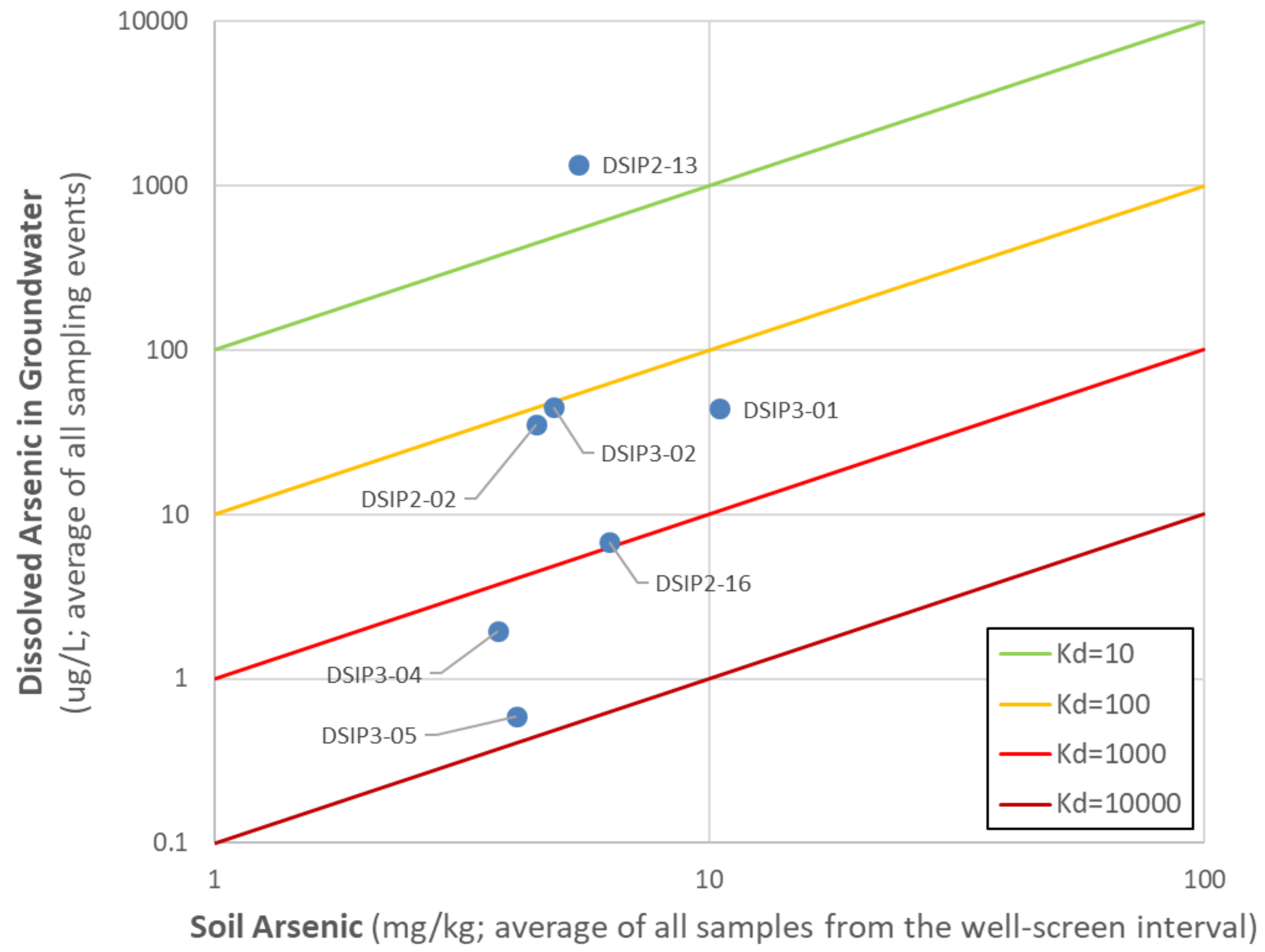

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Figure 6

Co-located Arsenic Soil and Groundwater Concentrations in the Arsenic Study Area

Remedial Investigation Addendum: Arsenic Characterization Study Memorandum

Duwamish Shipyard, Inc. Arsenic Characterization Study

Attachment A

Attachment A-1

Field Logs

Attachment A-2

Boring and Well Logs

Attachment A-3

Photographs

Attachment B

Attachment B-1

Laboratory Reports

Attachment B-2

Data Validation Reports

Attachment C

Attachment C-1
RI Data Summary Tables within Arsenic Study Area

Attachment C-2

RI Boring and Well Logs within Arsenic Study Area