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July 25, 2019

Mohsen Kourehdar
Washington State Department of Ecology
Toxics Cleanup Program
300 Desmond Drive
Lacey, WA 98503-1274

Subject: Feasibility Study Data Gap Investigation Report
Former Arkema Manufacturing Site
2901 and 2920 Taylor Way, Tacoma, Washington
Agreed Order No. DE 5668, Facility/Site ID No. 1220, Cleanup Site ID No. 3405

Dear Mr. Kourehdar:

On behalf of the Port of Tacoma (Port), PIONEER Technologies Corporation is submitting for your review the Feasibility Study (FS) Data Gap Investigation Report (Report) for the Former Arkema Manufacturing Site (Site). As you know, this report documents the results of investigation and evaluation activities that were conducted to address four FS data gaps in accordance with a February 2017 FS Data Gap Investigation Work Plan.

As discussed during our May 2019 meetings, the Port would like to schedule a meeting with you to discuss the Report contents after you have had some time to delve into the Report. In the meantime, please do not hesitate to contact me at (360) 570-1700 or Scott Hooton at (253) 383-9428 if you have any questions about the Report.

Respectfully,

Troy Bussey Jr.

Troy Bussey, Jr., P.E. (WA, CA, NC, SC), L.G. (WA, CA, NC, SC), L.HG. (WA)
Principal Engineer

Enclosures:
FS Data Gap Investigation Report

cc: Andy Smith, Washington State Department of Ecology (electronic copy only)
Scott Hooton, Port of Tacoma (electronic copy only)
Rob Healy, Port of Tacoma (electronic copy only)
Kim Seely, Coastline Law Group (electronic copy only)
Paul Fuglevand, Dalton, Olmsted & Fuglevand, Inc. (electronic copy only)
Joel Massmann, Keta Waters (electronic copy only)
Rebecca Neumann, University of Washington (electronic copy only)

Feasibility Study Data Gap Investigation Report

Former Arkema Manufacturing Site

Agreed Order No. DE 5668
Facility/Site ID No. 1220
Cleanup Site ID No. 3405

Prepared for:

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July 2019

Professional Certification

This document was prepared under my direction. The information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I hereby certify that I was in responsible charge of the work performed for this document.

TROY D. BUSSEY, JR.
38877
EXPIRES 12/06/20

Hydrogeologist
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TROY D. BUSSEY, JR.

July 25, 2019

Troy D. Bussey Jr.
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Date

Executive Summary

The primary purpose of this Feasibility Study (FS) Data Gap Investigation Report (Report) is to present the results of the investigation and evaluation activities that were performed to address the following four FS data gaps associated with arsenic releases at the Former Arkema Manufacturing Site (Site):

- Data Gap #1: Shoreline Concentrations
- Data Gap #2: Arsenic Plume Stability
- Data Gap #3: Wall Integrity
- Data Gap #4: Feasibility of Focused Soil Excavation Alternative

FS data gap investigation activities conducted at this Model Toxics Control Act (MTCA) Site in 2017 and 2018 included sampling and analysis for groundwater, pore water, surface water, soil, and sediment samples, and an inspection of the existing sheet pile wall (SPW). Completed evaluations included:

- Evaluating water results in order to improve the understanding of dissolved arsenic concentrations along the shoreline where groundwater discharges to surface water.
- Evaluating multiple lines of evidence to determine the stability of the dissolved arsenic plume over the past four decades and since 2004, when the last completed remedial action within the plume core was finished.
- Evaluating the condition of the SPW and potential leakage of groundwater through the SPW.
- Evaluating soil results to determine if distinct arsenic and/or pH soil source areas remained in the subsurface that could practicably be removed via soil excavation.

Key conclusions from the investigation and evaluation activities included:

- Dissolved arsenic concentrations were less than the preliminary cleanup level (PCL) of 5 ug/L in all surface water samples and were less than the MTCA screening level for protection of aquatic organisms (36 ug/L) in all but three representative pore water samples. Highly favorable geochemical conditions along the shoreline enable arsenic attenuation to occur as groundwater migrates towards surface water.
- Dissolved arsenic concentrations within the arsenic plume have declined since the 1980s and early 1990s, and have been stable or declining since circa 2007 or 2008 when viewed holistically. However, dissolved arsenic concentrations in nine monitoring wells (MWs) appear to be increasing slightly since circa 2007 or 2008 likely as a result of residual waste material in the arsenic source area and unfavorable geochemical conditions within portions of the plume.
- The SPW is in good condition and has a life expectancy of many decades. However, groundwater leaks through the SPW joints.
- A focused excavation of elevated arsenic soil concentrations (e.g., greater than 20,000 mg/kg) within the arsenic source area would remove similar amounts of arsenic mass as more aggressive excavation options, and is likely the only practicable soil excavation option at this Site. A focused soil excavation for elevated pH is not practicable due to the lack of a defined source.
- Since the FS data gaps have been filled, the FS Report can be initiated once Site groundwater models are ready for use.

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List of Acronyms

Acronym	Explanation
ARI	Analytical Resources, Inc.
BATs	Batch Adsorption Tests
bgs	Below Ground Surface
BAL	Brooks Applied Labs
Caustic	Sodium Hydroxide
CB/NT	Commencement Bay/Nearshore Tide Flats
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CF	Chloroform
CSEM	Conceptual Site Exposure Model
CSM	Conceptual Site Model
COPC	Constituent of Potential Concern
CY	Cubic Yards
DOF	Dalton, Olmsted, & Fuglevand, Inc.
Ecology	Washington State Department of Ecology
Eh	Activity of Electrons
ERM	Environmental Resources Management
Free Flow	Free Flow Technologies, Ltd.
FS	Feasibility Study
IA	Interim Action
ICF	ICF Technology Incorporated
ITRC	Interstate Technology & Regulatory Council
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
MTCA	Model Toxics Control Act
MW	Monitoring Well
NSDS	Nylon-Screen Diffusion Sampler
NOAA	National Oceanic and Atmospheric Administration
ORP	Oxidation Reduction Potential
PCE	Tetrachloroethylene
PCL	Preliminary Cleanup Level

Acronym	Explanation
Penite	Sodium Arsenite
PGG	Pacific Groundwater Group
pH	Activity of Hydrogen Ions
PIONEER	PIONEER Technologies Corporation
Port	Port of Tacoma
POC	Point of Compliance
PPS	Pushpoint Sampler
PSEMP	Puget Sound Ecosystem Monitoring Program
P&T	Pump & Treat
Redox	Reduction-Oxidation
Report	FS Data Gap Investigation Report
RI	Remedial Investigation
Ricker	Ricker Plume Stability Analysis
Site	Former Arkema Manufacturing Site
SPW	Sheet Pile Wall
SQO	Sediment Quality Objective
TCE	Trichloroethylene
TCLP	Toxicity Characteristic Leaching Procedure
TPCHD	Tacoma-Pierce County Health Department
Ursus	Ursus Remediation Testing & Technologies LLC
USEPA	United States Environmental Protection Agency
USG	United States Gypsum
VC	Vinyl Chloride
VOC	Volatile Organic Compound
V	Volts
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
Work Plan	FS Data Gap Investigation Work Plan
Wypenn	Wypenn Property
XRF	X-ray Fluorescence

SECTION 1: INTRODUCTION

1.1 Purpose

The primary purpose of this Feasibility Study (FS) Data Gap Investigation Report (Report) is to present the results of the investigation and evaluation activities that were performed to address four FS data gaps identified for the Former Arkema Manufacturing Site (Site).[1] Arsenic is the primary concern at this Site, and the four FS data gaps are associated with potential migration of arsenic from the main arsenic plume to the Hylebos Waterway.[2] A secondary purpose of this Report is to present an updated conceptual site model (CSM) for the main arsenic plume based on the results of the FS data gap investigation and evaluation activities and other insights gained since the FS Data Gap Investigation Work Plan (Work Plan) was prepared in 2017 (see Appendix A). The four FS data gaps identified for this Model Toxics Control Act (MTCA) Site and discussed in this Report are:

- Data Gap #1: Shoreline Concentrations
- Data Gap #2: Arsenic Plume Stability
- Data Gap #3: Wall Integrity
- Data Gap #4: Feasibility of Focused Soil Excavation Alternative

Investigation and evaluation activities were needed to address these four FS data gaps in order to prepare the FS Report (e.g., assemble cleanup alternatives and evaluate retained cleanup alternatives).

1.2 Site Location

The approximately 48-acre Site is a former chemical manufacturing facility that operated from 1927 to 1997 in the Tacoma Tideflats, adjacent to the Hylebos Waterway in Tacoma, Washington (see Figure 1-1).[3] The addresses for the Site are 2901 and 2920 Taylor Way, Tacoma, Washington.[4] The Site boundary includes a triangular-shaped portion of the adjacent Arkema Mound site (see Figure 1-2).[5]

Consistent with past practices, "Site north" will be used as the basis for describing locations and/or directions in this report. "Site north" is approximately 45 degrees west (counter clockwise) of true north. Both "Site north" and true north arrows are shown on figures, beginning with Figure 1-2.

The Site is bounded by the former United States Gypsum (USG) facility to the north (i.e., Site north), the Hylebos Waterway to the east, the Arkema Mound site to the south, and Taylor Way, the Blair Backup Property, and the Former Reichhold site to the west (see Figure 1-2).

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[1] The term Arkema refers to Arkema and all other companies that operated the former manufacturing facility (i.e., Tacoma Electrochemical Company, Pennsylvania Salt Manufacturing Company of Washington, Pennwalt Corporation, Atochem Inc., Elf Atochem North America, and Atofina Inc.).

[2] A definition of the main arsenic plume for the purposes of this Report is provided in Section 2.8.

[3] The Port of Tacoma (Port) purchased the Site from Arkema in May 2007.

[4] The tax parcel numbers are 0321351053 and 0321362056, respectively. The Wypenn property (Wypenn) is located at 2920 Taylor Way.

[5] The Site boundary for this triangular-shaped area only applies to the Intermediate Aquifer (Dalton, Olmsted, & Fuglevand, Inc. [DOF] 2013). The Arkema Mound site is a separate site and was not used for manufacturing operations.

Areas/features that are often used to reference locations within the Site boundary in this Report include the former Central Manufacturing Area, the former Penite Pits, the former Taylor Lake area surface impoundments, the former Caustic Manufacturing Area, the sheet pile wall (SPW), Wypenn, and the North Boundary Area (see Figure 1-3).

1.3 Report Organization

The remainder of this report is organized as follows:

- Section 2: Background Information
- Section 3: Overview of FS Data Gaps
- Section 4: Summary of Investigation Activities
- Section 5: Investigation Results
- Section 6: Evaluation of Results and Discussion
- Section 7: Updated CSM for the Main Arsenic Plume
- Section 8: Conclusions
- Section 9: References

SECTION 2: BACKGROUND INFORMATION

A summary of key Site background information is presented in this section. The information presented in this section about the Site setting, operational history, and completed remedial actions is based on the Final Remedial Investigation Report (DOF 2013) and/or the Evaluation of Media and Chemicals of Potential Concern, Exposure Pathways, and Clean Up Standards – Part 1 (Malcolm Pirnie 2006), unless otherwise noted or refined based on new insights subsequent to the 2017 Work Plan.

2.1 Site Setting

2.1.1 Climate

The marine-influenced climate at the Site is typical of Western Washington and is relatively mild. The average annual precipitation for Tacoma is approximately 40 inches, with most of the precipitation falling between October and April (Western Regional Climate Center 2019).

2.1.2 Topography and Drainage

The Site is relatively flat, with the shoreline sloping to the Hylebos Waterway. With the exception of the shoreline, topographic elevations generally range between 15 feet and 20 feet mean lower low water (MLLW).

When the former manufacturing facility was operating, stormwater runoff was not considered a significant contaminant transport pathway (Ecology 1993). None of the stormwater infrastructure from the former manufacturing facility remains. Currently, virtually all stormwater infiltrates to Site soil.

2.1.3 Geology

The regional geology is dominated by Quaternary ice age glacial deposits. In general, regional glacial deposits include sand and gravel aquifers associated with glacial outwash and low permeability glacial till deposits containing clay and silt.

The Site is located within the tideflats of the Puyallup River delta. In general, the pre-development tideflats consisted of alternating layers of lower permeability silt/clay and sandy deposits. Sediment dredged from Commencement Bay and its tributaries, as well as other fill material, were used to raise the land elevation during the industrial development of the tideflats.

The relevant lithologic units at the Site, from shallowest to deepest, include the following:

- **Fill**: The fill unit consists primarily of dredge sand and imported fill.
- **Upper Silt**: The upper silt unit consists primarily of clayey silt to fine sandy silt, with fibrous organic material associated with former tideflat vegetation at the top of the unit.
- **Intermediate Sand**: The intermediate sand unit consists primarily of a native fine to medium sand with shell fragments and silt interbeds.
- **Lower Silt**: The lower silt unit consists primarily of clayey silt to fine sandy silt.
- **Lower Sand**: The lower sand unit primarily consists of a fine to medium sand with silt interbeds.

2.1.4 Hydrogeology

The relevant hydrostratigraphic units at the Site, from shallowest to deepest, correspond to a specific lithologic unit and include the following:

- **Upper Aquifer**: The Upper Aquifer is the saturated portion of the fill unit. The thickness of the Upper Aquifer is approximately ten to 15 feet. Upper Aquifer groundwater is typically encountered at depths of less than six feet below ground surface (bgs) in most portions of the Site, and is encountered at depths less than two feet bgs within portions of the main arsenic plume.
- **First Aquitard**: The First Aquitard is the upper silt unit. The thickness of the First Aquitard is approximately five to ten feet. Thin and/or leaky portions of the upper silt have been identified in portions of the Site (see Section 2.8.3).
- **Intermediate Aquifer**: The Intermediate Aquifer is the intermediate sand unit. The thickness of the Intermediate Aquifer is approximately ten to 20 feet.
- **Second Aquitard**: The Second Aquitard is the lower silt unit. The thickness of the Second Aquitard is approximately five to 15 feet.
- **Deep Aquifer**: The Deep Aquifer is the lower sand unit. The thickness of the Deep Aquifer appears to be at least 20 feet thick.

In general for the main arsenic plume, groundwater in all three aquifers flows east towards the Hylebos Waterway. There may also be localized groundwater flow in the Upper Aquifer and Intermediate Aquifer towards the north or south near the SPW. The Intermediate Aquifer and the Deep Aquifer are tidally influenced and can experience flow reversals. Tidal fluctuations and mixing occur seaward of the SPW in the Upper Aquifer, but are less noticeable in the Upper Aquifer landward of the SPW.

The Upper Aquifer, First Aquitard, and Intermediate Aquifers are the primary hydrostratigraphic units of interest for this Report because the overwhelming majority of the arsenic mass is located in these three units.

2.1.5 Hylebos Waterway

The Hylebos Waterway was formed from the 1910s to the 1960s through multiple dredges of Hylebos Creek to create a Waterway capable of accommodating ocean-going ships, and was designed for industrial and port use with straight deep channels and developed/protected banks.[6] The Hylebos Waterway is classified under the Clean Water Act as Class B marine water with the following designated uses (DOF 2013):[7]

- Fish (good quality salmon migration and rearing; other fish migration, rearing, and spawning; clam, oyster, and mussel rearing and spawning; crustaceans and other shellfish rearing and spawning)
- Recreation (secondary contact recreation, sport fishing, boating, and aesthetic recreation)
- Harvesting

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[6] Personal correspondence in July 2019 from Rob Healy (Port) to Troy Bussey (PIONEER).

[7] This marine water is salty and cannot be used for drinking water.

- Commerce and Navigation

Based on the Published Benchmark Sheet for Commencement Bay Station (Station ID 9446484), the mean higher high water (MHHW) waterline is at an elevation of approximately 11.8 feet above MLLW (National Oceanic and Atmospheric Administration [NOAA] 2016).

2.1.6 Site Land Use

Site land use has been industrial historically and is currently Port-owned, vacant, industrial land awaiting redevelopment. The Site is covered with vegetation, crushed rock, and some former building/tank foundations. The planned future land use for the Site is Port maritime industrial use, consistent with the Port's Land Use Plan (Port 2014).

2.2 Overview of Operational History

The Site was used as a manufacturing facility historically and the majority of the manufacturing operations were performed in the former Central Manufacturing Area (see Figure 1-3). The products that were manufactured in that area included chlorine, sodium hydroxide (caustic), sodium chlorate, hydrochloric acid, and sodium arsenite (Penite). Operations started in 1927 with the manufacturing of chlorine and caustic. Penite, which is the product most relevant to this Report, was manufactured between circa 1944 and the early 1970s. Penite was produced by combining hot caustic soda with arsenic trioxide (Malcolm Pirnie 2006). The remaining chlorine-based manufacturing facility operations ceased in 1997, at which time the manufacturing facilities were dismantled and removed from the Site. The Port removed all remaining aboveground structures in 2008. Some subsurface features remain in-place (e.g., utilities, vaults, injection wells, extraction wells, and piping associated with the former pump-and-treat [P&T] system for the main arsenic plume).

2.3 Overview of Regulatory History

Investigation and cleanup work associated with the Site has been performed under three separate but interrelated regulatory programs:

- Comprehensive Environmental Response, Compensation and Liability Act (CERCLA): The Site is one of many source areas associated with the Commencement Bay/Nearshore Tide Flats (CB/NT) site. Cleanup of the Site shoreline and the Head of the Hylebos Waterway (the portion of the Waterway where Site groundwater discharges) were completed as part of remedial actions for the CB/NT CERCLA site.
- Clean Water Act: Previous upland Site investigations and remedial actions were completed pursuant to a 1987 Consent Decree between Arkema and the Washington State Department of Ecology (Ecology).
- MTCA: The recently-completed Remedial Investigation (RI) Report (DOF 2013; Ecology 2013) and the FS are being conducted pursuant to Agreed Order No. DE 5668 between the Port and Ecology (the Agreed Order became effective on July 25, 2011). The activities presented in this Report were conducted per Agreed Order No. DE 5668.

2.4 Overview of Site Chronology

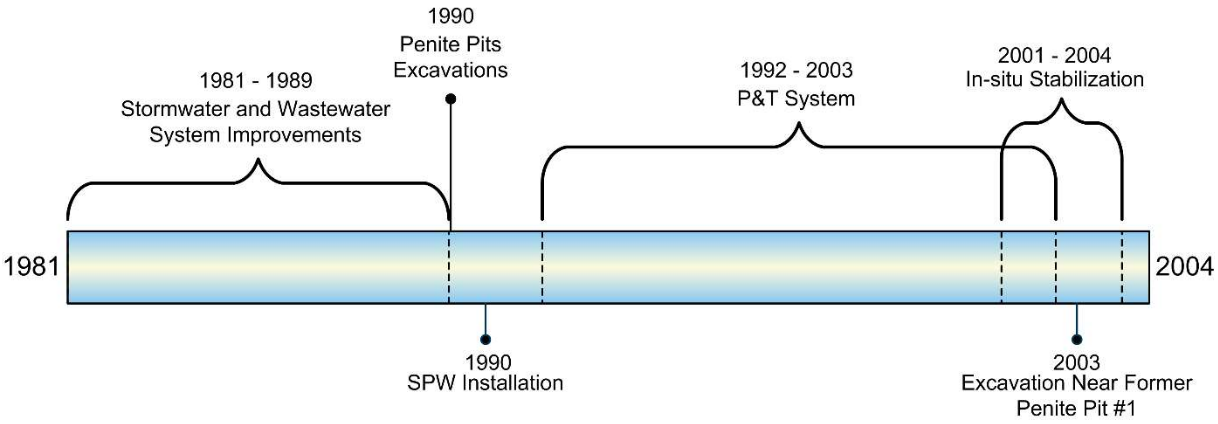
Numerous investigation, evaluation, and cleanup activities have been performed at the Site since 1981 and approximately $78 million dollars have been spent to-date (Groff Murphy Trachtenberg & Everard, PLLC 2006; DOF 2011; PIONEER Technologies Corporation [PIONEER] 2016). Hundreds of technical and regulatory documents have been prepared since the first Site investigation activities were conducted in 1981. Soil, groundwater, pore water, surface water, sediment, and air have been investigated and evaluated. Based on the results of these investigations and evaluations, arsenic was identified as the primary constituent of potential concern (COPC) at the Site. Numerous remedial actions have been completed to address releases of arsenic and other constituents (see Section 2.5). The Site chronology is presented in detail in the final RI Report (DOF 2013) and summarized in the following table.

Regulatory Program	Completed Phases
CB/NT CERCLA Site (Head of Hylebos)	RI, FS, Remedial Design, Remedial Action Implementation
1987 Arkema Clean Water Act Consent Decree	RI, FS, Remedial Design, Remedial Action Implementation
2011 Arkema MTCA Agreed Order	RI Data Gaps, RI Report, Wypenn Interim Action (IA)

2.5 Overview of Completed Remedial Actions

Numerous remedial actions have been completed for the Site, including improving historical stormwater and wastewater systems, removing soil and sediment, installing soil and sediment caps, installing a SPW, installing and operating a P&T system for the main arsenic plume, conducting in-situ stabilization for the main arsenic plume, remediating volatile organic compound (VOC) source areas, and completing remediation for miscellaneous other releases. The completed remedial actions are summarized in Table 2-1 and shown on Figures 2-1A and 2-1B.[8]

A timeline of the most important completed remedial actions within the plume core of the main arsenic plume are presented in the following graphic.



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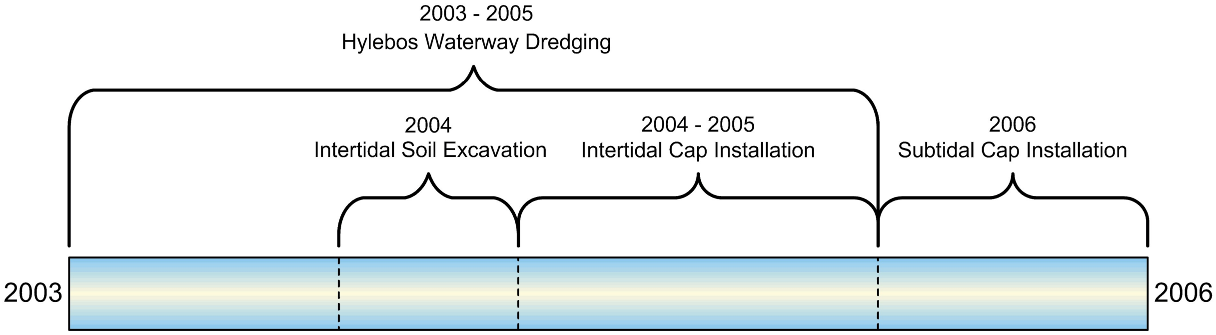
[8] The locations of the historical stormwater and wastewater improvements are not shown on Figures 2-1A and 2-1B because it is impossible to define the entire extent of the areas affected by these improvements.

A timeline of the most important completed remedial actions along the shoreline and within the Hylebos Waterway (on the seaward side of the main arsenic plume) are presented in the following graphic.



The remedial actions related to arsenic have reduced arsenic concentrations within the main arsenic plume, the mass discharge of arsenic to the Hylebos Waterway, and arsenic concentrations in the Hylebos Waterway. Sediment remediation in the Head of the Hylebos Waterway (the portion of the Waterway where Site groundwater discharges) began in 2004 because "known source control actions were implemented and deemed to be complete enough to begin sediment remediation" (USEPA 2014). However, the ongoing Site FS was included as an action item for the CB/NT site in the latest CB/NT Five-Year Review Report because additional source control measures may be necessary. Furthermore, USEPA certification of remedial action completion under the Head of Hylebos Consent Decree is dependent upon cleanup of the Site to USEPA's satisfaction (USEPA 2014).

2.6 Constituents of Potential Concern

Nine COPCs were identified in the MTCA RI Report (DOF 2013); however, arsenic is the key COPC for the Site and the focus of this Report.[9] The magnitude and extent of arsenic at the Site are greater than the other COPCs and the potential risk and regulatory concern associated with arsenic are also greater than the other COPCs. All of the FS data gap investigation activities were associated with the potential migration of arsenic from the main arsenic plume to the Hylebos Waterway.

The eight other COPCs identified in the MTCA RI Report were:

- Copper;
- Lead;
- Mercury;
- Nickel;

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[9] Four constituents (chromium, selenium, zinc, and dichloro-diphenyl-trichloroethane) were identified in the RI as COPCs for the potential terrestrial ecological pathway only. However, the Site is excluded from a terrestrial ecological evaluation in accordance with Washington Administrative Code (WAC) 173-340-7491(1)(b) because the Site was previously developed for industrial use and it will be redeveloped in the future for Port maritime industrial use (e.g., grading activities and installation of a cap/cover, construction of buildings and industrial operational areas). Thus, these four constituents will not be considered COPCs during the FS phase.

- Tetrachloroethylene (PCE);
- Trichloroethylene (TCE);
- Vinyl chloride (VC); and
- Chloroform (CF).

2.7 Preliminary Arsenic Cleanup Standards

Preliminary cleanup levels (PCLs) for arsenic and potential points of compliance (POCs) were identified in the Work Plan for the purpose of evaluating FS data gap investigation results. Cleanup standards will be proposed for each cleanup alternative evaluated in the FS Report, and the final cleanup standards for the selected remedy will be established in the Cleanup Action Plan.

2.7.1 Soil

The arsenic soil PCL identified in the Work Plan was 88 mg/kg and was based on the protection of commercial/industrial workers for the soil direct contact pathway. The soil PCL is the MTCA Standard Method C industrial soil cleanup level for the soil direct contact pathway. This same arsenic soil PCL was used for the Wypenn IA (DOF 2015b) and other recent cleanups at nearby sites such as Arkema Mound (DOF 2015a), Superlon (Pacific Environmental & Redevelopment Corporation and PIONEER 2014), and the Former Reichhold Site (Floyd Snider 2008).

The POC for the soil direct contact pathway depends on the type of remedial action. In accordance with WAC 173-340-740(6)(d), the standard POC depth is 15 feet; however, per WAC 173-340-740(6)(f), there is no depth requirement for a cap/cover action.

2.7.2 Groundwater/ Surface Water

The current arsenic groundwater/surface water PCL identified in the Work Plan was 5 ug/L and was based on the protection of potential surface water receptors and the current Ecology-accepted background concentration for arsenic in groundwater. Specifically, this default arsenic PCL of 5 ug/L is based on protection of human health (e.g., consumption of seafood by recreators/fishers). If appropriate, the arsenic PCL for groundwater/surface water may be adjusted up in the future to account for regional or site-specific background concentrations.

Another important arsenic groundwater/surface water criterion for this Site is the MTCA screening level for protection of aquatic organisms (36 ug/L). Protection of aquatic organisms is the primary concern for arsenic being transported from the Site towards the Hylebos Waterway since the USEPA concluded in the 1980s that arsenic in CB/NT surface water does not pose an unacceptable risk to human health (TetraTech 1985; USEPA 1989). In the site-specific CB/NT human health risk assessment, USEPA found that arsenic concentrations in CB/NT fish (including Hylebos Waterway fish) were similar to arsenic concentrations in fish from Carr Inlet (which was representative of background conditions).[10] Thus,

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[10] English sole, which were deemed the most contaminated fish species in the CB/NT habitat, were used in the site-specific human health risk assessment. A total of 1,020 adult (greater than three years old) fish collected from trawl transects were used in the site-specific human health risk assessment.

USEPA concluded that arsenic does not pose an unacceptable risk to human health "because of its lower risk level and because arsenic concentrations in CB/NT fish are similar to concentrations in fish from the reference area [Carr Inlet]" (USEPA 1989).[11] In other words, if recreators/fishers were to consume seafood from the Hylebos Waterway, the seafood would have the same arsenic concentration as seafood obtained from a pristine Puget Sound location. The lack of a human health risk from consumption of seafood downgradient of the Site was further supported by arsenic concentrations in mussels sampled by the Washington Department of Fish and Wildlife (WDFW) Puget Sound Ecosystem Monitoring Program (PSEMP) and Tacoma-Pierce County Health Department (TPCHD) during two 2014 studies (WDFW PSEMP 2014; TPCHD 2014). The WDFW PSEMP and TPCHD results indicated that arsenic concentrations in mussels collected along the Site shoreline in 2014 were similar to arsenic concentrations throughout Puget Sound, including locations representative of background conditions (see Table 2-2). Thus, USEPA's quantitative human health risk assessment, as supported by the WDFW PSEMP and TPCHD results, could be used to evaluate the protection of human health in the FS Report for select cleanup alternatives that use the MTCA screening level for protection of aquatic organisms (36 ug/L) as a remediation level.[12]

A number of groundwater/surface water POC options may be applicable to this Site based on MTCA regulations for the protection of potential surface water receptors. The standard groundwater POC per WAC 173-340-720(8)(b) is all groundwater across a site. However, this standard POC is typically not appropriate for complicated sites like this Site because it is not practicable to achieve cleanup levels throughout the site within a reasonable restoration time frame. There are three potentially applicable conditional POCs for this Site. Per WAC 173-340-720(8)(c), the first conditional POC option is "as close as practicable to the source of hazardous substances" but not exceeding the property boundary. Since this Site abuts surface water, a second conditional POC option per WAC 173-340-720(8)(d)(i) if certain criteria are met is "within the surface water as close as technically possible to the point or points where ground water flows into the surface water." A third conditional POC option per WAC 173-340-730(6)(a) is "points at which hazardous substances are released to the surface waters of the state" (i.e., pore water nylon-screen diffusion sampler [NSDS] locations below the surface water interface). The second and third conditional POC options are representative of locations where potential Site exposures to arsenic in water could occur. By contrast, the standard groundwater POC and first conditional POC option are based on the assumption that aquatic organisms are present in groundwater monitoring wells (MWs) and recreators/fishers consume seafood obtained from groundwater MWs.

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[11] Extensive source control and sediment remediation activities have been completed for the CB/NT site since the CB/NT fish samples were collected for the site-specific human health risk assessment in 1984. Thus, current arsenic concentrations in Hylebos Waterway surface water and sediment are likely lower than when the fish samples were collected in 1984.

[12] Although the risk assessment procedures in WAC 173-340-357 focus on allowable modifications to default exposure assumptions in MTCA Method B and C equations, USEPA's human health risk assessment is consistent with the intent of WAC 173-340-357(2) by using a quantitative approach to evaluate if a particular cleanup action alternative is protective of human health and the environment. More importantly, in accordance with WAC 173-340-380(4), the determination in the CB/NT Record of Decision that arsenic does not pose an unacceptable human health risk for the CB/NT site (USEPA 1989) can be used to satisfy the MTCA remedy selection criteria in WAC 173-340-360 (e.g., ensuring protection of human health and the environment and compliance with cleanup standards).

Groundwater is defined in WAC 173-340-200 as "water in a saturated zone or stratum beneath the surface of land or below a surface water." For the purposes of this Report, pore water is defined as the subset of groundwater that is located within the 0-10 centimeter biologically active zone used for the CB/NT site (DOF 2011).

2.8 Overview of Sources and Transport for the Main Arsenic Plume

2.8.1 Definition of Plume Terms

To facilitate clear communication about arsenic in groundwater, the following terms are used for the purposes of this Report:

- The main arsenic plume is generally defined as the plan-view area encompassed by the 2017 Upper Aquifer dissolved arsenic isoconcentration contour of 500 ug/L shown on Figure 2-2, and areas downgradient of this contour (i.e., between the 500 ug/L contour and the Hylebos Waterway). The main arsenic plume includes groundwater within this plan-view area in the Upper, Intermediate, and Deep Aquifers.
- The source area for the main arsenic plume is generally defined as the area encompassed by the known and potential Penite manufacturing features shown on Figure 2-2.
- The plume core is loosely defined as the areas where historical and/or 2017 arsenic concentrations in MWs exceeded 50,000 ug/L.

2.8.2 Sources

The primary sources for the main arsenic plume are former Penite Pit #1, former Penite Pit #2, and the former Penite Manufacturing Building (see Figure 2-2).[13] Former Penite Pits #1 and #2 have been firmly established as the known primary sources for the main arsenic plume since the 1980s. Sludges, washdown water, and filter cake generated by the Penite manufacturing process were disposed of in the former Penite Pits #1 and #2 (DOF 2013). Former Penite Pit #1 was in operation from circa 1944 to the early 1950s, and Former Penite Pit #2 was in operation from the early 1950s to the late 1960s or early 1970s. It is expected that wastes disposed of in former Penite Pits #1 and #2 were placed within the Upper Aquifer saturated zone. Waste and soil within and immediately surrounding Penite Pits #1 and #2 were excavated and disposed of off-site as discussed in Section 2.5. The former Penite Manufacturing Building is a suspected primary source based on the results of the Data Gap #2 evaluation (see Section 6.2.3) and recent groundwater modeling results.[14] Penite was manufactured within the former Penite Manufacturing Building from circa 1944 to the early 1970s. It is suspected that some residual waste material is present in Upper Aquifer soil underneath or immediately surrounding the former Penite Manufacturing Building (but has yet to be encountered in soil borings).

The cause(s) of the elevated arsenic soil and groundwater concentrations immediately west of the primary sources discussed in the previous paragraph is not well understood. Dispersion, diffusion, and

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[13] When used in this Report, the term former Penite Manufacturing Building refers to the former building itself and the three adjacent former tanks located immediately southeast of the former building.

[14] Groundwater monitoring results were provided in April 2019 personal correspondence from Dr. Joel Massmann (KetaWaters) to Troy Bussey (PIONEER).

reverse gradients from tidal fluctuations prior to SPW installation would have caused some plume spreading and arsenic sorption onto soil upgradient of the primary sources. Historical pumping of the Upper Aquifer P&T extraction trench and extraction wells located to the west of the primary sources would also have caused some plume spreading and arsenic sorption onto soil upgradient of the primary sources. Likewise, the thin/leaky First Aquitard location southwest of the primary sources (see Figure 2-2) could have created a hydraulic preferential pathway that transported some Upper Aquifer arsenic mass towards the southeast. In addition, it is possible that one or more secondary sources exist upgradient of the primary sources (e.g., between the 50,000 ug/L and 500 ug/L isoconcentration contours). Identified former features that may have been associated with former Penite manufacturing operations include (1) a former dry pit that was present in the 1950s and 1960s west of former Penite Pit #2, and (2) a former pond that was present for a few years in the early 1970s west of former Penite Pit #1 (see Figure 2-2). Although the existing lines of evidence suggest that the former dry pit and former pond were likely not sources (based on the nature of features and historical and current arsenic concentrations in soil and groundwater near the features), these two features are examples of potential Penite waste management activities that may have released arsenic upgradient of the primary sources.

2.8.3 Transport Towards the Hylebos Waterway

Transport of arsenic in groundwater from the source area towards the Hylebos Waterway is currently conceptualized (based in part on recent groundwater modeling results) as three separate plume lobes emanating from each of the three primary sources (former Penite Pit #1, former Penite Pit #2, and former Penite Manufacturing Building). These three conceptual plume lobes (as depicted by three slightly different groundwater flow arrows on Figure 2-2) have combined to form a single large arsenic plume. Arsenic in groundwater in the Upper and Intermediate Aquifers near former Penite Pit #1 generally flows due east towards the SPW. By contrast, groundwater in the Upper and Intermediate Aquifers near former Penite Pit #2 and the former Penite Manufacturing Building has a slightly different flow trajectory. Arsenic in groundwater in the Upper and Intermediate Aquifers near former Penite Pit #2 has a slight southeastern flow direction, which means portions of this plume lobe encounter elevated activity of hydrogen ions (pH) from the former Taylor Lake Area surface impoundments that exacerbates arsenic transport (see Figure 2-2). Similarly, arsenic in groundwater in the Upper and Intermediate Aquifers near the former Penite Manufacturing Building has a slight northeastern flow direction, which means portions of this plume lobe encounter elevated pH from the former Caustic Manufacturing Area that exacerbates arsenic transport.[15] In addition, Upper Aquifer groundwater emanating from the former Penite Manufacturing Building encounters previously identified locations where the First Aquitard is thin or leaky (Intera 1995). These locations with a thin or leaky First Aquitard likely provide a preferential pathway for arsenic migration from the Upper Aquifer to the Intermediate Aquifer.

Several factors combine to reduce the arsenic groundwater concentrations that remain on the order of 50,000 ug/L near the source area to less than 5 ug/L in Hylebos Waterway surface water at the

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[15] The former Caustic Manufacturing Area includes the former Caustic Manufacturing Building as well as known and suspected locations of infrastructure associated with caustic manufacturing (e.g., caustic tanks).

groundwater/surface water interface. The completed remedial actions summarized in Section 2.5 (e.g., soil removals, arsenic P&T system, in-situ stabilization) have reduced the source strength of the main arsenic plume. The SPW continues to facilitate reductions of arsenic concentrations from the upgradient (west) side of the SPW to the downgradient (east) side of the SPW. Although elevated concentrations remain in MWs on the downgradient side of the SPW since some groundwater flows through SPW joints, arsenic on the downgradient side of the SPW is attenuated prior to surface water due to mixing of marine surface water within groundwater along the Site shoreline. Specifically, this mixing increases hydraulic tidal dispersion and produces favorable geochemical conditions for arsenic attenuation (see Section 2.9 and Section 7). Finally, the engineered intertidal and sediment caps that were installed downgradient of the source area enhance arsenic attenuation along the shoreline by providing sorption surfaces and enhancing marine surface water mixing.

2.9 Primer on Geochemical Attenuation of Arsenic

Since arsenic does not degrade in the environment and geochemistry plays a critical role in attenuating arsenic, this section presents a brief primer on geochemical attenuation to provide context for the investigation and evaluation results presented in Sections 5 and 6. The natural attenuation of arsenic in groundwater in general, and the natural attenuation that is occurring within portions of the main arsenic plume in particular, is dependent on three geochemical attenuation mechanisms and several geochemical conditions (Argonne National Laboratory 2003; Savannah River National Laboratory 2011; USEPA 2007a, 2007b, 2015).[16] The three geochemical attenuation mechanisms (in decreasing order of long-term stability) are (1) precipitation or co-precipitation with recalcitrant and highly stable minerals, (2) co-precipitation with metal oxides (e.g., iron oxides), and (3) sorption. The occurrence of these three mechanisms, which involve partitioning of dissolved arsenic from the aqueous phase to the solid phase (i.e., soil or sediment), was verified for this Site by analyzing soil and sediment samples using a sequential extraction procedure. A brief description of each mechanism, along with the geochemical conditions typically associated with the mechanism, is presented in the three following paragraphs.

Arsenic that has precipitated or co-precipitated with highly stable minerals is not environmentally available for transport back to the dissolved phase because the arsenic has been incorporated into the mineral and the mineral will remain intact under a wide range of geochemical conditions (including current and anticipated future geochemical conditions at the Site). Arsenic-containing minerals incorporate arsenic directly as the mineral precipitates. Arsenic can also be incorporated indirectly with non-arsenic minerals as an impurity during mineralization. A preliminary evaluation of Upper Aquifer chemistry in six MWs containing a range of geochemical conditions indicated that a variety of highly stable minerals would be expected to precipitate at the Site that could have incorporated arsenic directly or indirectly during precipitation.[17] More importantly, the presence of arsenic within highly

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[16] The information in this section is based on these references and personal correspondence between Dr. Rebecca Neumann (University of Washington) and Troy Bussey (PIONEER) from November 2016 through June 2019.

[17] The MWs were 4D4-1, 5D5-1, 5D7-1R, 5E4-1, 6D14-1, and 6E6-1. The 2017 and 2018 activity of electrons (Eh) values in the MWs ranged from -0.15 to 0.35 volts (V). The 2017 and 2018 pH results ranged from 6.01 to 11.47.

stable minerals under a wide range of geochemical conditions was verified for the Site with the sequential extraction results (see Section 5.2.2.1).

Co-precipitation of arsenic with metal oxides (e.g., iron oxides) is not as favorable in terms of long-term attenuation stability as precipitation/co-precipitation with highly stable minerals because metal oxides can be reduced and dissolved by bacteria as part of their respiration process. However, co-precipitation of arsenic with metal oxides can provide stable attenuation of arsenic as long as oxygen is present. When oxygen is present, bacteria use oxygen instead of metal oxides in respiration, leaving the metal oxides intact. Precipitation of metal oxides, and incorporation of arsenic indirectly in the metal oxide mineral as a co-precipitate, occurs in locations where reduction-oxidation (redox) conditions transition from reducing (e.g., Eh less than 0 V) to oxidizing (e.g., Eh greater than 0 V). Thus, as long as redox conditions remain oxidizing (and favorable for metal oxides), arsenic that has co-precipitated with metal oxides will remain in the solid phase. The presence of arsenic within metal oxide minerals under a wide range of geochemical conditions was verified for the Site with the sequential extraction results.

Although sorption of arsenic on the solid phase is an important geochemical attenuation mechanism, sorption is considered the least stable of the three geochemical attenuation mechanisms because arsenic can desorb from the solid phase and mobilize back to the aqueous phase if one or more geochemical conditions change. In particular, sorption of the key arsenic species (arsenate and arsenite) can be affected by changes to pH and/or redox conditions. The ability of arsenic to sorb to the solid phase is better when pH is in a neutral range (e.g., pH between 6 and 8) compared to a basic pH (e.g., pH greater than 9).[18,19] Furthermore, the ability of arsenic to sorb to the solid phase decreases proportionally as the pH becomes increasingly basic (elevated).[20] The ability of arsenic to sorb to the solid phase is better in oxidizing conditions (e.g., Eh greater than 0 V) than reducing conditions (e.g., Eh less than 0 V). Oxidizing conditions are better for arsenic sorption primarily because iron oxide minerals are typically present in oxidizing conditions, and iron oxide minerals provide solid-phase sorption surfaces for arsenic.[21] These sorption surfaces can consist of existing iron oxide minerals that have already precipitated or fresh iron oxide minerals that form where redox conditions transition from reducing to oxidizing. Locations in which Eh exceeds 0 V and iron oxide concentrations exceed 1,000 mg/kg are considered favorable for arsenic sorption (Savannah River National Laboratory 2011). Beyond pH and redox conditions, secondary geochemical conditions that can affect sorption include ionic strength and the presence/absence of competitive anions. The ability of arsenic to sorb to the solid phase generally increases as the ionic strength of the aqueous phase increases because sorption

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[18] At a neutral pH, the surface charge of metal oxides (which sorb arsenic in the aquifers) is positive, aqueous arsenate exists as negatively charged oxyanions, and aqueous arsenite exists as a neutrally charged species. Because the charges on the sorption surface and arsenic species are aligned to attract each other, the electrostatic attractions that facilitate sorption are more compatible in a neutral pH range. By contrast, the sorption surface and arsenic species are less attracted to each other at a basic (elevated) pH because the metal oxide surface and both arsenic species are negatively charged.

[19] Arsenate sorption increases and arsenite sorption decreases as pH becomes more acidic (e.g., decreases from pH 6 to pH 1).

[20] As pH becomes more basic (e.g., increases from pH 9 to pH 11), the sorption surface becomes more negatively charged, which further reduces the attraction of negatively charged arsenic species to the sorption surface.

[21] Manganese and aluminum oxides can also provide sorption surfaces for arsenic.

surfaces are more positively charged at higher ionic strengths, which facilitates increased sorption of negatively charged arsenic oxyanions.[22] If excessive concentrations of competitive anions such as ortho-phosphate and silicate are present, the ability of arsenic to sorb to the solid phase can decrease because ortho-phosphate and silicate can compete with arsenic oxyanions for sorption surfaces.

In summary, ideal conditions for arsenic attenuation (in general order of importance) include:

- The presence of arsenic within highly stable minerals;
- Oxidizing conditions (e.g., Eh greater than 0 V);
- pH in a neutral range (e.g., pH between 6 and 8);[23]
- Iron oxide concentrations greater than 1,000 mg/kg;
- Elevated ionic strength (e.g., elevated conductivity values); and
- Lower concentrations of competitive anions such as ortho-phosphate and silicate.

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[22] Conductivity and total dissolved solids are indicators of the ionic strength of the aqueous phase.

[23] Alternatively, ideal attenuation conditions could include an acidic pH if arsenate is the predominant species. For instance, during 2001 to 2004 in-situ stabilization activities at the Site, ideal sorption conditions where temporarily created within treatment areas by injecting ferric chloride and hydrogen peroxide to create strongly acidic conditions (as low as pH 1 in some locations), additional iron oxides, and oxidize arsenite to arsenate.

SECTION 3: OVERVIEW OF FS DATA GAPS

A brief overview of the four FS data gaps described in the Work Plan (see Appendix A) is presented in this section.

3.1 Data Gap #1: Shoreline Concentrations

In summary, Data Gap #1 was that concentrations of arsenic were unknown (1) within pore water (a subset of groundwater below the surface water interface), and (2) within surface water as close as technically possible to where groundwater flows into surface water. Filling this data gap was necessary in order to (1) evaluate protectiveness of human health and the environment, and (2) evaluate different POC options for select cleanup alternatives in the FS Report. The data gap activities proposed in the Work Plan consisted of installing NSDSs at select shoreline locations in order to collect representative pore water and surface water samples. The NSDSs, which are passive samplers that are left in-place over a period of time, are more representative of actual groundwater and surface water conditions near the surface water interface than previous sampling methods. For instance, pushpoint samplers (PPSs) have been used to collect grab groundwater samples with the pump intake at a location approximately one foot landward of the surface water interface. This data gap was subdivided by NSDS location: Upper Aquifer pore water (Data Gap #1A), Intermediate Aquifer pore water (Data Gap #1B), and surface water as close as technically possible to where groundwater flows into surface water (Data Gap #1C).

3.2 Data Gap #2: Arsenic Plume Stability

In summary, Data Gap #2 was to determine the stability of dissolved arsenic groundwater concentrations within the main arsenic plume.[24] Filling this data gap was necessary in order to determine the effectiveness of completed remedial actions and natural attenuation processes so that appropriate cleanup alternatives could be developed and evaluated in the FS Report. For instance, more aggressive cleanup actions would be appropriate if the main arsenic plume was increasing in source strength or expanding in size while less aggressive cleanup actions would be appropriate if the main arsenic plume was stable or declining. The data gap activities proposed in the Work Plan consisted of conducting two groundwater, pore water, and surface water sampling events, and collecting soil and sediment geochemical data in order to evaluate plume stability. This data gap was subdivided by aquifer unit/media: Upper Aquifer (Data Gap #2A), Intermediate Aquifer (Data Gap #2B), Deep Aquifer (Data Gap #2C), and soil/sediment geochemistry (Data Gap #2D).

3.3 Data Gap #3: Wall Integrity

In summary, Data Gap #3 was to determine the current integrity of the SPW (i.e., corrosion on the SPW, condition of the SPW joints, and condition of the SPW gaps that were repaired in 2004). Filling this data

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[24] MTCA surface water cleanup levels are based on Chapter 173-201A of the WAC, regulations developed pursuant to Section 304 of the Clean Water Act, and 40 Code of Federal Regulations 131. These regulations explicitly indicate that the criteria are intended for use with dissolved arsenic. Thus, dissolved arsenic concentrations are used for evaluating compliance.

gap was necessary in order to determine the utility and anticipated life of the SPW when developing and evaluating cleanup alternatives in the FS Report. The data gap activities proposed in the Work Plan consisted of having a corrosion engineer inspect the current integrity of the SPW and estimate the anticipated life expectancy of the SPW. Subsequent to preparation of the Work Plan, a desktop evaluation of leakage through the SPW joints using existing water level data was added as an additional data gap activity.

3.4 Data Gap #4: Feasibility of Focused Soil Excavation Alternative

In summary, Data Gap #4 was to identify whether or not distinct arsenic and/or pH soil source areas remained in the subsurface that could practicably be removed via soil excavation. Key uncertainties regarding a potential focused soil excavation for arsenic were (1) the locations and depths of the highest arsenic soil concentrations in the vicinity of the former Penite Pits, (2) the amount of soil in the vicinity of the former Penite Pits that exceeds the toxicity characteristic leaching procedure (TCLP) criteria for hazardous waste, and (3) site-specific effectiveness of ex-situ stabilization to treat potential excavated soil. The key uncertainty regarding a potential focused soil excavation for pH was whether or not a distinct pH source area could be identified within the former Taylor Lake Area surface impoundments and/or the former Caustic Manufacturing Area. Filling Data Gap #4 was necessary in order to develop and evaluate focused soil excavation options as part of cleanup alternatives in the FS Report. The data gap activities proposed in the Work Plan consisted of collecting and analyzing soil samples from soil borings within, surrounding, and downgradient of the former Penite Pits, within the former Taylor Lake Area surface impoundments, and within the former Caustic Manufacturing Area. This data gap was subdivided by constituent: arsenic (Data Gap #4A) and pH (Data Gap #4B).

SECTION 4: SUMMARY OF INVESTIGATION ACTIVITIES

This section summarizes the field and laboratory investigation activities that were conducted in 2017 and 2018 to address the four FS data gaps described in the Work Plan (see Appendix A). Investigation activities included sampling and analysis for pore water, surface water, groundwater, soil, and sediment samples, and an inspection of the SPW.

4.1 Deviations from the Work Plan

All investigation activities were conducted in general accordance with the Work Plan (see Appendix A). Identified deviations from the Work Plan are presented in Table 4-1. Many of the deviations were identified prior to field implementation and submitted to Ecology for concurrence prior to starting the fieldwork. For example, 2018 investigation activities for Data Gaps #1, #2, and #4 were refined based on evaluations of 2017 investigation results. The deviations did not compromise the investigation objectives or the use of the data obtained during the investigation.

4.2 Field Activities

A summary of field activities is presented in the following subsections by data gap. Appendix B includes a detailed description of field procedures, boring logs, field forms, field water quality measurements, and waste disposal documentation for the 2017 field investigation activities. Appendix C includes a detailed description of field procedures, boring logs, field forms, field water quality measurements, and waste disposal documentation for the 2018 field investigation activities.

4.2.1 Data Gap #1: Shoreline Concentrations

In summary, Data Gap #1 field activities consisted of:

- Installing pore water NSDSs at select shoreline locations in order to collect representative pore water samples where Upper Aquifer groundwater discharges to surface water (Data Gap #1A);
- Installing pore water NSDSs at select shoreline locations in order to collect representative pore water samples where Intermediate Aquifer groundwater discharges to surface water (Data Gap #1B); and
- Installing surface water NSDSs at select shoreline locations in order to collect representative surface water samples where Intermediate Aquifer groundwater discharges to surface water (Data Gap #1C).

Locations where NSDSs were installed in 2017 and 2018 for Data Gaps #1A, #1B, and #1C are presented in Figures 4-1A, 4-1B, and 4-1C, respectively.

4.2.2 Data Gap #2: Arsenic Plume Stability

In summary, Data Gap #2 field activities consisted of:

- Collecting field water quality measurements (e.g., pH, oxidation reduction potential [ORP], conductivity) and collecting groundwater and pore water NSDS samples from locations within the Upper Aquifer (Data Gap #2A);

- Collecting field water quality measurements (e.g., pH, ORP, conductivity) and collecting groundwater, PPS, pore water NSDS, and surface water samples from locations within the Intermediate Aquifer or where Intermediate Aquifer groundwater discharges to surface water (Data Gap #2B);
- Collecting field water quality measurements (e.g., pH, ORP, conductivity) and collecting groundwater samples from MWs within the Deep Aquifer (Data Gap #2C); and
- Conducting x-ray fluorescence (XRF) field screening for arsenic in all Data Gap #2D soil borings, conducting pH field screening in the four soil borings also associated with Data Gap #4B, and collecting soil and sediment samples for geochemical analyses (Data Gap #2D).

Two groundwater, pore water, and surface water sampling events were conducted for Data Gaps #2A through #2C (in 2017 and 2018). Almost all Site MWs were sampled during the 2017 comprehensive water sampling event. By contrast, the water sampling event conducted in 2018 focused on key MWs within the main arsenic plume (e.g., 12 main arsenic plume MWs identified with potential post-2004 rebound after the 2017 sampling event, MWs in the plume core, and shoreline MWs). PPSs, pore water NSDSs, and surface water samples were collected during both sampling events. The types of water samples collected and the locations where water samples were collected in 2017 and 2018 for Data Gaps #2A, #2B, and #2C are presented in Figures 4-2A, 4-2B, and 4-2C, respectively. A conceptual cross section showing the relative locations of Upper Aquifer Angled Shoreline MWs, Upper Aquifer pore water NSDSs, and surface water samples is presented in an inset graphic in Figure 4-2A (and subsequent Upper Aquifer figures).[25] A conceptual cross section showing the relative locations of Intermediate Aquifer PPSs, Intermediate Aquifer pore water NSDSs, and surface water samples is presented in an inset graphic in Figure 4-2B (and subsequent Intermediate Aquifer figures).

Soil and sediment samples were collected pursuant to Data Gap #2D to support the evaluation of plume stability and/or for potential use in developing and calibrating groundwater models. Samples related to Data Gap #2D were collected from 17 soil borings and 8 sediment sampling locations (see Figure 4-2D).[26] The field team considered field XRF arsenic concentrations, field pH results (for the four Data Gap #4B soil borings), and field observations when selecting soil sample depth intervals for laboratory analyses. The soil samples selected for laboratory analyses within a given lithologic unit were typically biased towards the highest field XRF arsenic concentrations, or the highest field pH results for the four Data Gap #2B soil borings. Geologic logs for 2017 and 2018 borings are presented in Appendices B and C, respectively.

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[25] Surface water sample locations are presented on Upper Aquifer figures (i.e., Figure 4-2A and subsequent Upper Aquifer figures) for context.

[26] Eleven of the 17 soil borings were also associated with Data Gap #4A (PTC-101, PTC-104, PTC-108, PTC-111 through PTC-113, PTC-120 through PTC-122, PTC-127, and PTC-129) and four of the 17 soil borings were also associated with Data Gap #4B (PTC-204, PTC-205, PTC-207, PTC-208).

4.2.3 Data Gap #3: Wall Integrity

In summary, Data Gap #3 field activities consisted of:

- Excavating two test pits to depths of approximately 3.5 feet bgs in order to expose the SPW at multiple locations and expose one of the 2004 SPW gap repairs;
- A corrosion engineer inspecting corrosion on the SPW, the condition of the SPW joints, and the condition of one of the 2004 SPW gap repairs; and
- A corrosion engineer collecting ultrasonic thickness measurements at multiple locations along the exposed portion of the SPW.

The test pits were excavated on September 28, 2017, and the corrosion engineer performed his fieldwork on the same day. The locations of the excavations and photographs taken during the inspection are presented in Figure 4-3. The northern test pit extended from approximately Hylebos Waterway Station 124+70 to 125+50, and the southern test pit extended from approximately Hylebos Waterway Station 127+65 to 127+85. The exposed 2004 SPW gap repair (which consisted of a 1.1-inch-thick steel plate that was welded to patch the SPW gap) was located at approximately Hylebos Waterway Station 124+75. Additional details about the excavations, inspections, and ultrasonic thickness measurements are included in Appendices B and D.

No new fieldwork was performed for the desktop evaluation of leakage through the SPW joints that was added as an additional data gap activity subsequent to preparation of the Work Plan.

4.2.4 Data Gap #4: Feasibility of Focused Soil Excavation

In summary, Data Gap #4 field activities consisted of:

- Conducting near-continuous XRF field screening for arsenic and collecting soil samples for laboratory analyses from soil borings within, surrounding, and downgradient of the former Penite Pits (Data Gap #4A); and
- Conducting near-continuous pH field screening and collecting soil samples for laboratory analyses from soil borings within the former Taylor Lake Area surface impoundments and within the former Caustic Manufacturing Area (Data Gap #4B).

A total of 30 soil borings were advanced and sampled pursuant to Data Gap #4A and four soil borings were advanced and sampled per Data Gap #4B. Locations where soil borings were advanced and sampled in 2017 and 2018 pursuant to Data Gaps #4A and #4B are presented in Figures 4-4A and 4-4B, respectively. All borings were advanced into the First Aquitard, and some borings were advanced into the Intermediate Aquifer or Second Aquitard. Geologic logs for 2017 and 2018 borings are presented in Appendices B and C, respectively. The field team considered field XRF arsenic concentrations, field pH results (for the four Data Gap #4B soil borings), and field observations when selecting soil sample depth intervals for laboratory analyses. The soil samples selected for laboratory analyses within a given lithologic unit were typically biased towards the highest field XRF arsenic concentrations, or the highest field pH results for the four Data Gap #4B soil borings. In general, one soil sample from each lithologic unit encountered (e.g., Upper Aquifer, First Aquitard) was submitted for laboratory analyses. In addition, a total of four soil samples were selected for ex-situ soil stabilization bench tests: the Upper

Aquifer and First Aquitard samples in the two 2018 borings that had the highest arsenic concentrations (PTC-102 and PTC-103).

4.3 Laboratory Activities

4.3.1 Data Gap #1: Shoreline Concentrations

No laboratory activities were conducted for Data Gap #1 per se since this data gap only involved the installation of NSDSs. The NSDSs were retrieved, sampled, and analyzed pursuant to Data Gap #2 according to the Work Plan. However, dissolved arsenic concentrations along the shoreline (including results from NSDSs) are presented and discussed as part of Data Gap #1 in Sections 5.1 and 6.1.

4.3.2 Data Gap #2: Arsenic Plume Stability

In summary, Data Gap #2 laboratory activities consisted of:

- Analyzing all water samples collected in 2017 for the five metal COPCs (total and dissolved), the four VOC COPCs, dissolved arsenic species (e.g., arsenite and arsenate), and dissolved conventionals (e.g., ortho-phosphorus, silicon);
- Analyzing all water samples collected in 2018 for dissolved arsenic, and select water samples (i.e., seaward of the SPW) for dissolved copper, lead, mercury, and nickel; and
- Analyzing all Data Gap #2D soil and sediment samples for arsenic and pH, and select samples for sequential extraction and follow-on analyses (e.g., arsenic and iron), other conventionals (e.g., ortho-phosphorus), and/or batch adsorption tests (BATs).

Samples were analyzed by the laboratories identified in the Work Plan. In general, Analytical Resources, Inc. (ARI) performed the bulk of the laboratory analyses. Brooks Applied Labs (BAL) performed specialty analyses (e.g., metals and conventionals for water samples near the shoreline, arsenic speciation, sequential extraction and follow-on analyses, and BATs). Information regarding the ARI and BAL analyses (e.g., sample receipt documentation, case narratives, analytical methods, and quality control information) is included in the laboratory reports presented in Appendix E.

4.3.3 Data Gap #3: Wall Integrity

No laboratory activities were conducted for Data Gap #3.

4.3.4 Data Gap #4: Feasibility of Focused Soil Excavation

In summary, Data Gap #4 laboratory activities consisted of:

- Analyzing all Data Gap #4A soil samples selected by the field team for total arsenic, pH, and TCLP metals;
- Analyzing all Data Gap #4B soil samples selected by the field team for total arsenic, pH, and TCLP metals; and
- Conducting ex-situ soil stabilization bench tests on the Upper Aquifer and First Aquitard samples selected by the field team from PTC-102 and PTC-103.

ARI performed the total arsenic, pH, and TCLP metals analyses not associated with the ex-situ soil stabilization bench tests. Information regarding the ARI analyses (e.g., sample receipt documentation, case narratives, analytical methods, quality control information) is included in the laboratory reports presented in Appendix E.

Free Flow Technologies, Ltd. (Free Flow) and Ursus Remediation Testing & Technologies LLC (Ursus) performed separate ex-situ soil stabilization bench tests on two PTC-102 samples and two PTC-103 samples. Information regarding the methodology used by Ursus and Free Flow during their bench tests are included in their respective reports (see Appendix F).

4.4 Data Validation

All laboratory analyses (except those associated with sequential extraction and BATs) were validated by an independent data validator, James McAteer of QA/QC Solutions, LLC. Overall, the data generated by the laboratories were considered of good quality and the laboratories' quality assurance/quality control procedures were generally acceptable. Nitrate results for groundwater samples collected from 14 MWs in the North Boundary Area that were initially reported as non-detect were rejected by the data validator due to poor matrix spike recoveries (bromide results in nine of these MWs were also rejected). Data validation qualifiers assigned by QA/QC Solutions, LLC were added to or replaced data qualifiers assigned by the laboratories. The QA/QC Solutions, LLC data validation reports are included with the laboratory reports in Appendix E.

SECTION 5: INVESTIGATION RESULTS

The purpose of this section is to present and summarize the 2017 and 2018 FS Data Gap Investigation results that are most relevant for evaluating the four FS data gaps. Although this section focuses on the most relevant results, additional field screening and laboratory results were generated during this investigation for Data Gap #2 that may be useful for future Site work (e.g., developing and calibrating groundwater models, preparing the FS Report). All analytical laboratory reports are presented in Appendix E.[27] All field screening and laboratory results are presented in tables in Appendix G.

5.1 Data Gap #1: Shoreline Concentrations

Although the specified Data Gap #1 activities only involved installation of NSDSs, the nature of the data gap was to improve the understanding of dissolved arsenic concentrations in pore water and surface water as close as technically possible to where groundwater flows into surface water. Thus, in order to provide context for the pore water and surface water results and to discuss the nature and extent of arsenic along the shoreline, this section presents all results seaward of the SPW (not just NSDS results). Dissolved arsenic concentrations seaward of the SPW for the 2017 and 2018 sampling events are presented in Figures 5-1 and 5-2, respectively.

5.1.1 2017 Results

Key Upper Aquifer dissolved arsenic results from the 2017 sampling event for the vertical shoreline MWs, Angled Shoreline MWs, pore water NSDSs, and surface water samples were:

- Four vertical shoreline MWs had concentrations exceeding 36 ug/L (5B1-R, 121+80-1, 124+00-1, and 125+50-1).
- The highest concentration in a vertical shoreline MW was 3,100 ug/L in 124+00-1, which is downgradient of the former Penite Manufacturing Building.
- 125+50-0 was the only Angled Shoreline MW with a concentration exceeding 36 ug/L.
- Three pore water NSDSs had concentrations exceeding 5 ug/L (122+60-0-DS, 125+50-0-DS, and 126+90-0-DS), but only 125+50-0-DS had a concentration exceeding 36 ug/L. Pore water NSDS location 125+50-0-DS is just downgradient of the Angled Shoreline MW with the highest dissolved arsenic concentration (125+50-0).
- Arsenic attenuation can occur in the relatively short distance between the vertical shoreline MWs and pore water. For example, concentrations were attenuated by almost three orders of magnitude between 124+00-1 and 124+00-0-DS.

Key Intermediate Aquifer dissolved arsenic results from the 2017 sampling event for the vertical shoreline MWs, PPSs, pore water NSDSs, and surface water samples were:

- The seven vertical shoreline MWs from 120+75-2 to 128+30-2 had concentrations exceeding 36 ug/L.

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[27] With the exception of the laboratory reports for the ex-situ soil stabilization bench tests, which are included in Appendix F.

- The five vertical shoreline MWs from 122+60-2 to 128+30-2 had concentrations that were at least an order of magnitude higher than the corresponding paired vertical shoreline MW in the Upper Aquifer (e.g., 39,000 ug/L in 124+00-2 compared to 3,100 ug/L in 124+00-1).
- The concentration of 39,000 ug/L in 124+00-2, which is downgradient of the former Penite Manufacturing Building, was an order of magnitude higher than any other vertical shoreline MW.
- 120+75-ST1 and 123+25-ST1 were the only two PPSs with concentrations exceeding 36 ug/L.
- Two pore water NSDSs had concentrations slightly exceeding 5 ug/L (125+00-ST1-DS and 128+50-ST1-DS).
- Concentrations in the three surface water samples where Intermediate Aquifer groundwater discharges to surface water ranged from 2.4 ug/L to 2.9 ug/L.

5.1.2 2018 Results

The 2018 dissolved arsenic concentrations and patterns for Upper Aquifer sampling locations seaward of the SPW were similar to 2017 results. The only new observation worth noting regarding the 2018 Upper Aquifer results was that one additional (fifth) vertical shoreline MW had a concentration exceeding 36 ug/L (126+90-1).

The 2018 dissolved arsenic concentrations and patterns for Intermediate Aquifer sampling locations seaward of the SPW were similar to 2017 results. The new observations worth noting regarding the 2018 Intermediate Aquifer results were:

- The concentration in 124+00-2 nearly doubled to 76,000 ug/L and concentrations in 121+80-2 and 128+30-2 were approximately an order of magnitude higher in 2018 compared to 2017.
- Three PPSs had concentrations exceeding 36 ug/L (120+75-ST1, 123+25-ST1, and 128+50-ST1). The 2018 concentration in 120+75-ST1 was lower than the 2017 concentration, and the 2018 concentration in 123+25-ST1 was similar to the 2017 concentration. However, the 2018 concentration in 128+50-ST1 was an order of magnitude higher than the 2017 concentration.
- All six of the pore water NSDSs had concentrations exceeding 5 ug/L, and two had concentrations exceeding 36 ug/L (123+25-ST1-DS and 125+00-ST1-DS).
- Arsenic attenuation can occur in the relatively short distance between the vertical shoreline MWs and pore water. For example, concentrations were attenuated by greater than one order of magnitude between 126+90-2 and 126+80-ST1-DS and between 128+30-2 and 128+50-ST1-DS.
- Concentrations in pore water NSDSs 120+75-ST1-DS, 125+00-ST1-DS, and 128+50-ST1-DS (ranging from 32 ug/L to 44 ug/L) were an order of magnitude higher than concentrations in the three surface water samples located immediately adjacent (ranging from 2.4 ug/L to 3.8 ug/L). These results indicate that the NSDSs are sampling pore water (not surface water).

5.2 Data Gap #2: Arsenic Plume Stability

This section presents and summarizes (1) 2017 and 2018 dissolved arsenic concentrations in groundwater, pore water, and surface water (see Section 5.1 for a more detailed summary of dissolved arsenic concentrations seaward of the SPW) and (2) key 2017 and 2018 results relevant to the geochemical attenuation of arsenic.

5.2.1 Arsenic Water Concentrations

The 2017 dissolved arsenic water concentrations (along with interpreted isoconcentration contours) for the Upper, Intermediate, and Deep Aquifers are presented in Figures 5-3 through 5-5, respectively. A conceptual cross-section of 2017 dissolved arsenic concentrations in all three aquifers along a transect that intersects former Penite Pit #1 is shown on Figure 5-6. The 2018 dissolved arsenic water concentrations (along with interpreted isoconcentration contours) for the Upper and Intermediate Aquifers are presented in Figures 5-7 and 5-8, respectively. The data-driven isoconcentration contours shown on the aforementioned figures are based on the current understanding of sources and transport. However, new insights about the main arsenic plume (e.g., in plume core locations without MWs) are being gained during ongoing calibration/verification of the groundwater models. As a result, the isoconcentration contours will most likely be revised in the future once calibration/verification activities for the three-dimensional model are completed.

5.2.1.1 2017 Results

Key Upper Aquifer dissolved arsenic results for the main arsenic plume from the 2017 sampling event were:

- The highest concentrations were adjacent to or downgradient of the former Penite Manufacturing Building (i.e., 97,000 ug/L in 5E4-1 and 91,000 ug/L in 5D7-1R).
- Although 2017 concentrations in 6E1-1 and 6D14-1 downgradient of former Penite Pit #1 have declined by one to two orders of magnitude compared to 1980s concentrations (see Section 6.2.1), 2017 concentrations in these two plume core MWs were on the order of 50,000 ug/L.
- Concentrations in MWs downgradient of the source area and landward of the SPW (i.e., 5D2-1R, 6D25-1, 6E2-1, and 7E3-1) were approximately one-half to one order of magnitude less than the MWs mentioned in the two previous bullets.
- The highest concentration in a vertical shoreline MW (seaward of the SPW) was 3,100 ug/L in 124+00-1, which is downgradient of the former Penite Manufacturing Building.
- The 500 ug/L isoconcentration contour was elongated to the north in the vicinity of 5C13-1, 5C12-1, 5B1-1R, and 121+80-1.
- Arsenic concentrations within the main arsenic plume were delineated to less than 5 ug/L with surface water and/or pore water samples.

Key Intermediate Aquifer dissolved arsenic results for the main arsenic plume from the 2017 sampling event were:

- The highest concentrations were downgradient of former Penite Pit #2 (i.e., 100,000 ug/L in 6E3-2) and the former Penite Manufacturing Building (i.e., 39,000 ug/L in 124+00-2).
- Concentrations downgradient of former Penite Pit #1 were relatively low (i.e., 3,000 ug/L in 6E9-2 and 2,700 ug/L in 6B19-2).
- The 500 ug/L isoconcentration contour was elongated to the north in the vicinity of 5C10-2 and 5C16-2R.
- Arsenic concentrations within the main arsenic plume were delineated to less than 5 ug/L with surface water and/or pore water samples.

Key Deep Aquifer dissolved arsenic results from the 2017 sampling event were:

- Only two MWs had concentrations exceeding 5 ug/L: (1) 230 ug/L in 6E7-3, which is downgradient of former Penite Pit #1, and (2) 17 ug/L in 5D1-3, which is downgradient/crossgradient of the former Penite Manufacturing Building.
- Arsenic concentrations within the main arsenic plume were delineated to less than 5 ug/L with MWs downgradient of 6E7-3 and 5D1-3.

5.2.1.2 2018 Results

The nature and extent of the main arsenic plume for both the Upper Aquifer and Intermediate Aquifer were similar in 2017 and 2018. The only new observations worth noting regarding the 2018 results were:

- Dissolved arsenic concentrations in two Upper Aquifer source area MWs near the former Penite Manufacturing Building were approximately 40% higher in 2018 compared to 2017 (5E4-1 and 5D5-1).
- The concentration in Intermediate Aquifer vertical shoreline MW 124+00-2 nearly doubled to 76,000 ug/L while the MW upgradient of 124+00-2 decreased by an order of magnitude (i.e., 6D25-2 decreased from 11,000 ug/L in 2017 to 1,400 ug/L in 2018).

MWs 6E7-3 and 5D1-3 were the only Deep Aquifer MWs sampled in 2018 and the dissolved arsenic concentrations in these two MWs were 240 ug/L and 12 ug/L, respectively (see Appendix G). Since the magnitude and extent of arsenic PCL exceedances in the Upper and Intermediate Aquifers overshadow those in the Deep Aquifer, almost all of the subsequent presentation and evaluation of results are focused on the Upper and Intermediate Aquifers.

5.2.2 Key Results Related to the Geochemical Attenuation of Arsenic

This section presents key results related to the ideal conditions for geochemical attenuation of arsenic, which are:

- The presence of arsenic within highly stable minerals;
- Oxidizing conditions (e.g., Eh greater than 0 V);
- pH in a neutral range (e.g., pH between 6 and 8);
- Iron oxide concentrations greater than 1,000 mg/kg;
- Elevated ionic strength (e.g., elevated conductivity values); and
- Lower concentrations of competitive anions such as ortho-phosphate and silicate.

Results related to highly stable minerals, Eh, pH, iron oxides, ionic strength, ortho-phosphate, and silicate are presented in the following figures and Table 5-1:

- The sequential extraction results for arsenic in soil and sediment show the relative percentage of arsenic associated with highly stable minerals relative to arsenic that is co-precipitated with metal oxides and sorbed to the solid phase (see Figure 5-9).
- The field Eh water results show where oxidizing conditions and reducing conditions are present in the Upper and Intermediate Aquifer (see Figure 5-10, Figure 5-11, and Table 5-1).
- The field pH water results show where pH is in the neutral range and where pH is elevated in the Upper and Intermediate Aquifer (see Figure 5-12, Figure 5-13, and Table 5-1).

- The sequential extraction results for iron oxide in soil and sediment show where iron oxide concentrations are high enough for favorable sorption of arsenic (see Figure 5-14).[28]
- The field conductivity water results show where ionic strengths are most favorable for sorption of arsenic in the Upper and Intermediate Aquifer (see Figure 5-15, Figure 5-16, and Table 5-1).
- The ortho-phosphorus and silicon concentrations in the Upper and Intermediate Aquifer provide an indication of ortho-phosphate and silicate concentrations in the dissolved phase that could be competing with arsenic for sorption surfaces (see Figures 5-17 through 5-20).

With the exception of Figure 5-9, the figures referenced in this section utilize a common symbology to display the results (i.e., a color gradient from yellow to brown or from brown to yellow). Yellow symbols are representative of geochemical conditions less favorable for arsenic attenuation and brown symbols are representative of geochemical conditions that are more favorable for arsenic attenuation. The symbology bins for the Eh, pH, and iron oxide figures were based on the aforementioned numerical criteria. The symbology bins for the conductivity, ortho-phosphorus, and silicon figures were selected to display the range of results. All investigation results are presented on these figures, with the exception of the 2018 Eh, pH, and conductivity results (which are presented in Table 5-1).[29]

5.2.2.1 Sequential Extraction Results for Arsenic in Soil and Sediment

Key sequential extraction results for arsenic in soil and sediment were (see Figure 5-9):

- Some amount of arsenic had precipitated or co-precipitated with highly stable minerals at every single sample location.
- The majority of arsenic in the following key locations was precipitated or co-precipitated with highly stable minerals:
    - Upper Aquifer sediment within the intertidal cap (125+50-0-SED);
    - Intermediate Aquifer sediment seaward of the SPW (125+00-ST1-SED and 128+50-ST1-SED);
    - Four of the seven First Aquitard soil samples within the main arsenic plume (PTC-120, PTC-108, PTC-112, and PTC-122); and
    - Four of the seven Intermediate Aquifer soil samples within the main arsenic plume (PTC-113, PTC-129, PTC-204, and PTC-208).
- The majority of arsenic was either precipitated or co-precipitated with highly stable minerals or co-precipitated with metal oxides in 22 of the 25 sequential extraction samples.

5.2.2.2 Field Eh Water Results

Key Upper Aquifer field Eh results (converted from field ORP results[30]) for the main arsenic plume were (see Figure 5-10 and Table 5-1):

- Most locations within the main arsenic plume had oxidizing conditions favorable for co-precipitation of arsenic with metal oxides and sorption of arsenic onto the solid phase (i.e., Eh greater than 0 V).

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[28] The iron oxide results are the iron concentrations associated with sequential extraction steps 3 and 4 only (see Appendix E).

[29] 2017 results for Eh, pH, and conductivity are presented on Figures 5-10 through 5-13, 5-15, and 5-16 because the 2017 data set is more robust than the 2018 data set.

[30] Eh results were conservatively estimated by adding 0.2 V to the ORP measurement based on the type of electrode and solution used for the ORP measurements (see Appendices B and C).

- Highly oxidizing conditions (e.g., Eh greater than 0.2 V) were present along the shoreline in the pore water NSDSs, the Angled Shoreline MWs, and many of the vertical shoreline MWs.[31]
- Reducing conditions (i.e., Eh less than 0 V) were present in MWs within or downgradient of the former Taylor Lake Area surface impoundments during the 2017 and/or 2018 water sampling events (i.e., 6E6-1, 7E8-1, 7E10-1, 7F3-1, 7F4-1, 8F1-1R, and 8G2-1).
- Reducing conditions (i.e., Eh less than 0 V) were present in MWs near the northern portion of the former Caustic Manufacturing Area during the 2018 water sampling event (i.e., 4D1-1, 5C12-1, 5C13-1, and 5D2-1R).

Key Intermediate Aquifer field Eh results (converted from field ORP results) for the main arsenic plume were (see Figure 5-11 and Table 5-1):

- Most locations within the main arsenic plume had oxidizing conditions favorable for co-precipitation of arsenic with metal oxides and sorption of arsenic onto the solid phase (i.e., Eh greater than 0 V).
- Highly oxidizing conditions (e.g., Eh roughly equal to or greater than 0.2 V) were present along the shoreline in the surface water samples, the pore water NSDSs, and many of the PPSs.[32]
- Reducing conditions (i.e., Eh less than 0 V) were present downgradient of the former Taylor Lake Area surface impoundments during the 2017 and/or 2018 water sampling events (i.e., 7E4-2, 7E6-2, 7E7-2, 8F2-2R, 8G3-2, 128+30-2, 129+65-2, and 128+50-ST1).
- Reducing conditions (i.e., Eh less than 0 V) were present downgradient of the northern portion of the former Caustic Manufacturing Area during the 2017 and/or 2018 water sampling events (i.e., 121+80-2 and 120+75-ST1).
- Reducing conditions (i.e., Eh less than 0 V) were present in 6D25-2 (which is near a thin or leaky First Aquitard location) in 2018 and downgradient 124+00-2 in 2017.

5.2.2.3 Field pH Results for Water Samples

Key Upper Aquifer field pH results for the main arsenic plume were (see Figure 5-12 and Table 5-1):

- Neutral pH values (e.g., between 6 and 8) were present along the shoreline in the pore water NSDSs, the Angled Shoreline MWs (except for 124+00-0 during the 2018 event), and many of the vertical shoreline MWs.[33]
- Neutral pH values (e.g., between 6 and 8) were present in many of the plume core MWs (e.g., 5D5-1, 5D7-1R, 5E1-1, 6D14-1, 6E1-1, 6E2-1, 6E5-1, 7E3-1).
- Elevated pH values exceeding 10 were present in MWs within or downgradient of the former Taylor Lake Area surface impoundments during the 2017 and/or 2018 water sampling events (i.e., 6E6-1, 7E8-1, 7E10-1, 7F3-1, 7F4-1, 8F1-1R, and 8G2-1).

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[31] All vertical shoreline MWs from 122+60-1 to 131+00-1 had Eh results exceeding 0.2 V during the 2018 event, and 122+60-1, 126+90-1, and 128+30-1 had Eh results exceeding 0.2 V during the 2017 event.

[32] 119+25-ST1 had an Eh of 0.19 V in 2018, 123+25-ST1 had Eh results of 0.18 V and 0.22 V, 125+00-ST1 had Eh results of 0.19 V and 0.24 V, 126+80-ST1 had Eh results of 0.24 V during both events, 128+50-ST1 had an Eh of 0.22 V in 2017, and 130+75-ST1 had an Eh of 0.23 V in 2017.

[33] All vertical shoreline MWs from 122+60-1 to 131+00-1 had a pH between 6 and 8, except 124+00-1 and 125+50-1 had pH values of 8.42 and 8.33, respectively, during the 2018 event. The 2018 pH values of 8.03 and 8.04 in 122+60-0 and 126+90-1 were considered to be equivalent to a pH of 8 since these values round to 8.0.

- Elevated pH values exceeding 10 were present in MWs near or downgradient of the northern portion of the former Caustic Manufacturing Area during the 2017 and/or 2018 water sampling events (i.e., 4C1-1, 4D1-1, 5C12-1, 5C13-1, 5D2-1R, 5B1-1R, and 121+80-1).

Key Intermediate Aquifer field pH results for the main arsenic plume were (see Figure 5-13 and Table 5-1):

- Neutral pH values (e.g., between 6 and 8) were present along the shoreline in the surface water samples, the pore water NSDSs, the PPSs, and several of the vertical shoreline MWs (i.e., 5B1-2R, 120+75-2, 125+50-2, 126+90-2, and 129+65-2).
- Neutral pH values (e.g., between 6 and 8) were present in key plume core MWs (e.g., 6B19-2, 6E3-2, 6E9-2).
- Elevated pH values ranging from 8.5 to 11.6 were present downgradient of the former Taylor Lake Area surface impoundments during the 2017 and/or 2018 water sampling events (i.e., 7E4-2, 7E6-2, 7E7-2, 7E13-2R, 7E16-2, 8F2-2R, 8G3-2, 128+30-2, and 131+00-2).
- Elevated pH values ranging from 8.9 to 9.6 were present near the northern portion of the former Caustic Manufacturing Area during the 2017 and/or 2018 water sampling events (i.e., 5C14-2, 121+80-2).
- Elevated pH values ranging from 8.4 to 9.7 were present in 6D25-2 (which is near a thin or leaky First Aquitard location) and downgradient 124+00-2.

5.2.2.4 Sequential Extraction Results for Iron Oxide in Soil and Sediment

Concentrations of iron oxides (e.g., ferric iron oxide) in soil and sediment samples within the main arsenic plume indicate that iron oxide concentrations are favorable for sorption of arsenic. Specifically, every soil and sediment sample had iron oxide concentrations greater than or equal to the 1,000 mg/kg criterion for favorable sorption (see Figure 5-14). The highest iron oxide concentrations were present in the First Aquitard and seaward of the SPW. The maximum iron oxide concentration in the First Aquitard was 14,000 mg/kg, and the maximum iron oxide concentration seaward of the SPW was 8,200 mg/kg. In addition, the presence of arsenic sorption at the Site was verified with the sequential extraction results (see Figure 5-9).[34]

5.2.2.5 Field Conductivity Results for Water Samples

Key Upper Aquifer field conductivity results for the main arsenic plume were (see Figure 5-15 and Table 5-1):

- Elevated conductivity values ranging from 19,000 uS/cm to 45,000 uS/cm were present along the shoreline in the pore water NSDSs, the Angled Shoreline MWs, and the vertical shoreline MWs located upgradient of the intertidal sediment cap (i.e., 122+60-1 through 131+00-1).[35]
- Elevated conductivity values ranging from 11,000 uS/cm to 54,000 uS/cm were present in MWs within or downgradient of the former Taylor Lake Area surface impoundments during the 2017 and/or 2018 water sampling events (i.e., 6E6-1, 7E8-1, 7E10-1, 7F3-1, 7F4-1, 8F1-1R, and 8G2-1).

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[34] The site-specific sorption isotherms that were developed using investigation results and describe the sorption capacity of different lithologic units will be presented in a future groundwater modeling document.

[35] With the exception of the anomalous value of 3,200 uS/cm in 131+00-1 during the 2017 event.

- Elevated conductivity values ranging from 3,600 uS/cm to 18,000 uS/cm were present in select MWs within the former Caustic Manufacturing Area or in-situ stabilization areas (i.e., 4C1-1, 4D1-1, 5C12-1, 5C13-1, 5D2-1R, 5D5-1, 5E4-1, 6D14-1, 6E2-1, and 6E5-1).

Key Intermediate Aquifer field conductivity results for the main arsenic plume were (see Figure 5-16 and Table 5-1):

- Conductivity values ranging from 36,000 uS/cm to 44,000 uS/cm were present in the surface water samples.
- Elevated conductivity values exceeding 15,000 uS/cm were present in almost every sample location.
- The small percentage of MWs within the main arsenic plume that did not have conductivity values exceeding 15,000 uS/cm during one of the two water sampling events (i.e., 6B19-2, 6D25-2, 6E9-2, 7E4-2, 7E6-2, 7E7-2, 7E9-2, 7E13-2R, 7E16-2R, 121+80-2, 131+00-2) had conductivity values ranging from 1,800 uS/cm to 15,000 uS/cm.

5.2.2.6 Results for Potential Competitive Anions

Since directly analyzing for ortho-phosphate and silicate was not a commercially available option, dissolved ortho-phosphorus and silicon results were used as conservative indicators of likely ortho-phosphate and silicate concentrations in the dissolved phase. In other words, it was assumed most of the ortho-phosphorus and silicon would be present as ortho-phosphate and silicate, respectively. Key ortho-phosphorus and silicon results for the main arsenic plume were (see Figures 5-17 through 5-20) were:

- Lower dissolved ortho-phosphorus and silicon concentrations were present along the Upper Aquifer shoreline in the pore water NSDSs, the Angled Shoreline MWs, and the vertical shoreline MWs located upgradient of the intertidal sediment cap (i.e., 122+60-1 through 131+00-1).
- Lower dissolved ortho-phosphorus and/or silicon concentrations were present along the Intermediate Aquifer shoreline in the surface water samples, the pore water NSDSs, and the PPSs.
- Higher dissolved ortho-phosphorus and silicon concentrations were present in the Upper Aquifer within or downgradient of the former Taylor Lake Area surface impoundments (i.e., 7F3-1, 7F4-1, and 7E8-1) and the northern portion of the former Caustic Manufacturing Area (i.e., 4C1-1, 4D1-1, and 5C12-1). However, higher dissolved ortho-phosphorus and silicon concentrations were not observed within these areas for the Intermediate Aquifer.

5.2.2.7 Figures of Other Ancillary Results

Figures displaying the following results, which are not explicitly discussed in this Report, but may be of interest for some readers, are presented in Appendix H:

- 2017 dissolved arsenite concentrations in the Upper and Intermediate Aquifers
- 2017 dissolved arsenate concentrations in the Upper and Intermediate Aquifers
- 2017 dissolved arsenate percentages in the Upper and Intermediate Aquifers
- 2017 bromide concentrations in the Upper and Intermediate Aquifers
- 2017 field dissolved oxygen concentrations in the Upper and Intermediate Aquifers
- 2017 ortho-phosphorus concentrations in soil and sediment

- Sequential extraction sorbed silicon concentrations for soil and sediment
- 2017 sulfide concentrations in soil and sediment
- 2017 field sulfide concentrations in the Upper and Intermediate Aquifers

5.3 Data Gap #3: Wall Integrity

Key results from the inspection of the SPW by the corrosion engineer on September 28, 2017 (see Appendix D) were:

- The SPW, the SPW joints, and the steel plate that was welded to the SPW were in good condition with only superficial rust staining and scattered minor pitting visible on the surface.
- No thinning of the SPW or the steel plate was detected in any of the ultrasonic thickness measurements.
- The aforementioned results were assumed by the corrosion engineer to be representative of the entire SPW because corrosion rates in soil tend to be highest near the ground surface (where dissolved oxygen concentrations are typically highest).

No new field or lab results were obtained to support the desktop evaluation of leakage through the SPW joints (see Section 6.3 for the evaluation of existing data).

5.4 Data Gap #4: Feasibility of Focused Soil Excavation

5.4.1 Data Gap #4A (Arsenic)

This section presents and summarizes (1) arsenic soil concentrations in samples collected from 30 soil borings advanced within, surrounding, and downgradient of the former Penite Pits, (2) TCLP metals concentrations in Upper Aquifer and First Aquitard samples collected from the aforementioned 30 borings, and (3) results from ex-situ soil stabilization bench tests performed on Upper Aquifer and First Aquitard samples collected from PTC-102 and PTC-103.

5.4.1.1 Total Arsenic Results

The total arsenic soil concentrations (for all field XRF and laboratory results) obtained from the 30 Data Gap #4A borings (i.e., PTC-101 through PTC-130) are presented in Table 5-2. In addition, the maximum arsenic concentrations for all soil and sediment samples collected pursuant to the Work Plan are summarized by lithologic unit in Figure 5-21 and by depth in Figure 5-22. Key total arsenic results from the 30 borings collected within, surrounding, and downgradient of the former Penite Pits were:

- A sludge-like material containing arsenic at 165,000 mg/kg was encountered at 7.5 to 8.5 feet bgs in PTC-102, which was advanced within former Penite Pit #2 (see Figure 5-23). This arsenic concentration was over an order of magnitude higher than any arsenic concentration obtained during this investigation and is consistent with concentrations in former Penite Pits #1 and #2 prior to the 1990 soil removal (MPS Incorporated 1990). The sludge-like material was encountered just beneath suspected excavation backfill material that extended from ground surface to 7.5 feet bgs. Although the 1990 excavation reportedly extended to 10 feet bgs, it is suspected that some sidewall sloughing occurred prior to backfilling based on the PTC-102 boring log and photographs taken during excavation activities (MPS Incorporated 1990).
- The lithologic descriptions in the boring logs for PTC-101 (see Appendix B) and PTC-102 (see Appendix C) suggest that the 1990 soil excavations for former Penite Pits #1 and #2 did not

extend to the top of the First Aquitard as originally reported. For instance, the suspected excavation backfill material in PTC-102 (e.g., the well sorted gravelly sand) only extends to 7.5 feet bgs, but the First Aquitard was not encountered until approximately 12 feet bgs.

- Some arsenic has precipitated or sorbed onto the clean backfill material that was placed during the 1990 excavations of former Penite Pits #1 and #2 (i.e., the maximum arsenic concentrations within the suspected backfill material were 11,000 mg/kg at 6 to 7 feet bgs in PTC-102 and 3,200 mg/kg at 6 to 8.2 feet bgs in PTC-101).
- Besides the 165,000 mg/kg arsenic concentration in a PTC-102 Upper Aquifer sample, PTC-101 (5,500 mg/kg) and PTC-103 (5,200 mg/kg) were the only two borings with a maximum Upper Aquifer arsenic concentration exceeding 5,000 mg/kg.
- Although PTC-101 through PTC-103 were the only locations with maximum Upper Aquifer arsenic concentrations exceeding 5,000 mg/kg, a large area contained Upper Aquifer arsenic concentrations exceeding 590 mg/kg. This area extends from PTC-120 on the west to PTC-129 on the east and from PTC-127 on the south to PTC-123 on the north.
- The highest arsenic concentrations were encountered in samples collected deeper than six feet bgs. These deeper samples were either (1) the aforementioned PTC-101 through PTC-103 samples, or (2) First Aquitard samples.
- Arsenic concentrations exceeding 5,000 mg/kg were encountered in the First Aquitard in a large area that extended from PTC-108 on the west to PTC-113 on the east and from PTC-110 on the south to PTC-123 on the north.
- In general, the highest concentrations within the First Aquitard were often encountered at the top of the First Aquitard (see Table 5-2).
- Arsenic concentrations within the Intermediate Aquifer exceeded 590 mg/kg in five of the nine Data Gap #4A borings with Intermediate Aquifer soil samples (i.e., PTC-101, PTC-102, PTC-113, PTC-121, and PTC-129).

Although not a FS data gap per se, it should be noted that all arsenic concentrations in the eight sediment samples collected during this investigation were less than the arsenic sediment quality objective (SQO) of 57 mg/kg established for the CB/NT CERCLA site (USEPA 1989). The maximum arsenic concentration in the eight sediment samples was 42 mg/kg in intertidal sediment sample 125+50-0-SED (see Figure 5-21). In addition, there have been no other arsenic SQO exceedances in post-remediation intertidal and subtidal sediment samples collected from the biologically active zone of 0 – 10 centimeters along the Site shoreline to date (DOF 2013, 2018).

5.4.1.2 TCLP Metals Results

The concentrations of TCLP metals (i.e., arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver) in the Upper Aquifer and First Aquitard soil samples collected from the 30 Data Gap #4A borings (i.e., PTC-101 through PTC-130) are presented in Table 5-3. In addition, the TCLP arsenic concentrations for all soil samples collected pursuant to the Work Plan are summarized by lithologic unit in Figure 5-24. Key TCLP metals results from the 30 borings collected within, surrounding, and downgradient of the former Penite Pits relative to the dangerous waste criteria in WAC 173-303-090(8) were:

- The TCLP arsenic concentration exceeded the 5 mg/L criterion in six Upper Aquifer soil samples collected within close proximity to former Penite Pits #1 and #2 (PTC-101, PTC-102, PTC-103, PTC-108, PTC-109, and PTC-121).
- The highest TCLP arsenic concentration in an Upper Aquifer sample was 120 mg/L in the same PTC-102 sample that had a total arsenic concentration of 165,000 mg/kg.
- TCLP arsenic exceedances were more prominent in the First Aquitard than the Upper Aquifer. The TCLP arsenic concentration exceeded the 5 mg/L criterion in 20 of the 30 First Aquitard soil samples.
- TCLP arsenic concentrations that were greater than ten times the 5 mg/L criterion were present in First Aquitard soil samples collected within former Penite Pits #1 and #2 (i.e., PTC-101 and PTC-102) and downgradient of former Penite Pits #1 and #2 (i.e., PTC-103, PTC-104, PTC-110, PTC-111, and PTC-117).
- None of the TCLP barium, cadmium, chromium, lead, mercury, selenium, or silver concentrations exceeded its respective dangerous waste criterion.

5.4.1.3 Ex-Situ Soil Stabilization Bench Test Results

Results from the ex-situ soil stabilization bench tests performed by Free Flow and Ursus on the PTC-102 and PTC-103 Upper Aquifer and First Aquitard soil samples are presented in Appendix F. Free Flow and Ursus used different versions of their stabilization products at varying dosage rates in an attempt to reduce TCLP arsenic concentrations in the PTC-102 and PTC-103 samples to less than the dangerous waste criterion of 5 ug/L. Free Flow and Ursus performed their own pre-stabilization and post-stabilization laboratory analyses on the sample aliquots received for bench testing. Key ex-situ soil stabilization bench test results were:

- The various stabilization products and dosing rates used by Free Flow were unable to successfully stabilize TCLP arsenic concentrations in the PTC-102 Upper Aquifer, PTC-102 First Aquitard, and PTC-103 First Aquitard samples to less than 5 mg/L. Free Flow was able to achieve TCLP arsenic concentrations of less than 5 mg/L in the PTC-103 Upper Aquifer sample, but the starting TCLP arsenic concentration in the sample aliquot that Free Flow analyzed was only 8.2 mg/L.
- The various Enviroblend® products and dosing rates used by Ursus were unable to successfully stabilize TCLP arsenic concentrations in the PTC-102 Upper Aquifer and PTC-102 First Aquitard samples to less than 5 mg/L. Ursus did not attempt to stabilize the PTC-103 samples based on the PTC-102 results.
- Ursus was able to successfully stabilize TCLP arsenic concentrations to less than 5 mg/L in all four PTC-102 and PTC-103 samples by using an oxidant (i.e., potassium permanganate) in conjunction with two Enviroblend® products. Dosing rates of 1% potassium permanganate, 3% Enviroblend® HX, and 5% Enviroblend® CS were able to stabilize both Upper Aquifer samples. Dosing rates of 7% potassium permanganate, 3% Enviroblend® HX, and 5% Enviroblend® CS were able to stabilize both First Aquitard samples.
- While the oxidant plus Enviroblend® approach was able to stabilize TCLP arsenic concentrations in all four samples, the revised geochemical conditions caused by the stabilization products appear to have caused slight TCLP mercury and/or selenium exceedances in some Ursus trials.

5.4.2 Data Gap #4B (pH)

The near continuous field pH results obtained from the four Data Gap #4B borings (i.e., PTC-204, PTC-205, PTC-207, and PTC-208) are presented in Table 5-4. In addition, the maximum pH values in all soil borings advanced pursuant to the Work Plan are summarized by lithologic unit in Figure 5-25. Key soil pH results were:

- Elevated soil pH values exceeding 10 were relatively dispersed and relatively deep within the former Caustic Manufacturing Area (i.e., at 5 feet bgs and from 7 to 12 feet bgs in PTC-204; from 1 to 14 feet bgs and from 18 to 25 feet bgs in PTC-205).
- Elevated soil pH values exceeding 10 were relatively dispersed and relatively deep within the former Taylor Lake Area surface impoundments (i.e., from 0.5 to 1 foot bgs and from 13 to 15 feet bgs in PTC-207; at 0.5 feet bgs, from 7 to 9 feet bgs, and from 12 to 15 feet bgs in PTC-208).
- Elevated soil pH values exceeding 9 were present downgradient of the former Penite Manufacturing Building (i.e., PTC-105, PTC-122, and PTC-114 Upper Aquifer samples, and PTC-114 through PTC-116 First Aquitard samples).

5.5 Figures of Water Results for Other COPCs

Since arsenic is the primary concern for this Site and the FS data gaps are related to arsenic, results for other COPCs (besides arsenic) are not explicitly discussed in this Report. However, figures displaying the following water results, which may be used in the FS Report, are presented in Appendix H:

- 2017 dissolved copper concentrations in the Upper and Intermediate Aquifers
- 2017 dissolved lead concentrations in the Upper and Intermediate Aquifers
- 2017 dissolved mercury concentrations in the Upper and Intermediate Aquifers
- 2017 dissolved nickel concentrations in the Upper and Intermediate Aquifers
- 2017 VOC exceedances in the Upper and Intermediate Aquifers
- 2017 non-arsenic exceedances in the Deep Aquifer

SECTION 6: EVALUATION OF RESULTS AND DISCUSSION

6.1 Data Gap #1: Shoreline Concentrations

Data Gap #1 has been filled because current arsenic concentrations in pore water and surface water samples collected as close as technically possible to where groundwater flows into surface water have been established (see Figures 5-1 and 5-2). Dissolved arsenic concentrations in all surface water samples were less than 5 ug/L. Dissolved arsenic concentrations in all pore water NSDSs were less than the MTCA screening level for protection of aquatic organisms (36 ug/L), with the exception of 125+50-0-DS (39 ug/L to 44 ug/L), 123+25-ST1-DS (550 ug/L during the 2018 event), and 125+00-ST1-DS (44 ug/L during the 2018 event). The slight exceedances of 36 ug/L in 125+50-0-DS were likely attributable to ongoing Upper Aquifer transport from the plume core (e.g., concentrations in 6D14-1 on the landward side of the SPW from 125+50-0-DS were 44,000 ug/L to 50,000 ug/L). The exceedances in 123+25-ST1-DS and 125+00-ST1-DS were likely attributable to ongoing transport from the former Penite Manufacturing Building and through the former Caustic Manufacturing Area that have resulted in high concentrations in the Intermediate Aquifer seaward of the SPW (i.e., concentrations of 39,000 ug/L to 76,000 ug/L in 124+00-2).

Although empirical data does not yet exist to know long-term arsenic concentration trends in representative pore water and surface water samples, arsenic concentrations in pore water and surface water are not expected to increase for several reasons. First, the geochemical conditions along the shoreline where groundwater discharges to surface water are highly favorable for arsenic attenuation. The geochemical conditions enable the majority of arsenic along the shoreline to be precipitated or co-precipitated with highly stable minerals, and will continue to facilitate co-precipitation with metal oxides and sorption. The geochemical conditions are a key reason why arsenic concentrations can attenuate dramatically within a short distance (e.g., concentrations attenuated by almost three orders of magnitude between 124+00-1 and 124+00-0-DS). Second, dissolved concentrations in the MWs just upgradient of the pore water and surface water sample locations are stable or declining. Time-series plots of dissolved arsenic concentrations in eight Upper Aquifer vertical shoreline MWs, seven Upper Aquifer Angled Shoreline MWs, and nine Intermediate Aquifer vertical shoreline MWs are presented in Figures 6-1A and 6-1B. These time-series plots show that dissolved arsenic concentrations in MWs seaward of the SPW have decreased or remained stable since 2005, with the possible exception of 124+00-1 and 124+00-2. Finally, the completed remedial actions have reduced the source strength within the plume core, and have reduced arsenic concentrations entering the shoreline area. A comparison of 2017 dissolved arsenic concentrations in vertical shoreline MWs and 1989 concentrations from similar locations slightly upgradient of the vertical shoreline MWs is presented in Figure 6-2. In general, Upper Aquifer concentrations entering the shoreline area have decreased by two to five orders of magnitude since 1989 due to the completed remedial actions (e.g., soil removals, SPW installation, arsenic P&T system operation, in-situ stabilization). The Intermediate Aquifer concentrations are more difficult to compare because the 1989 and 2017 MW locations are not well aligned spatially; however, the maximum arsenic concentration entering the shoreline has decreased by two orders of magnitude (from 1,100 mg/L in 1989 to 39 mg/L in 2017).

6.2 Data Gap #2: Arsenic Plume Stability

Multiple lines of evidence were used to evaluate the stability of the main arsenic plume as documented in this section. The 2017 and 2018 results presented in Section 5.2 were combined with pre-2017 Site data to conduct the evaluation. The evaluation was divided into two parts: (1) lines of evidence associated with all data (i.e., including when the completed remedial actions were still underway), and (2) lines of evidence associated with post-2004 data only (i.e., only considering data collected after the last completed remedial action within the plume core was finished in 2004).

6.2.1 Lines of Evidence Associated with All Data

The following lines of evidence were evaluated to determine the overall effect of the completed remedial actions on plume stability:

- Time-series plots for plume core MWs (1981 – 2018 data)
- Mann-Kendall trend analysis (1993 – 2017 data)[36]
- Ricker plume stability analysis (1981 – 2017 data)

6.2.1.1 Time-Series Plots for Plume Core MWs (1981 – 2018 Data)

Time-series plots of dissolved arsenic concentrations in plume core MWs were evaluated in order to determine the effect of the completed remedial actions on the source strength of the main arsenic plume. Time-series plots of all available dissolved arsenic concentrations were prepared for every MW with a maximum concentration of greater than 50,000 ug/L and more than five post-1990 results spanning a duration of at least eight years. The time-series plots for the Upper Aquifer MWs and Intermediate Aquifer MWs satisfying this criterion are shown in Figures 6-3 and 6-4, respectively. A larger version of each time-series plot shown in Figures 6-3 and 6-4 is included in Appendix I.

Key evaluation observations for the Upper Aquifer plume core MWs based on a visual interpretation of the time-series plots were:

- The completed remedial actions facilitated arsenic concentration reductions through 2004 in all 16 plume core MWs, with the following exception. Early 1990s concentrations in 7E12-1 were higher than 1980s concentrations because SPW installation in October 1990 caused some lateral Upper Aquifer plume spreading in the early 1990s, but 7E12-1 concentrations then decreased between the early 1990s and early 2000s.
- Of the 11 plume core MWs with post-2004 data, seven had negligible rebound after 2004 (5E1-1, 6D14-1, 6E1-1, 6E2-1, 6E5-1, 7E8-1, and 7E10-1). The overall concentration reductions in these seven MWs (from the maximum concentration in the 1980s or early 1990s to the maximum post-2004 concentration) were approximately two to three orders of magnitude.

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[36] The Mann-Kendall trend analysis and Ricker plume stability analysis were performed after the 2017 water sampling event and before the 2018 water sampling event.

- Of the 11 plume core MWs with post-2004 data, four had potential post-2004 rebound (5D5-1, 5D7-1/5D7-1R, 5E4-1, and 7E3-1). Although it appears that arsenic concentrations have increased since 2004 in these four MWs, the highest post-2004 concentration in each MW was approximately one-half to one order of magnitude less than maximum concentrations in the 1980s or early 1990s. See Section 6.2.3 for a discussion of why there may be potential post-2004 rebound in these MWs.
- Three of the four MWs identified with potential post-2004 rebound are located in close proximity to the former Penite Manufacturing Building (5D5-1, 5D7-1/5D7-1R, and 5E4-1).[37]

Key evaluation observations for the Intermediate Aquifer plume core MWs based on a visual interpretation of the time-series plots were:

- Noticeable increases in concentrations from the 1980s to the early 1990s (due to increased vertical migration of arsenic in groundwater to the Intermediate Aquifer immediately following SPW installation in October 1990) were evident in five MWs (6D7-2, 6D15-2, 6E3-2, 6E9-2, and 7D1-2).[38]
- The completed remedial actions facilitated overall arsenic concentration reductions through 2004 in 11 plume core MWs (5C10-2, 6D7-2, 6D10-2, 6D12-2, 6D15-2, 6D22-2, 6E3-2, 6E9-2, 7D1-2, 7E6-2, and 7E7-2).
- Of the five plume core MWs with post-2004 data, four had negligible rebound after 2004 (5C10-2, 6E9-2, 7E6-2, and 7E7-2). The overall concentration reductions in these four MWs (from the maximum concentration in the 1990s to the maximum post-2004 concentration) were approximately two to three orders of magnitude.
- Of the five plume core MWs with post-2004 data, only 6E3-2 had potential post-2004 rebound. Concentrations have increased since 2004 in 6E3-2, which is downgradient of former Penite Pit #2. See Section 6.2.3 for a discussion of why there may be increases in 6E3-2 concentrations since 2004.

6.2.1.2 Mann-Kendall Trend Analysis (1993 – 2017 Data)

A Mann-Kendall trend analysis was performed for each Site MW with a sufficient data record after 1990 in order to assess if there was a statistically significant increasing or decreasing trend in dissolved arsenic concentrations in that MW. Site MWs with at least five post-1990 results spanning a duration of at least eight years were included in the analysis. Pre-1993 results were excluded from the analysis because installation of the SPW in October 1990 caused lateral plume spreading in the Upper Aquifer and increased arsenic transport to the Intermediate Aquifer in the early 1990s.[39] The results of the Mann-

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[37] The former Penite Manufacturing Building was demolished between 1990 and 2002 (based on existing aerial photographs), and was likely demolished circa 1997 (when other manufacturing facilities were dismantled). Demolishing the former Penite Manufacturing Building would have increased recharge at this suspected source location, and may have caused a new arsenic release.

[38] The increases in arsenic concentrations were accompanied by pH increases. All five MWs had a neutral pH before the SPW was installed, and elevated pH values (e.g., pH values greater than 11 in 6D15-2, 6E9-2, and 7D1-2) after the SPW was installed.

[39] The first arsenic-related groundwater sampling event after October 1990 did not occur until October 1992 (Boateng 1994). However, the Port and PIONEER do not have reports or data for the groundwater sampling that occurred between October 1992 and September 1993. Thus, data collected during and after October 1993 were used for this analysis.

Kendall trend analyses are included in Appendix I, and summarized for the Upper, Intermediate, and Deep Aquifers in Figures 6-5 through 6-7, respectively.[40]

Key Mann-Kendall trend analysis results for Upper Aquifer MWs were:

- Dissolved arsenic concentrations were decreasing in 82% of the MWs (31 of 38 MWs) and no trend was identified in another 13% of MWs (five MWs).
- Two MWs near the northern portion of the former Caustic Manufacturing Area had increasing dissolved arsenic concentrations (i.e., 4C1-1 and 5C12-1).

Key Mann-Kendall trend analysis results for Intermediate Aquifer MWs were:

- Dissolved arsenic concentrations were decreasing in 73% of the MWs (22 of 30 MWs) and no trend was identified in another 17% of MWs (five MWs).
- Three MWs had increasing dissolved arsenic concentrations (i.e., 3A5-2, 5C2-2, and 6D2-2). However, these results are not relevant to current conditions since all three MWs were decommissioned by 2003. In addition, the apparent increase in 3A5-2 may be associated with differences in reporting limits for non-detect results.

Key Mann-Kendall trend analysis results for Deep Aquifer MWs were:

- Dissolved arsenic concentrations were decreasing in 75% of the MWs (three of four MWs).
- Although 6D11-3 had increasing dissolved arsenic concentrations, this result is not relevant to current conditions since the MW was decommissioned by 2003. In addition, the apparent increase in 6D11-3 may be associated with differences in reporting limits for non-detect results.

6.2.1.3 Ricker Plume Stability Analysis (1981 – 2017 Data)

A Ricker plume stability analysis (Ricker) was performed for groundwater sampling events between 1981 and 2017 to provide a comprehensive, plume-wide evaluation of dissolved arsenic plume stability within the main arsenic plume. The methodology developed by Joseph Ricker produces four primary plume metrics for each groundwater sampling event included in the analysis: (1) average concentration within the plume, (2) plume mass, (3) plume area, and (4) plume center of mass (Ricker 2008). In order to produce comparable results between sampling events, the plume metrics are calculated relative to a consistent base isoconcentration contour (e.g., 500 ug/L) that is interpolated with kriging. As a result, the plume metrics are relative values rather than absolute values (e.g., the plume mass result for a given sampling event is comparable to the plume mass from another event, but may not be a precise estimate of the total mass within the plume). Because the Ricker methodology consistently aggregates, interpolates, and evaluates all available data within the groundwater sampling events, it is less susceptible to biases and variations associated with evaluations of concentrations in individual MWs.

The site-specific inputs and assumptions used for the Ricker plume stability analysis included:

- A total of 22 groundwater sampling events were used in the Ricker plume stability analysis.[41] In general, one groundwater sampling event was selected for each year in which comprehensive

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[40] Even though the Deep Aquifer is not a key concern for plume stability, a Mann-Kendall trend analysis was conducted for applicable Deep Aquifer MWs for completeness.

[41] The 22 events were the July 1981, January 1986, September 1987, November 1988, July 1989, January through February 1990, December 1993, December 1994, May 1995, September 1997, September 1998, September 1999, September 2000,

groundwater sampling was conducted. If multiple events were conducted within a given year, then the event with the most MWs sampled was selected for use in the Ricker plume stability analysis.

- To maximize comparability of results between events, MWs located within Wypenn, the North Boundary Area, and seaward of the SPW were excluded because these MWs were sampled infrequently. In addition, arsenic in Wypenn and North Boundary Area MWs is not associated with the main arsenic plume.
- Plume metrics were calculated separately for the Upper and Intermediate Aquifers.
- The four primary Ricker metrics were only calculated for a given aquifer in a given groundwater sampling event if more than ten MWs were sampled within the aquifer during that event.
- A 500 ug/L base isoconcentration contour for dissolved arsenic was used because it minimized issues associated with (1) differences in the specific MWs being sampled during each event (e.g., MWs with concentrations less than 500 ug/L were sampled sporadically), and (2) elevated reporting limits (e.g., 200 ug/L) for non-detect results in many sampling events.
- Non-detect results were assumed to equal the reporting limit.
- In order to calculate the estimated dissolved phase plume mass in each aquifer, an aquifer thickness of 10 feet and a porosity of 30% were assumed.
- Dissolved arsenic concentrations were assumed to equal total arsenic concentrations in select MWs for the July 1989 and January through February 1990 groundwater sampling events since dissolved arsenic results were not available.
- In addition to the four aforementioned primary Ricker metrics, the maximum concentration and number of MWs sampled were calculated for each event in order to provide context for the four primary Ricker metrics.

The maximum concentrations and average concentrations calculated by the Ricker plume stability analysis for the applicable 22 groundwater sampling events demonstrate that reductions in plume concentrations have occurred (see Charts 6-1 and 6-2). The maximum dissolved arsenic concentration in the Upper Aquifer decreased from 3,700,000 ug/L in 1981 to 100,000 ug/L in 2017, while the maximum dissolved arsenic concentration in the Intermediate Aquifer decreased from 1,100,000 ug/L in 1989 to 100,000 ug/L in 2017. The average dissolved arsenic concentration in the Upper Aquifer decreased from 150,000 ug/L in 1989 to 13,000 ug/L in 2017, while the average dissolved arsenic concentration in the Intermediate Aquifer decreased from 88,000 ug/L in 1994 to 6,400 ug/L in 2017. Thus, the maximum and average concentrations in the Upper and Intermediate Aquifers have decreased by more than one order of magnitude since the 1980s or early 1990s.

The plume masses and plume areas calculated by the Ricker plume stability analysis for the applicable 22 groundwater sampling events demonstrate that the source strength and extent of the main arsenic plume have shrunk over time (see Charts 6-3 and 6-4). If the main arsenic plume was shrinking, then the total plume mass and total plume area would decrease over time. The total plume mass decreased from 200,000 kg in 1993 to 19,000 kg in 2017, while the total plume area decreased from 980,000 square feet

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December 2001, September 2002, May 2003, August 2004, May through June 2005, September 2006, November through December 2008, February through May 2012, and October through November 2017 events.

in 1993 to 550,000 square feet in 2017. Thus, the total plume mass has decreased by one order of magnitude since 1993, while the total plume area in 2017 was roughly half the size of the 1993 plume area.

The plume center of mass locations calculated by the Ricker plume stability analysis for the applicable 22 groundwater sampling events demonstrate that the extent of the main arsenic plume is stable (see Figure 6-8). If the extent of the main arsenic plume was stable, then the center of mass would remain in approximately the same location over time (with some expected variability due to differences in the number and locations of MWs sampled during each event). The center of mass in the Upper Aquifer consistently remained within the source area near former Penite Pit #1 or slightly downgradient of the source area between 1989 and 2017. Likewise, the center of mass in the Intermediate Aquifer consistently remained at a location between the source area and the SPW.

The number of MWs sampled during each of the 22 groundwater sampling events are presented in Chart 6-5. Ricker results for groundwater sampling events with fewer sampled MWs are likely biased low (compared to results from events with more sampled MWs) since smaller MW networks cannot represent the full nature and extent of the main arsenic plume as well as larger MW networks. For instance, the Ricker results for the 2004 through 2006 events are likely biased low due to the limited number of MWs sampled during these events.[42]

6.2.2 Lines of Evidence Associated with Post-2004 Data Only

The following lines of evidence were evaluated to determine whether or not post-2004 rebound of the main arsenic plume has occurred since the last completed remedial action within the plume core was finished in 2004:

- Ricker plume stability analysis (2005 – 2017 data)
- Mann-Kendall trend analysis (2005 – 2017 data)
- Time-series plots for all MWs (2005 – 2018 data)
- Current geochemical conditions

The potential post-2004 rebound results for the first three lines of evidence are conservative because groundwater samples collected during 2005 and 2006 were representative of temporary geochemical conditions following in-situ stabilization between 2001 and 2004 (rather than long-term equilibrium conditions). For instance, pH values in some MWs within in-situ stabilization areas were still acidic in 2005 and 2006, and the arsenate that was produced by in-situ stabilization sorbs best to the solid phase under acidic conditions. In other words, the apparent increasing trends in some MWs within stabilized areas are actually an artifact of the temporary, non-equilibrium conditions in 2005 and 2006 (rather than an increasing trend from circa 2007 or 2008 to present). Thus, the period from circa 2007 or 2008 (once geochemical conditions within stabilized areas reached equilibrium) to 2018 was considered the most relevant period for evaluating the current stability of the main arsenic plume.

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[42] In addition, the 2004 through 2006 events focused sampling on MWs within areas where in-situ stabilization was performed between 2001 and 2004.

6.2.2.1 Ricker Plume Stability Analysis (2005 – 2017 Data)

The results from the Ricker plume stability analysis were re-evaluated for the period between 2005 and 2017. In the period between 2005 and 2017, the Ricker metrics in Charts 6-1 through 6-4 show two clear patterns: (1) decreased concentrations, plume masses, and plume areas in 2005 and 2006 (compared to results prior to 2004), and (2) stable or declining concentrations, plume masses, and plume areas from 2008 to 2017. As previously discussed, the Ricker metrics for 2005 and 2006 were temporarily depressed due to (1) non-equilibrium geochemical conditions following stabilization and (2) the limited number of MWs that were sampled in 2005 and 2006. Within the most relevant period for evaluating current plume stability (e.g., 2007 to 2018), all Ricker metrics (i.e., maximum concentration, average concentration, plume mass, plume area, and center of mass) indicate that the main arsenic plume is stable or declining.

6.2.2.2 Mann-Kendall Trend Analysis (2005 – 2017 Data)

A Mann-Kendall trend analysis was performed for each Site MW with a sufficient data record after 2004 in order to assess if there was a statistically significant increasing or decreasing trend in dissolved arsenic concentrations in that MW. Site MWs with at least four post-2004 results were included in the analysis. The results of the Mann-Kendall trend analyses are included in Appendix I, and summarized in Figure 6-9 (Upper Aquifer) and Figure 6-10 (Intermediate Aquifer).

Key Mann-Kendall trend analysis results for Upper Aquifer MWs were:

- No trend in dissolved arsenic concentrations was identified in 61% of the MWs (25 of 41 MWs) and dissolved arsenic concentrations were decreasing in another 22% of MWs (nine MWs).
- An increasing trend was identified by the Mann-Kendall trend analysis for seven MWs. Of the seven MWs, two were near the former Penite Manufacturing Building (5D5-1 and 5D7-1R), two were downgradient of former Penite Pit #2 (7E3-1 and 7E8-1), one was downgradient of former Penite Pits #1 and #2 (6D14-1), one was upgradient of the source area (5E1-1), and one was upgradient of the main arsenic plume (6G1-1).
- Three of the seven MWs identified to have an increasing trend with the Mann-Kendall trend analysis (i.e., 5E1-1, 6D14-1, and 7E8-1) actually had stable dissolved arsenic concentrations after circa 2007 to 2008 (see Section 6.2.2.3). The Mann-Kendall trend analysis for these three MWs was biased by the concentration increases that occurred in these MWs from 2005 to 2007 or 2008 as temporary geochemical conditions from in-situ stabilization were returning to equilibrium conditions.

Key Mann-Kendall trend analysis results for Intermediate Aquifer MWs were:

- No trend in dissolved arsenic concentrations was identified in 75% of the MWs (18 of 24 MWs) and dissolved arsenic concentrations were decreasing in another 21% of MWs (five MWs).
- The only MW with an increasing trend was 6E3-2, which is located downgradient of former Penite Pit #2.

6.2.2.3 Time-Series Plots for All MWs (2005 – 2018 Data)

Time-series plots of post-2004 dissolved arsenic concentrations in all Site MW were evaluated in order to determine whether dissolved arsenic concentrations appeared to be increasing or decreasing between 2005 and 2018 (with emphasis on the period between 2007 and 2018). This comprehensive evaluation was conducted to (1) ensure MWs not included in the Mann-Kendall trend analysis for 2005 to 2017 data were evaluated, and (2) provide a "scorecard" of the visual interpretation of post-2004 time-series plots for all MWs. Time-series plots of all available dissolved arsenic concentrations were prepared for every MW with at least three post-2004 results. The time-series plots for the Upper Aquifer MWs and Intermediate Aquifer MWs satisfying this criterion are shown in Figures 6-11 and 6-12, respectively.[43] A larger version of each time-series plot shown in Figures 6-11 and 6-12 is included in Appendix I.

Key evaluation observations for the Upper Aquifer MWs based on a visual interpretation of the time-series plots were:

- Dissolved arsenic concentrations were stable or decreasing in 87% of the MWs (59 of 68 MWs) between 2005 and 2018 (with emphasis on the period between 2007 and 2018).
- Of the nine MWs that appeared to have increasing concentrations between 2005 and 2018, three were surrounding the former Penite Manufacturing Building (5D7-1R, 5D5-1, and 5E4-1), one was downgradient of the former Penite Manufacturing Building (124+00-1), one was downgradient of former Penite Pit #2 (7E3-1), one was near the northern portion of the former Caustic Manufacturing Area (5C16-1R), one was upgradient of the source area (5E8-1), and two were upgradient of the main arsenic plume (4F1-1 and 6H1-1).

Key evaluation observations for the Intermediate Aquifer MWs based on a visual interpretation of the time-series plots were:

- Dissolved arsenic concentrations were stable or decreasing in 93% of the MWs (43 of 46 MWs) between 2005 and 2018 (with emphasis on the period between 2007 and 2018).
- Three MWs appeared to have increasing concentrations between 2005 and 2018. Of these three MWs, one was downgradient of the former Penite Manufacturing Building (124+00-2), and two were downgradient of former Penite Pit #2 (6E3-2 and 7E16-2).

6.2.2.4 Current Geochemical Conditions

In general, the extent and magnitude of the main arsenic plume are expected to remain stable or decrease based on highly favorable geochemical conditions along the shoreline and favorable geochemical conditions within most of the plume core. As discussed in Sections 5.2.2 and 6.1, geochemical conditions along the shoreline enable the majority of arsenic to be precipitated or co-precipitated with highly stable minerals, and will continue to facilitate co-precipitation with metal oxides (due to the highly oxidizing conditions). In addition, geochemical conditions along the shoreline are ideal for arsenic sorption (i.e., highly oxidizing, neutral pH, high iron oxide concentrations, high conductivity values, and lower competitive anion concentrations). As discussed in Section 5.2.2, geochemical conditions within most of the plume core enable the majority of arsenic in the Upper Aquifer, First Aquitard, and Intermediate Aquifer to be precipitated or co-precipitated with highly stable minerals and/or co-precipitated with metal oxides. In addition, geochemical conditions within much of

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[43] To conserve space, the post-2004 time-series plots for MWs seaward of the SPW and plume core MWs were not included on Figures 6-11 and 6-12 since these plots were presented on previous figures (i.e., Figures 6-1A, 6-1B, 6-3, and 6-4).

the plume core are favorable for sorption (e.g., oxidizing conditions, neutral pH, high iron oxide concentrations, and elevated conductivity values).

The apparent increase in dissolved arsenic concentrations in select MWs (e.g., 5D7-1R, 5E4-1, 5D5-1, 124+00-2, 6E3-2, 7E3-1) within the northern and southern portions of the main arsenic plume are likely associated with less favorable geochemical conditions in these areas. Specifically, elevated pH levels in these areas limit opportunities for sorption and cause reducing conditions (e.g., Eh less than 0 volts) that further hamper sorption and limit co-precipitation with metal oxides. Figure 6-13 presents an interpretation of the current Upper Aquifer areas with pH values greater than or equal to 9 based on recent soil and groundwater pH results.[44] In the northern portion of the main arsenic plume, elevated pH values exceeding 11 are present in the Upper Aquifer near the northern portion of the former Caustic Manufacturing Area. In addition, elevated pH values exceeding 9 extend across almost all of the former Caustic Manufacturing Area. In the southern portion of the main arsenic plume, elevated pH values exceeding 11 are present in the Upper Aquifer across most of the former Taylor Lake Area surface impoundments and extend towards the southern SPW wing. Figure 6-14 presents an interpretation of the current First Aquitard and/or Intermediate Aquifer areas with pH values greater than or equal to 9 based on recent soil and groundwater pH results. Although the magnitude and extent of elevated pH values in the First Aquitard and Intermediate Aquifer are not as extensive as the Upper Aquifer, elevated pH values exceeding 9 are present in the northern and eastern portions of the former Caustic Manufacturing Area, most of the former Taylor Lake Area surface impoundments, and areas downgradient of these surface impoundments. Perhaps most importantly, pH values near 11 are present near the thin or leaky First Aquitard locations downgradient of the former Penite Manufacturing Building.

6.2.3 Plume Stability Evaluation Summary

The weight of evidence presented in Section 6.2.1 clearly demonstrates that the main arsenic plume has declined in terms of both magnitude and extent since the 1980s and early 1990s. Specifically, the remedial actions completed within the plume core between 1990 and 2004 have combined to reduce dissolved arsenic concentrations and shrink the plume between the 1980s/early 1990s and current conditions. The maximum post-2004 dissolved arsenic concentrations in 11 of 16 plume core MWs within the Upper and Intermediate Aquifer are two to three orders of magnitude less than maximum concentrations in the 1980s or early 1990s, and concentrations in another four MWs have decreased by one-half to one order of magnitude. These are significant reductions, especially since concentration reductions of two orders of magnitude in individual MWs is the recommended Interstate Technology & Regulatory Council (ITRC) objective for site closure at complex sites (ITRC 2016). Furthermore, dissolved arsenic concentrations have decreased in 82% of the Upper Aquifer MWs and 73% of the Intermediate Aquifer MWs between 1993 and 2017. Finally, the five Ricker metrics (i.e., maximum concentration,

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[44] Elevated pH values exceeding 9 were historically more widespread across the main arsenic plume prior to the in-situ stabilization activities from 2001 to 2004. For instance, elevated pH values were historically present in the vicinity of the former Penite Manufacturing Building and between former Penite Pit #1 and the SPW.

average concentration, plume mass, plume area, and plume center of mass) all demonstrate that there have been decreases in the main arsenic plume since the 1980s and early 1990s. The maximum and average concentrations in the Upper and Intermediate Aquifers have decreased by more than one order of magnitude between the 1980s or early 1990s and 2017. Likewise, the total plume mass decreased by one order of magnitude between 1993 and 2017, while the total plume area in 2017 was roughly half the size of the 1993 plume area.

When viewed holistically, the weight of evidence presented in Section 6.2.2 indicates that the main arsenic plume has been stable or declining since the last completed remedial action within the plume core was finished in 2004. Although there are a few select MWs with apparent increasing trends between circa 2007 or 2008 and current, dissolved arsenic concentrations in the rest of the MWs have decreased or been stable. All five Ricker metrics indicate the main arsenic plume is stable or declining since circa 2007 or 2008. The Mann-Kendall trend analysis results indicated that dissolved arsenic concentrations have either decreased or not increased (i.e., no trend was identified) in 83% of the Upper Aquifer MWs and 96% of the Intermediate Aquifer MWs between 2005 and 2017. A comprehensive evaluation of time-series plots produced similar results: 87% of Upper Aquifer MWs and 93% of Intermediate Aquifer MWs were stable or declining between circa 2007 or 2008 and 2018. Finally, the extent and magnitude of the main arsenic plume are expected to remain stable or decrease based on highly favorable geochemical conditions along the shoreline and favorable geochemical conditions within most of the plume core.

Nine MWs in either the northern plume lobe emanating from the former Penite Manufacturing Building or the southern plume lobe emanating from former Penite Pit #2 appear to have slightly increasing dissolved arsenic concentrations (see Table 6-1). Potential post-2004 rebound was identified in a total of 16 MWs based on the Mann-Kendall trend analysis of 2005 to 2017 data and/or the evaluation of time-series plots for 2005 to 2018 data. However, three of the 16 MWs are located upgradient of the main arsenic plume (4F1-1, 6G1-1, 6H1-1), three additional MWs (5E1-1, 6D14-1, and 7E8-1) were stable after circa 2007 or 2008, and a seventh MW (5E8-1) is not a concern because the MW is upgradient of the source area and dissolved arsenic concentrations in the MW are relatively low. Thus, the nine relevant MWs with apparent increasing concentrations are 5D7-1R, 5E4-1, 5D5-1, 124+00-2, 124+00-1, and 5C16-1R associated with the northern plume lobe and 6E3-2, 7E3-1, and 7E16-2 associated with the southern plume lobe. Suspected Upper Aquifer source material near the former Penite Manufacturing Building and/or elevated pH and reducing conditions are likely contributing to the apparent increasing trends in 5D7-1R, 5E4-1, 5D5-1, 124+00-2, 124+00-1, and 5C16-1R since circa 2007 or 2008. In addition, the thin or leaky First Aquitard locations upgradient of 124+00-2 likely provide preferential pathways for Upper Aquifer mass to enter the Intermediate Aquifer upgradient of 124+00-2. Upper Aquifer source material near former Penite Pit #2 (e.g., sludge-like material encountered in PTC-102 at 7.5 to 8.5 feet bgs) and/or elevated pH and reducing conditions are likely contributing to the apparent increasing trends in 6E3-2, 7E3-1, and 7E16-2 since circa 2007 or 2008.

6.3 Data Gap #3: Wall Integrity

6.3.1 *Corrosion Engineer Evaluation*

Based on the results of the September 28, 2017 inspection, the corrosion engineer concluded that (1) the SPW, the SPW joints, and the steel plate that was welded to the SPW were in good condition, and (2) the SPW is expected to remain in good condition for multiple decades (see Appendix D).

6.3.2 *KetaWaters Leakage Evaluation*

KetaWaters conducted an evaluation of potential leakage through the SPW joints using existing 1990 and 2004 water level data from MWs near the SPW (see Appendix J). The evaluation of 1990 data involved comparing tidal fluctuations in MWs before and after the SPW was installed in October 1990. The evaluation of 2004 data involved comparing tidal fluctuations in MWs on the seaward and landward sides of the SPW. The evaluation demonstrated that leakage of water through the SPW joints does occur. The hydraulic conductivity through the SPW joints was estimated to be on the order of $8x10^{-4}$ feet/day ($2.8x10^{-7}$ cm/s).[45] The hydraulic conductivity through the SPW was previously assumed to be $1x10^{-20}$ feet/day (Pacific Groundwater Group [PGG] 2004).

6.4 Data Gap #4: Feasibility of Focused Soil Excavation

6.4.1 *Data Gap #4A (Arsenic)*

In order to evaluate the feasibility of different soil excavation scenarios, arsenic soil concentration data from 2017 and 2018 borings was integrated with pre-2017 arsenic soil concentration data. For data visualization purposes, a conceptual cross section along a transect near the center of the plume (e.g., through former Penite Pit #1) was prepared that shows 2017 and 2018 arsenic soil and sediment concentrations relative to pre-2017 arsenic soil concentrations (see Figure 6-15). To date, arsenic soil concentrations exceeding 20,000 mg/kg have been limited to samples collected within and surrounding former Penite Pits #1 and #2. Soil concentrations within former Penite Pit #1 (prior to excavation of this soil in 1990) ranged from 9,600 mg/kg to 150,000 mg/kg. In-place arsenic soil concentrations exceeding 20,000 mg/kg remain in only two samples: 25,000 mg/kg in a PT-33 sample that was just upgradient of former Penite Pit #1, and 165,000 mg/kg in the PTC-102 sample that contained sludge-like material. The arsenic concentrations in these PTC-102 and PT-33 samples are one to two orders of magnitude higher than any other remaining soil concentration at the Site, and are consistent with soil concentrations within the Penite Pits prior to the 1990 and 2003 Penite Pit excavations. Figure 6-15 also displays the relatively widespread presence of arsenic soil concentrations in the 5,000 mg/kg to 10,000 mg/kg range in the top of the First Aquitard. The elevated arsenic concentrations in the top of the First Aquitard typically do not extend to the bottom of the First Aquitard or deeper lithologic units, perhaps due to the fact that most arsenic within the First Aquitard is either precipitated or co-precipitated with highly stable minerals or co-precipitated with metal oxides.

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[45] The individual values calculated in the evaluation ranged from $9x10^{-5}$ feet/day ($3x10^{-8}$ cm/s) to $2x10^{-3}$ feet/day ($7E^{-7}$ cm/s).

6.4.1.1 Evaluation of Potential Soil Excavation Scenarios

The following four scenarios were developed to conduct a preliminary feasibility evaluation of different soil excavation options for elevated arsenic soil concentrations remaining at the Site (excluding the North Boundary Area)[46]:

- Scenario #1: Excavate soil with arsenic concentrations exceeding 88 mg/kg (the PCL) to a depth of 15 feet bgs.
- Scenario #2: Excavate soil with arsenic concentrations exceeding 590 mg/kg to a depth of 15 feet bgs or the top of the 1st Aquitard (whichever occurs first).[47]
- Scenario #3: Excavate soil with arsenic concentrations exceeding 10,000 mg/kg to a depth of 15 feet bgs or the top of the 1st Aquitard (whichever occurs first).
- Scenario #4: Excavate soil with arsenic concentrations exceeding 20,000 mg/kg to a depth of 15 feet bgs or the top of the 1st Aquitard (whichever occurs first).

Conceptual soil excavation areas and volumes were developed for Scenarios #1 through #4 based on arsenic soil concentrations in 2017 and 2018 borings as supported by soil boring data collected from 2001 to 2012 (see Figures 6-16 through 6-19). When determining each conceptual excavation area, the 2017 and 2018 data were given more weight than the 2001 to 2012 data because (1) selection of sample depths in many of the 2001 to 2012 borings was not based on field screening results (e.g., samples were collected at one or more pre-determined depths), and (2) 2017 and 2018 field XRF results demonstrated that there can be variability in arsenic soil concentrations within a given lithologic unit in a given boring. For simplicity, three conceptual areas were developed for each scenario: an area for the 0 to 5 feet bgs depth interval, an area for the 5 to 10 feet bgs depth interval, and an area for the 10 to 15 feet bgs depth interval. Excavation volumes were then calculated by multiplying the size of the applicable conceptual area by the associated excavation depth interval (e.g., five feet) as shown in Table 6-2.

The total estimated arsenic mass associated with each excavation scenario was calculated as shown in Table 6-2. In summary, the average concentration within each conceptual excavation area was calculated based on the actual arsenic soil concentrations in soil samples encompassed within the conceptual excavation area. The estimated arsenic mass was then calculated by multiplying the estimated excavation volume by an assumed soil density (i.e., 1.5 tons per CY) and the average arsenic concentration. The estimated arsenic mass for Scenarios #1 through #4 were 343,000 kg, 145,000 kg, 134,000 kg, and 134,000 kg, respectively. In addition, a mass of 936,000 kg for a baseline scenario (excavating arsenic concentrations exceeding 20 mg/kg to a depth of 15 feet bgs) was calculated using the same methodology.

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[46] The concentration targets used for scenarios are not proposed soil remediation levels. Rather, the concentration targets were selected to provide a range of evaluation results. Soil remediation levels will be proposed in the FS Report as appropriate.

[47] Generally speaking, it would not be prudent to excavate soil from the First Aquitard because that activity would compromise the integrity of this important vertical transport barrier. That said, if a focused soil excavation was conducted at the Site, the very top of the First Aquitard (e.g., top one foot) would likely be scraped to remove some arsenic mass that is concentrated at the top of the First Aquitard. However, for the purposes of this Report, it was assumed no excavation would occur within the First Aquitard for Scenarios #2 through #4.

Based on the estimated volumes and masses for the four excavation scenarios, a very focused excavation of elevated arsenic soil concentrations is expected to be the only practicable soil excavation option that can satisfy the remedy selection criterion (i.e., disproportionate cost analysis) in WAC 173-340-360(2)(b)(i) when the FS Report is prepared. For instance, Scenario #3 or Scenario #4 would remove essentially the same amount of arsenic mass (14%) as Scenario #2 (13%). However, Scenario #3 and Scenario #4 would involve less than 5% of the excavation volume as Scenario #2 (i.e. 1,400 CY versus 32,100 CY). In other words, a focused soil excavation of the highest arsenic soil concentrations would remove nearly as much arsenic mass as larger excavations that attempt to achieve lower remediation levels. In addition, trying to excavate soil to achieve lower remediation levels would likely be ineffective, because arsenic will resorb and re-precipitate onto clean backfill (as witnessed in the PTC-101 and PTC-102 arsenic results for samples collected from backfill material). Thus, a practicable soil excavation scenario would likely entail excavating Upper Aquifer source material in and surrounding former Penite Pits #1 and #2 and the former Penite Manufacturing Area.[48]

6.4.1.2 Potential Dangerous Waste Considerations

If additional soil excavation is a component of the recommended cleanup alternative in the FS Report, key dangerous waste considerations for excavated soil include:

- Based on a comparison of existing paired TCLP arsenic and total arsenic soil concentrations, excavated soil that is designated as a waste and has a total arsenic concentration exceeding approximately 1,000 mg/kg would likely exceed the TCLP arsenic criterion of 5 mg/L (see Chart 6-6). Waste exceeding the TCLP criterion of 5 mg/L would be characterized as a dangerous waste unless the waste could be stabilized so that TCLP arsenic concentrations were less than 5 mg/L.
- Even though the bench test results for ex-situ stabilization with an oxidant (i.e., potassium permanganate) in conjunction with two Enviroblend® products were promising, field applications would likely require some trial and error to get the correct dosing. In addition, it is likely that some percentage of waste could not be treated to pass all TCLP criteria due to the arsenic composition in the waste or TCLP exceedances of other metals (e.g., selenium) due to addition of an oxidant and Enviroblend® products.

6.4.2 Data Gap #4B (pH)

A discrete layer of high pH soil that could be practicably excavated was not encountered in the former Taylor Lake Area surface impoundments or the former Caustic Manufacturing Area. For instance, it was hypothesized in the Work Plan that perhaps a distinct layer of residual sludge (a few feet thick) was still present within the former Taylor Lake Area surface impoundments that was serving as the source for elevated pH. Elevated pH levels in soil are relatively widespread in terms of horizontal and vertical extent. Since focused layers of elevated pH in soil were not encountered with the former Taylor Lake Area surface impoundments or the former Caustic Manufacturing Area, excavation of pH sources in soil is not a practicable remedial action.

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[48] The extent of any soil excavation activities would need to be refined with a pre-design investigation.

SECTION 7: UPDATED CSM FOR THE MAIN ARSENIC PLUME

A summary of the updated CSM for the main arsenic plume (and co-mingled VOCs) is presented in this section. The CSM was updated based on the results of 2017 and 2018 data gap investigation and evaluation activities as well as other insights gained since the Work Plan was prepared in 2017. The CSM includes conceptual site fate and transport elements and a conceptual site exposure model (CSEM). The CSM will be updated as new information is obtained.

7.1 Overview of Sources and Transport

In summary, key source and transport concepts for the main arsenic plume are:

- Former Penite Pits #1 and #2 are known primary sources and the former Penite Manufacturing Building is a suspected primary source for the main arsenic plume.
- The elevated arsenic soil and groundwater concentrations immediately west of the primary sources may be due to (1) dispersion, diffusion, and reverse gradients from tidal fluctuations prior to SPW installation, (2) historical pumping from Upper Aquifer extraction wells and trenches, (3) a preferentially pathway associated with a thin/leaky First Aquitard location southwest of the primary sources, and/or (4) potential secondary sources.
- Transport of arsenic in groundwater from the source area towards the Hylebos Waterway is currently conceptualized as three separate plume lobes emanating from each of the three primary sources that have combined to form a single large arsenic plume. The central plume lobe emanating from former Penite Pit #1 is currently less prominent than the northern and southern lobes because of the success of completed remediation actions within and downgradient of former Penite Pit #1.
- Arsenic in groundwater in the Upper and Intermediate Aquifers near former Penite Pit #1 generally flows due east towards the SPW, while groundwater near former Penite Pit #2 has a slight southeastern flow direction and groundwater near the former Penite Manufacturing Building has a slight northeastern flow direction.
- The SPW causes some lateral spreading of the plume in the Upper Aquifer and increases vertical transport of groundwater from the Upper Aquifer to the Intermediate Aquifer.
- Groundwater leaks through the SPW joints at an estimated hydraulic conductivity on the order of 8×10^{-4} feet/day (2.8×10^{-7} cm/s).[49]
- Two thin/leaky First Aquitard locations upgradient of 124+00-2 on the landward side of the SPW are preferential pathways that likely contribute to elevated dissolved arsenic concentrations at 124+00-2 and two pore water NSDSs downgradient of 124+00-2 (i.e., 123+25-ST1-DS and 125+00-ST1-DS).

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[49] Existing boring logs and groundwater concentrations do not support the existence of a swale underneath the SPW in the vicinity of 125+00-2. The swale concept was previously proposed in 2004, likely in part because the 2004 groundwater model had no other hydraulic mechanism to transport water from the plume core to the shoreline since the assumed hydraulic conductivity through the SPW was assumed to be 1×10^{-20} feet/day (PGG 2004).

- Arsenic transport is affected by three geochemical attenuation mechanisms (see Section 7.2). Two of the three geochemical attenuation mechanisms can be affected by area-specific geochemical conditions (see Section 7.3).

7.2 Key Arsenic Attenuation Mechanisms

Several key attenuation mechanisms are causing a stable or declining main arsenic plume and mitigating arsenic migration to the Hylebos Waterway. Key attenuation mechanisms for the main arsenic plume include:

- The three geochemical attenuation mechanisms: (1) precipitation or co-precipitation with recalcitrant and highly stable minerals, (2) co-precipitation with metal oxides (e.g., iron oxides), and (3) sorption. The majority of arsenic within the main arsenic plume is either precipitated or co-precipitated with highly stable minerals or co-precipitated with metal oxides. Co-precipitation with metal oxides and sorption can be affected by geochemical conditions. Conceptual geochemical zones at the Site are presented in Section 7.3.
- The mixing of surface water within groundwater in the hyporheic transition zone along the Site shoreline causes hydraulic tidal dispersion. In other words, the proportion of fresh upland groundwater within the total amount of water discharged over time at the groundwater/surface water interface is relatively small. As a result, the arsenic concentrations at the groundwater/surface water interface are lower than arsenic concentrations just upgradient of the transition zone. A recent literature review of field studies for tidally-influenced areas around the world indicated that fresh groundwater typically only accounts for 1% - 20% of the total water discharged to surface water (McKeon 2016). The remaining 80% - 99% of the water discharged to surface water is re-circulated surface water. The results from this literature review are consistent with the results from a previous site-specific evaluation, which concluded that surface water accounts for approximately 80% - 99% of the water in the Angled Shoreline MWs (DOF 2013). Although much of the water in the hyporheic transition zone originated from surface water, WAC 173-340-200 defines groundwater as “water in a saturated zone or stratum beneath the surface of land or below a surface water.”
- As elevated pH in the northern and southern portions of the main arsenic plume mixes with the neutral pH in marine surface water, the decrease of the elevated groundwater pH to a more neutral range causes silicon and magnesium minerals (which were initially solubilized by the elevated pH landward of the SPW) to re-precipitate and form a cemented layer along the shoreline (Intera 1995). This cementation decreases the aquifer permeability and likely increases arsenic sorption. Although the 2003 to 2005 CB/NT sediment dredging project removed some of the obvious shoreline cementation, the same geochemical conditions will create more cementation over time.
- Completed remedial actions (i.e., soil excavations and operation of the arsenic P&T system) have removed arsenic mass from the main arsenic plume.
- The engineered intertidal and subtidal caps enhance attenuation along the shoreline by providing sorption surfaces and enhancing marine surface water mixing within the transition zone, which increases hydraulic tidal dispersion and produces more favorable geochemical conditions.
- Diffusion, dispersion, and aquifer recharge help attenuate arsenic throughout the plume.

7.3 Geochemical Zones for Co-precipitation with Metal Oxides and Sorption

Based on observed geochemical conditions at the Site, conceptual geochemical zones for co-precipitation with metals oxides and sorption were developed for the Upper Aquifer and Intermediate Aquifer (see Figures 7-1 and 7-2). The geochemical zones do not include precipitation or co-precipitation with highly stable minerals because (1) arsenic is precipitated or co-precipitated with highly stable minerals across the entire Site, and (2) highly stable minerals are not environmentally available for transport under current and anticipated future geochemical conditions at the Site. Geochemical zones for co-precipitation with metals oxides and sorption were determined based on Eh, pH, iron oxide concentrations, conductivity values, and relative concentrations of competitive anions. Three types of conceptual geochemical zones were identified in both the Upper Aquifer and Intermediate Aquifer:

- Zone 1: Highly favorable for co-precipitation with metal oxides and sorption. Zone 1 is present near the shoreline in both aquifers. Zone 1 is generally characterized by highly oxidizing conditions (e.g., Eh greater than 0.2 V), neutral pH (e.g., between 6 and 8), high iron oxide concentrations (e.g., greater than 1,000 mg/kg), high conductivity values (e.g., greater than 15,000 uS/cm), and lower competitive anion concentrations.
- Zone 2: Favorable for co-precipitation with metal oxides and sorption. Zone 2 is present in both aquifers across most of the plume core in the center portion of the main arsenic plume. Zone 2 is generally characterized by oxidizing conditions (e.g., Eh greater than 0 V), neutral pH (e.g., between 6 and 8), high iron oxide concentrations (e.g., greater than 1,000 mg/kg), and conductivity values between 1,000 and 15,000 uS/cm.
- Zone 3: Least favorable for co-precipitation with metal oxides and sorption. Zone 3 is present in the northern and southern portions of the main arsenic plume in both aquifers. Zone 3 is generally characterized by elevated pH levels (e.g., pH greater than 9) that limit opportunities for sorption and cause reducing conditions (e.g., Eh less than 0 volts) that further hamper sorption and limit co-precipitation with metal oxides. In addition, higher competitive anion concentrations are present within portions of Zone 3.

7.4 Conceptual Site Exposure Model

The CSEM is a framework for understanding potential site exposures/risks based on current and planned future land use. For the purposes of the FS, potential current/future exposures/risks are included in the CSEM for the following scenarios:

- Baseline Case: This scenario assesses exposures/risks assuming that no further action (e.g., additional remediation, engineering controls, and/or institutional controls) will be implemented at the Site, even though that is not a realistic scenario. The baseline case is not based on current conditions, but rather is used to determine the pathways of potential concern and compare risk reductions achieved by the post-remediation and post-redevelopment scenario.
- Post-Remediation and Post-Redevelopment: This scenario assesses exposures/risks assuming that further action (e.g., additional remediation, engineering controls, and/or institutional controls) will be implemented at the Site. In other words, this scenario is based on an evaluation of the risks at the Site after remediation and redevelopment have occurred. Variations of this scenario may be evaluated in the FS Report based on the nature of the cleanup alternatives evaluated.

- Off-Site: This scenario assesses exposures/risks to receptors that are located off-site and may be exposed to COPCs in media that have migrated off-site. For this Site, the only potential off-site receptors are aquatic organisms and recreators/fishers located in the Hylebos Waterway.

The fundamental assumption for the Baseline Case and Post-Remediation and Post-Redevelopment scenarios is that the future land use at the Site will be Port maritime industrial use. As such, the potentially exposed populations (i.e., exposure scenarios) applicable to the Site are the same for both scenarios (see Figure 7-3):

- Commercial/Industrial Workers: This exposure scenario assumes that workers will be on the Site regularly (e.g., 250 days per year). It is assumed that these workers do not perform intrusive soil activities.
- Utility Workers: This exposure scenario assumes that utility workers may perform outdoor, intermittent, occasional intrusive soil activities intermittently at the Site (e.g., 14 days per year).
- Trespassers: This exposure scenario assumes that trespassers may be outdoors on the Site, intermittently (e.g., 14 days per year).
- Terrestrial Organisms: This exposure scenario is included in Figure 7-3 for completeness with MTCA requirements to evaluate potential terrestrial ecological exposures. However, the Site is excluded from a terrestrial ecological evaluation in accordance with WAC 173-340-7491(1)(b) because the Site was previously developed for industrial use and it will be redeveloped in the future for Port maritime industrial use (e.g., grading activities and installation of a cap/cover, construction of buildings and industrial operational areas). In other words, this exposure scenario is incomplete due to a lack of terrestrial ecological habitat. Thus, this exposure pathway is not discussed further in the CSEM.

While the exposed populations are identical for the Baseline Case and the Post-Remediation and Post-Redevelopment scenarios, the complete exposure pathways are different. A complete exposure pathway consists of the following four elements:

1. A source that released a COPC to the environment (e.g., a spill).
2. An environmental transport mechanism for the released COPC (e.g., soil, runoff, groundwater flow).
3. An exposure point (i.e., a point of potential receptor contact with the contaminated exposure medium) that includes a location where receptors are present and where this is activity that results in exposure (referred to as an exposure scenario).
4. An exposure route at the exposure point (i.e., ingestion, dermal contact, and/or inhalation).

If any one of these four elements is not present, then the pathway is considered incomplete, and there is no exposure and no risk associated with this pathway.

The only complete exposure pathways at the Site are (see Figure 7-3):

- Incidental ingestion, dermal contact, and inhalation of particulates from surface soil by commercial/industrial workers, utility workers, and trespassers in the baseline case.
- Incidental ingestion, dermal contact, and inhalation of particulates from subsurface soil by utility workers in the baseline case.
- Ingestion and dermal contact with surface water and sediment by aquatic organisms in the Hylebos Waterway.

- Consumption of seafood by aquatic organisms in the Hylebos Waterway.
- Consumption of seafood by recreators/fishers in the Hylebos Waterway.
- Incidental ingestion and dermal contact with surface water and sediment by recreators/fishers in the Hylebos Waterway.

The potentially complete exposure pathways for the Site are (see Figure 7-3):

- Incidental ingestion, dermal contact, and inhalation of particulates from surface soil by commercial/industrial workers, utility workers, and trespassers in the post-remediation and post-redevelopment scenario.
- Incidental ingestion, dermal contact, and inhalation of particulates from subsurface soil by utility workers in the post-remediation and post-redevelopment scenario.
- Inhalation of indoor air vapors by commercial/industrial workers for both the baseline case and post-remediation and post-redevelopment scenarios if an occupied building is constructed without vapor intrusion mitigation systems in the few isolated areas that have VOCs.
- Dermal contact with subsurface groundwater by utility workers in the baseline case and post-remediation and post-redevelopment scenarios.

Potentially-complete pathways associated with the post-remediation and post-redevelopment scenario may or may not be complete under future land use. The completeness of the exposure pathways ultimately depends on the cleanup alternatives (i.e., the combination of additional remediation, engineering controls, and institutional controls) that are selected for the Site. For example, if the selected remedy for the Site is to implement a soil cap/cover with engineering and institutional controls to address potential subsurface excavations, then the incidental ingestion, dermal contact, and inhalation of particulates pathways would be incomplete for all receptors because there would be no point of contact (i.e., exposure point) for the receptors with contaminated soil.

The following pathways are incomplete for the following reasons:

- Ingestion of groundwater is an incomplete pathway for all receptors because groundwater is not used for drinking water at the Site.
- Dermal contact with groundwater is an incomplete pathway for commercial/industrial workers and trespassers because groundwater is not used for drinking water and commercial/industrial workers and trespassers will not have access to groundwater at the Site.
- Indoor air inhalation of vapors is an incomplete pathway for utility workers and trespassers because they are assumed to be outdoors.

7.5 Summary of the Conceptual Site Model

A summary of the key conceptual fate and transport elements and the key complete and potentially complete exposure pathways in the CSEM is presented in Figure 7-4.

Key conceptual fate and transport elements are:

- Former Penite Pits #1 and #2 are known primary sources and sludge-like material remains in former Penite Pit #2.
- The former Penite Manufacturing Building is a suspected primary source based on the nature of historical Penite manufacturing operations, evaluation results presented in this Report, and recent groundwater modeling results.

- Completed remedial actions (i.e., soil excavations and operation of the arsenic P&T system) have removed arsenic mass from the main arsenic plume.
- The majority of arsenic within the main arsenic plume is either precipitated or co-precipitated with highly stable minerals or co-precipitated with metal oxides.
- Elevated pH levels within the northern and southern portions of the main arsenic plume limit opportunities for sorption and cause reducing conditions (e.g., Eh less than 0 volts) that further hamper sorption and limit co-precipitation with metal oxides.
- Two thin/leaky First Aquitard locations upgradient of 124+00-2 on the landward side of the SPW are preferential pathways that likely contribute to elevated dissolved arsenic concentrations at 124+00-2 and two pore water NSDSs downgradient of 124+00-2.
- The main arsenic plume is stable or declining due to completed remedial action and ongoing natural attenuation processes.
- The SPW, intertidal cap, and subtidal cap help attenuate arsenic concentrations in groundwater prior to discharge to surface water.
- Highly favorable geochemical conditions for arsenic attenuation are present near the shoreline due to mixing of marine surface water with groundwater.
- The mixing of surface water within groundwater in the transition zone along the Site shoreline causes hydraulic tidal dispersion.

The key complete and potentially complete exposure pathways are[50]:

- Ingestion and dermal contact with surface water and sediment by aquatic organisms
- Consumption of seafood by aquatic organisms
- Incidental ingestion and dermal contact with surface water and sediment by recreators/fishers
- Consumption of seafood by recreators/fishers
- Incidental ingestion, dermal contact, and inhalation of particulates from surface soil by on-site workers and trespassers
- Incidental ingestion, dermal contact, and inhalation of particulates from subsurface soil by utility workers
- Inhalation of indoor air vapors by on-site workers if an occupied building is constructed without vapor intrusion mitigation systems in the few isolated areas that have VOCs

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[50] Just because a pathway is complete or potentially complete does not mean that the pathway poses an unacceptable risk. The significance of the complete and potentially complete pathways will be evaluated in the FS Report.

SECTION 8: CONCLUSIONS

Key conclusions from the investigation and evaluation activities documented in this Report are:

- Dissolved arsenic concentrations in the surface water samples that were collected as close as technically possible to where groundwater flows into surface water were less than 5 ug/L.
- Dissolved arsenic concentrations in all pore water NSDSs were less than the MTCA screening level for protection of aquatic organisms (36 ug/L), with the exception of one Upper Aquifer location and two Intermediate Aquifer locations.
- Dissolved arsenic concentrations entering the shoreline area near the SPW have likely decreased by at least two orders of magnitude between 1989 and 2017.
- Overall, dissolved arsenic concentrations within the main arsenic plume have declined by at least one order of magnitude since the 1980s and early 1990s.
- Overall, dissolved arsenic concentrations within the main arsenic plume have been stable or declining since circa 2007 or 2008.
- Dissolved arsenic concentrations in nine MWs within the main arsenic plume appear to be increasing slightly since circa 2007 or 2008. Remaining Upper Aquifer source material (e.g., sludge-like material encountered in PTC-102) and elevated pH and reducing conditions are likely contributing to the apparent increasing trends in these nine MWs.
- Highly favorable geochemical conditions along the shoreline enable the majority of arsenic to be precipitated or co-precipitated with highly stable minerals, and will continue to facilitate co-precipitation with metal oxides and sorption.
- Precipitation or co-precipitation of arsenic with highly stable minerals is occurring within the plume core. In addition, geochemical conditions within most of the plume core are favorable for co-precipitation of arsenic with metal oxides and sorption of arsenic. However, the northern and southern portions of the main arsenic plume are less favorable for co-precipitation of arsenic with metal oxides and sorption of arsenic due to elevated pH levels and reducing conditions.
- The SPW, the SPW joints, and a steel plate that was welded to the SPW are in good condition, and the SPW is expected to remain in good condition for multiple decades.
- The hydraulic conductivity through the SPW joints was estimated to be on the order of $8\text{x}10^{-4}$ feet/day ($2.8\text{x}10^{-7}$ cm/s).
- Upper Aquifer source material is present in former Penite Pit #2, and is suspected to be present in the vicinity of the former Penite Manufacturing Building.
- A focused excavation of elevated arsenic soil concentrations (e.g., greater than 20,000 mg/kg) within the source area would remove similar amounts of arsenic mass as more aggressive excavation options. A focused source area excavation is expected to be the only practicable soil excavation option that can satisfy the remedy selection criterion (i.e., disproportionate cost analysis) in WAC 173-340-360(2)(b)(i) when the FS Report is prepared.
- If soil is excavated, designated as a waste, and has a total arsenic concentration exceeding approximately 1,000 mg/kg, the waste would likely exceed the TCLP arsenic criterion of 5 mg/L. Although bench test results for ex-situ stabilization with potassium permanganate in conjunction with two Enviroblend® products were promising for any excavated soil waste, it is likely that some percentage of the waste could not be treated to pass all TCLP criteria.

- A focused soil excavation for elevated pH is not practicable due to the lack of a defined source and the widespread extent of elevated pH in soil.
- The CSM for the main arsenic plume has been updated to account for new insights gained during the investigation and evaluation activities.
- The FS data gaps have been adequately filled and the FS Report can be initiated as soon as groundwater models that can predict future arsenic concentrations at various potential POCs are ready for use.

SECTION 9: REFERENCES

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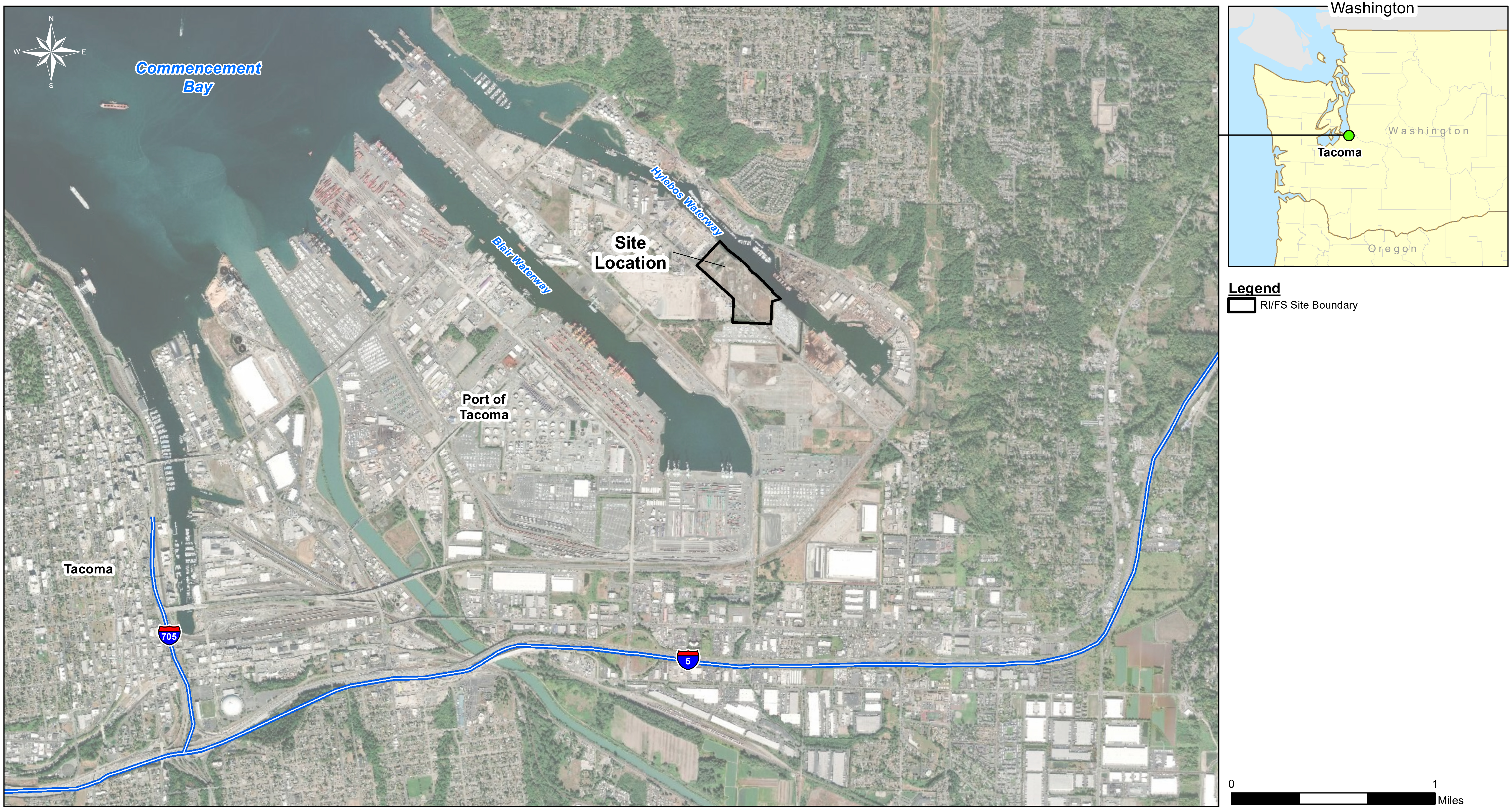
Figures



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Vicinity Map
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 1-1

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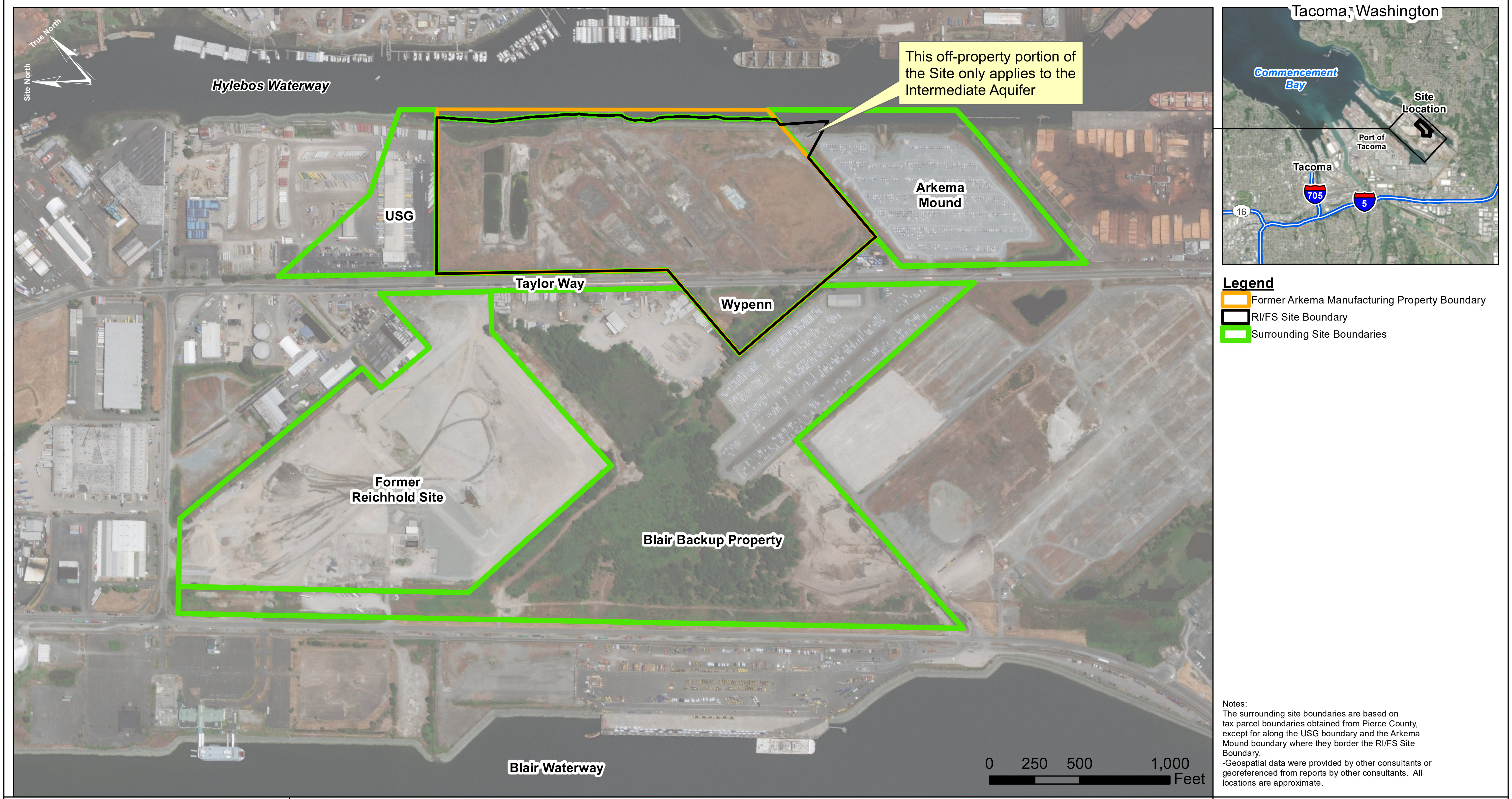

Legend

- 🟧 Former Arkema Manufacturing Property Boundary
- ⬛ RI/FS Site Boundary
- 🟩 Surrounding Site Boundaries

Notes:
The surrounding site boundaries are based on tax parcel boundaries obtained from Pierce County, except for along the USG boundary and the Arkema Mound boundary where they border the RI/FS Site Boundary.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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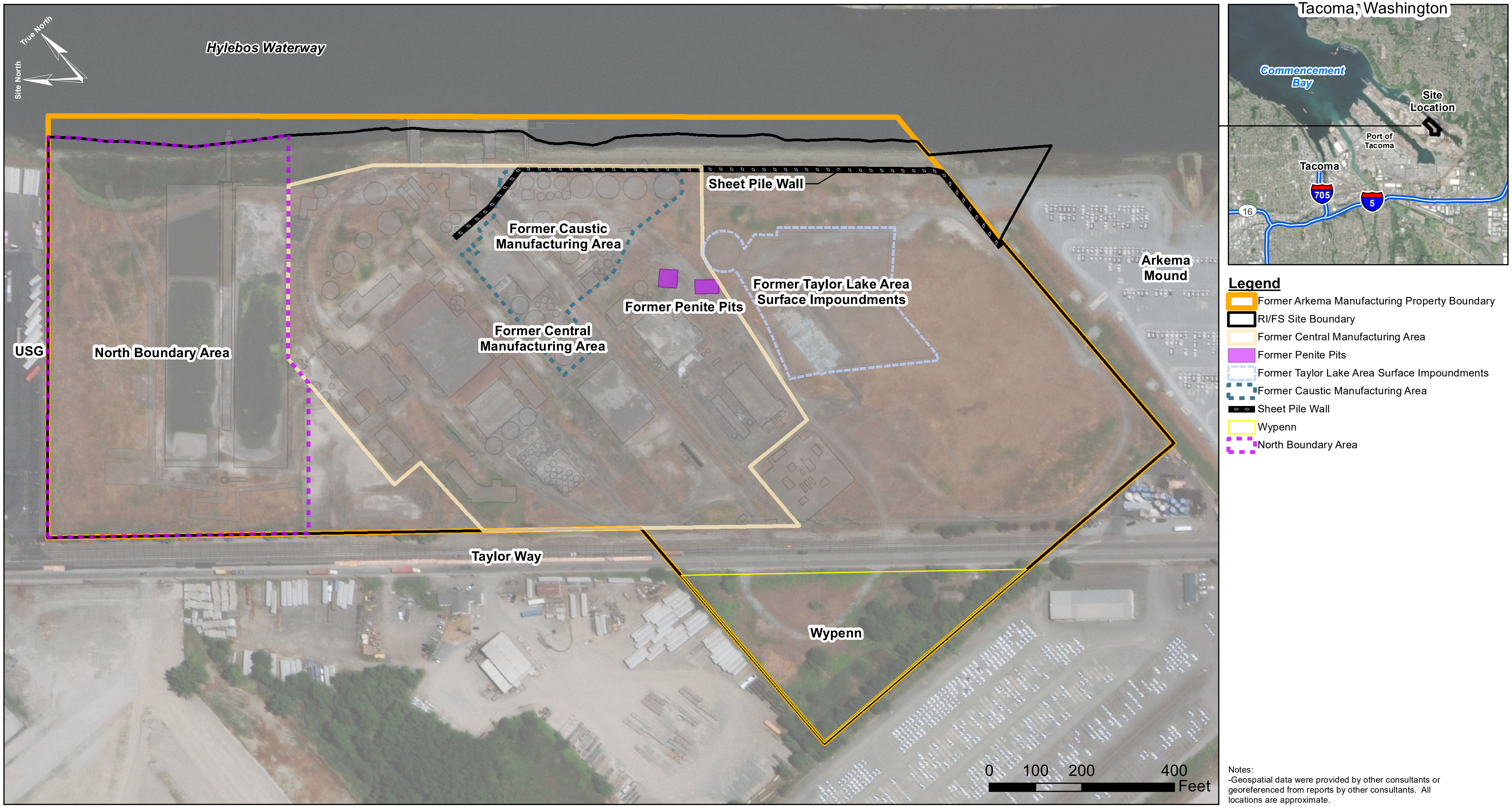
Site Location
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 1-2

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\1-2_Site Location.mxd; Author: VN; Date Saved: 2/21/2019



Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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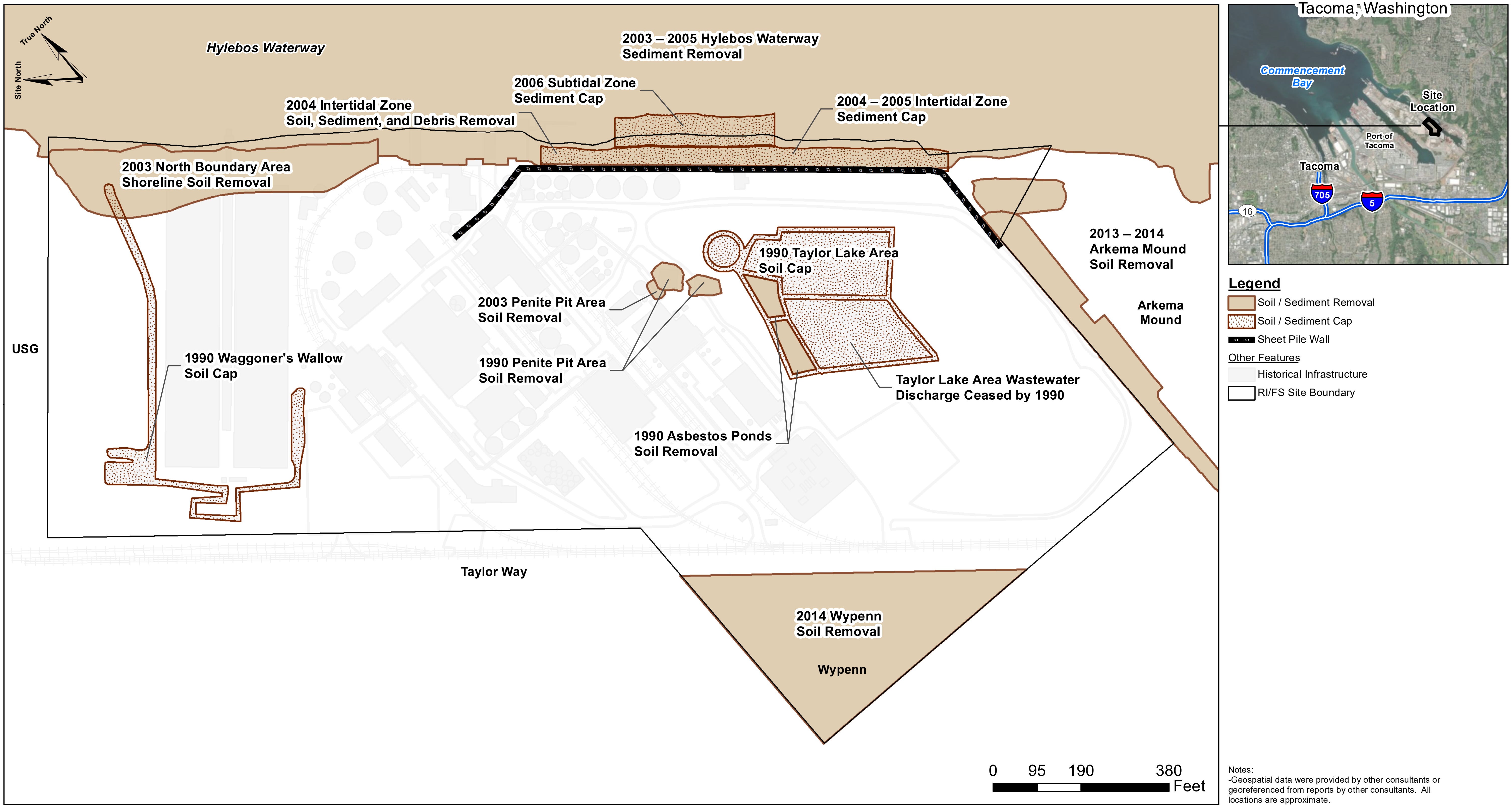
Site Areas
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 1-3



Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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Completed Remedial Actions – Part A
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 2-1A

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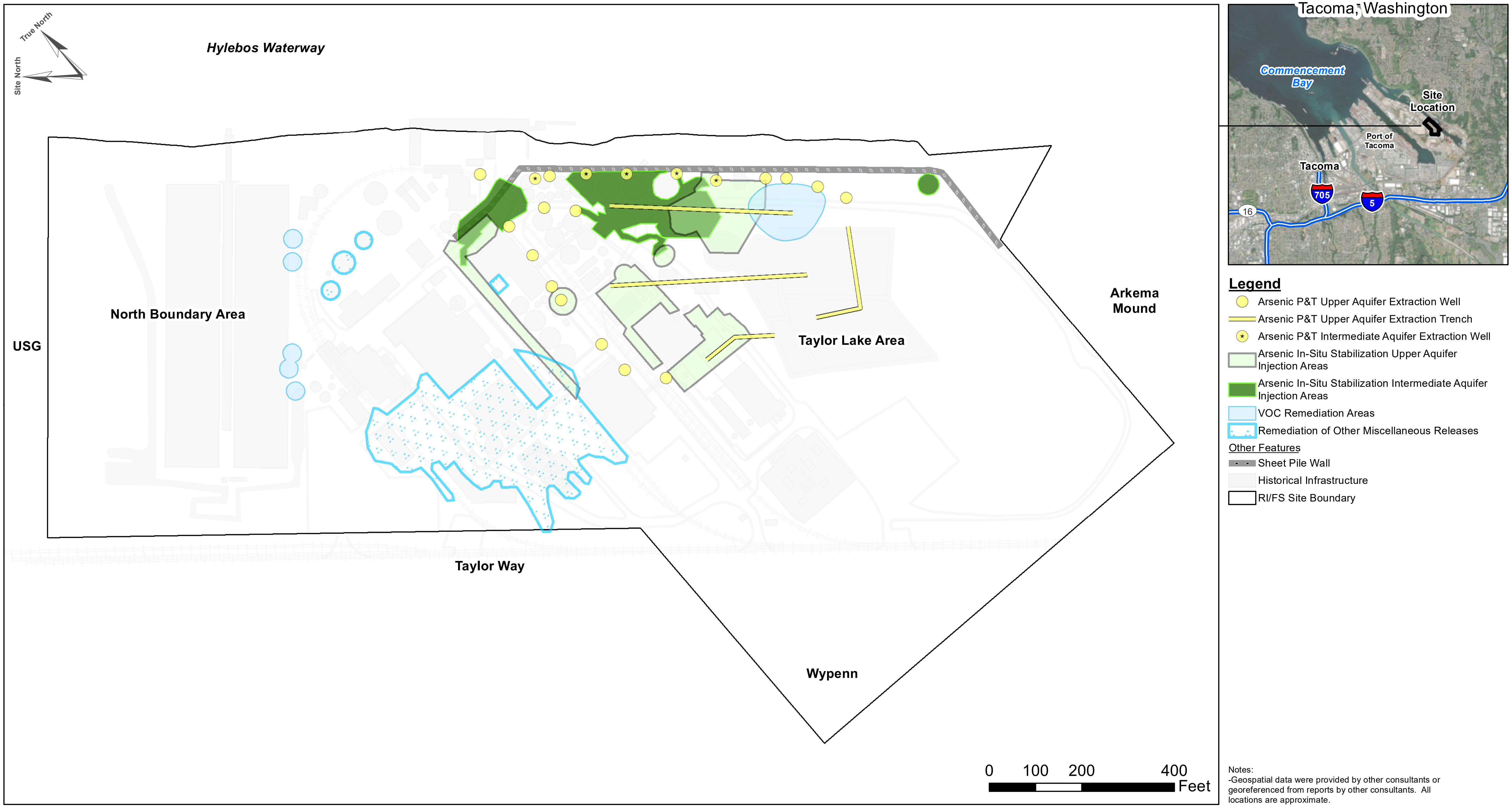

Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

PIONEER
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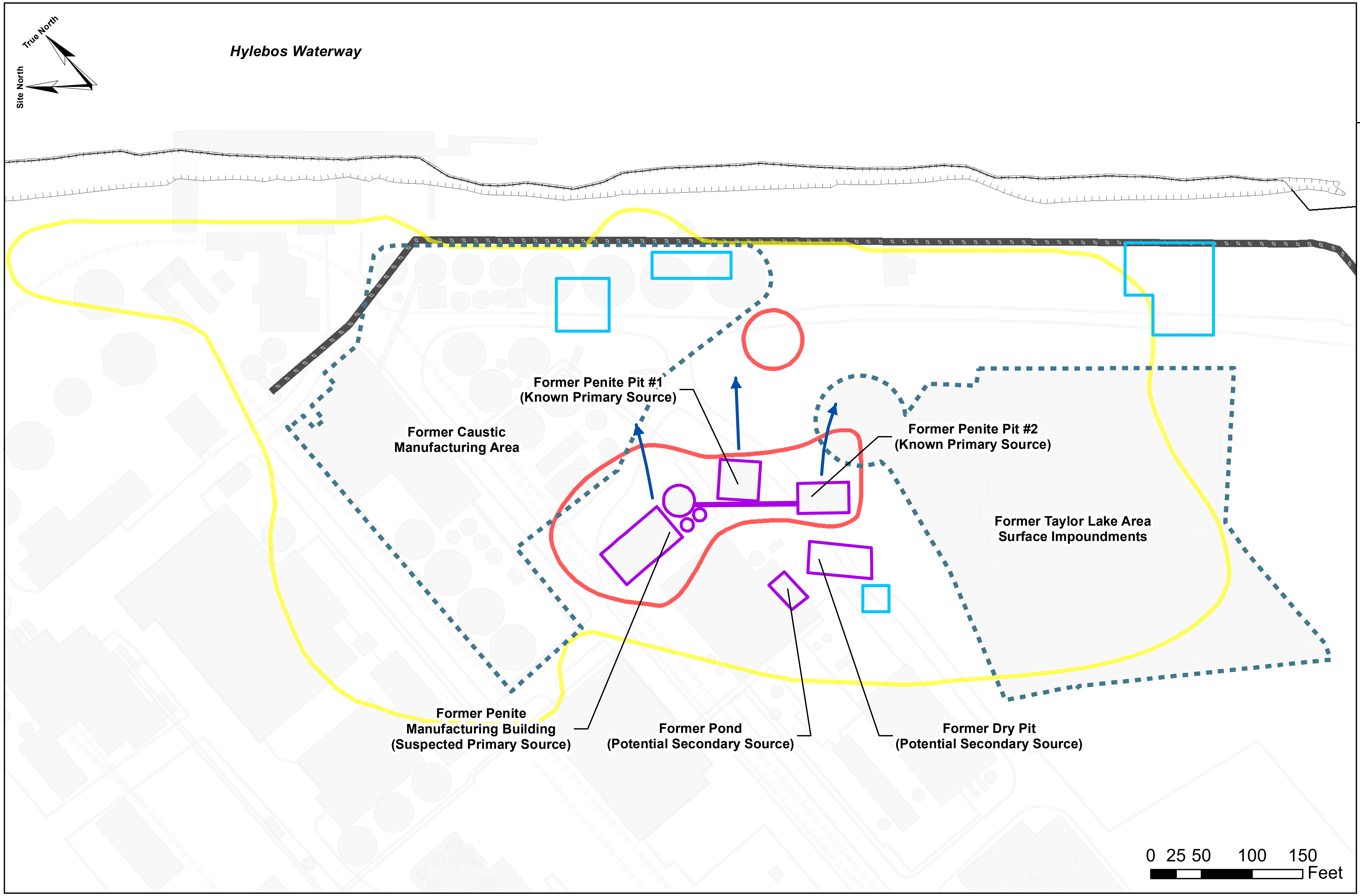
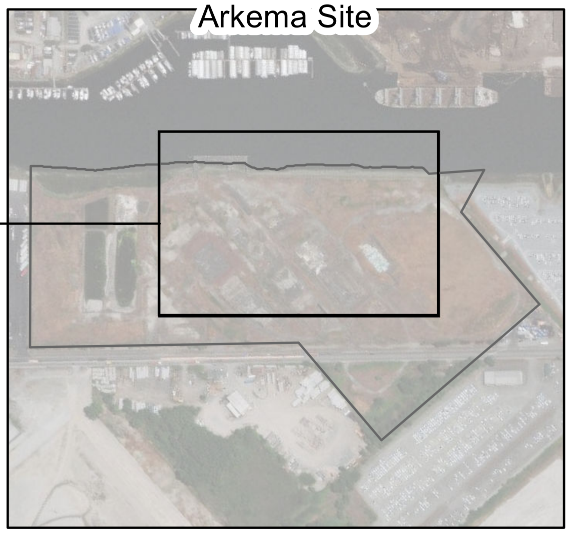
Completed Remedial Actions – Part B
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 2-1B





Legend

- ▭ Known and Potential Penite Manufacturing Features
- ┅ Historical Manufacturing Operation Potentially Associated With Elevated pH
- ▭ Thin or Leaky First Aquitard Location (Intera 1995)
- → Conceptual Current Groundwater Flow Direction East of the Source Area

2017 Upper Aquifer Dissolved Arsenic Groundwater Isoconcentration Contours[1]

- — 500 ug/L
- — 50,000 ug/L

Other Features

- ▭ Historical Infrastructure
- ▭ Intermediate Aquifer Outcrop
- ▭ RI/FS Site Boundary
- ▬ Sheet Pile Wall

Notes:
[1]The contours will most likely be revised in the future based on insights gained during ongoing calibration/verification of the groundwater models.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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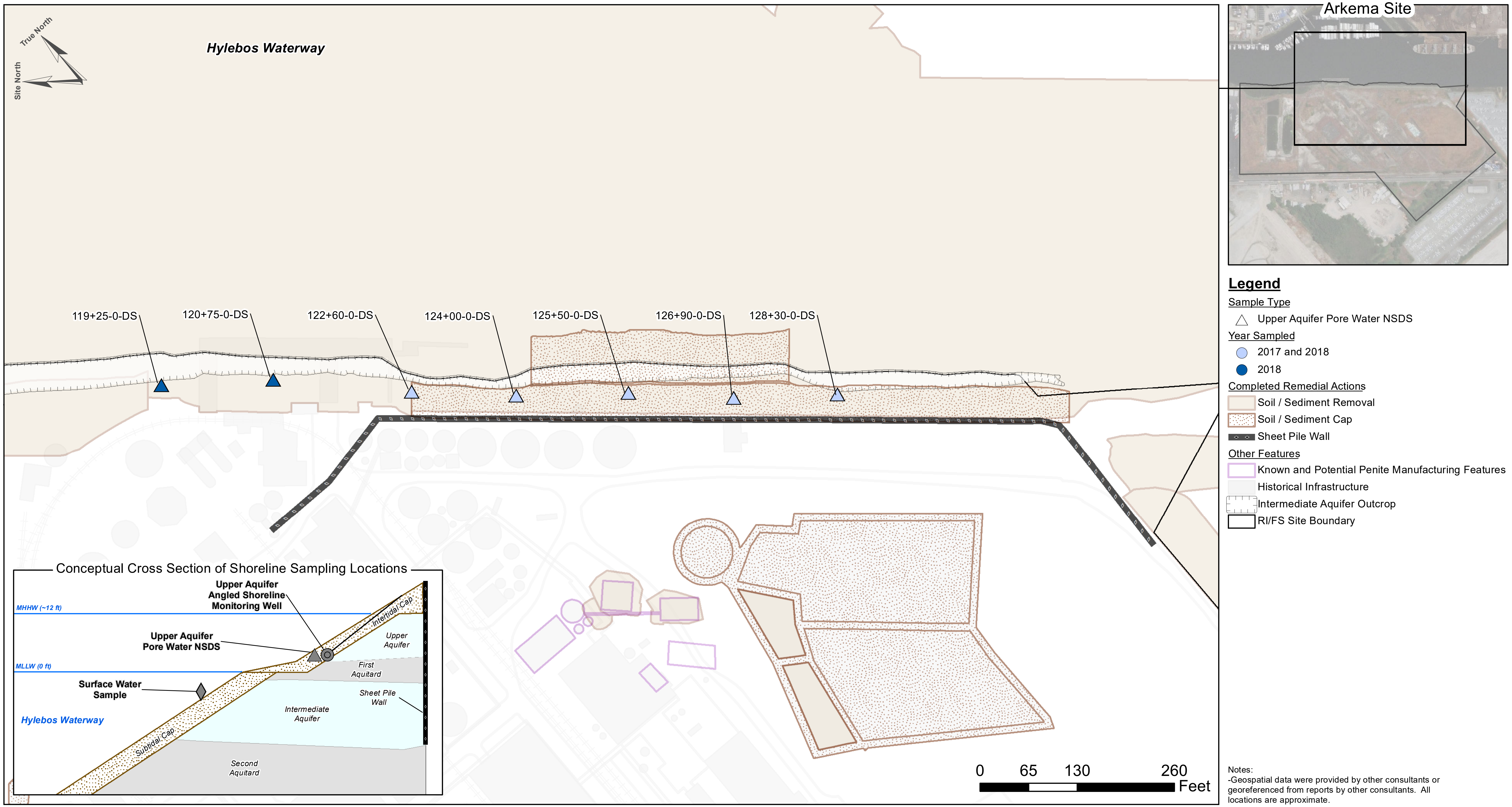
Key Features Related to Arsenic Plume Transport
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 2-2



Legend

Sample Type

△ Upper Aquifer Pore Water NSDS

Year Sampled

● 2017 and 2018

● 2018

Completed Remedial Actions

▭ Soil / Sediment Removal

▨ Soil / Sediment Cap

▬ Sheet Pile Wall

Other Features

▭ Known and Potential Penite Manufacturing Features

▭ Historical Infrastructure

▭ Intermediate Aquifer Outcrop

▭ RI/FS Site Boundary

Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

PIONEER
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Investigation Locations for Data Gap #1A
Shoreline Concentrations (Upper Aquifer Pore Water NSDSs)
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 4-1A

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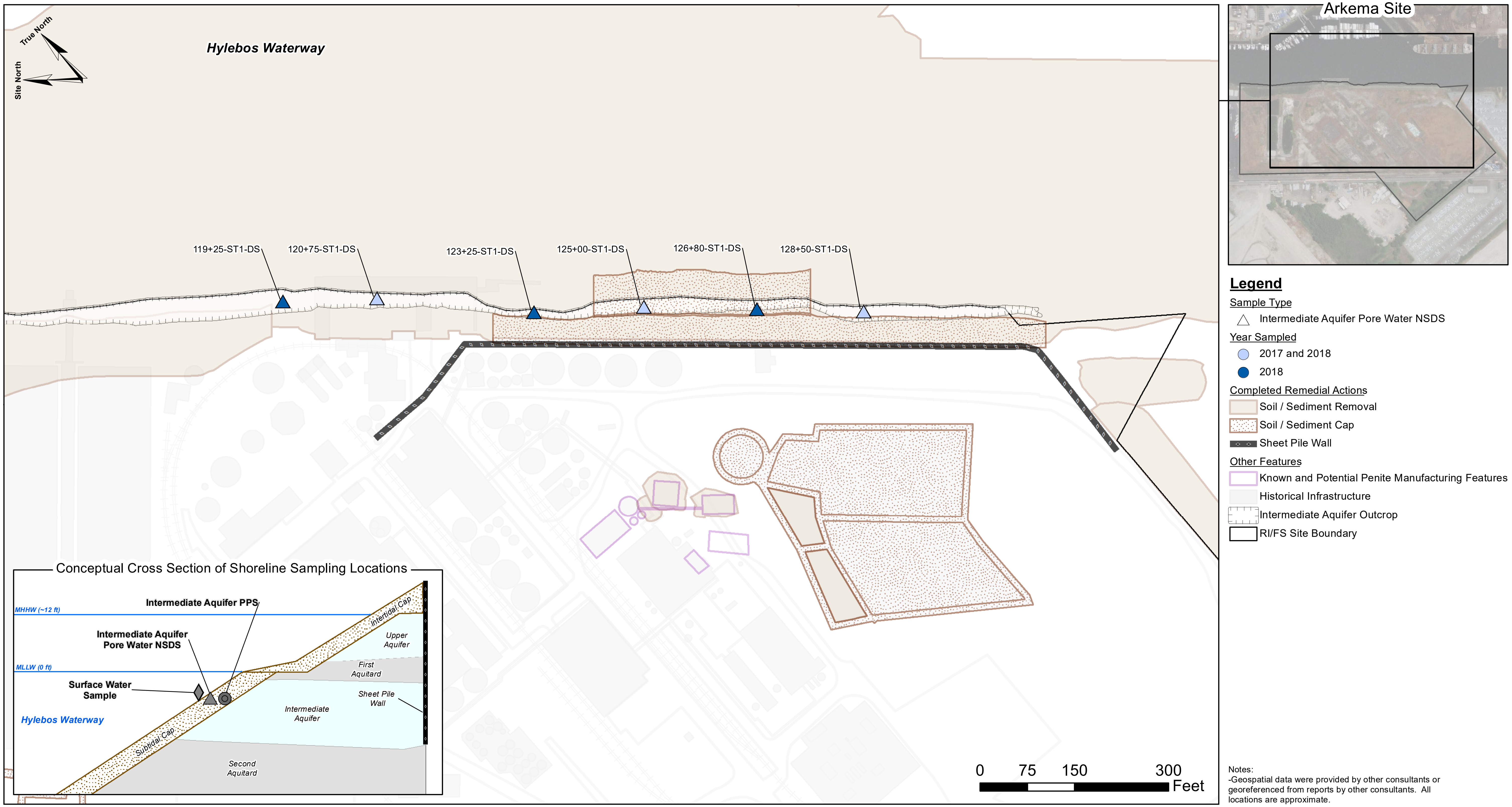

Legend

Sample Type

- △ Intermediate Aquifer Pore Water NSDS

Year Sampled

- ● 2017 and 2018
- ● 2018

Completed Remedial Actions

- ▨ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- ▬ Sheet Pile Wall

Other Features

- ☐ Known and Potential Penite Manufacturing Features
- ▨ Historical Infrastructure
- ☐ Intermediate Aquifer Outcrop
- ☐ RI/FS Site Boundary

Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

PIONEER
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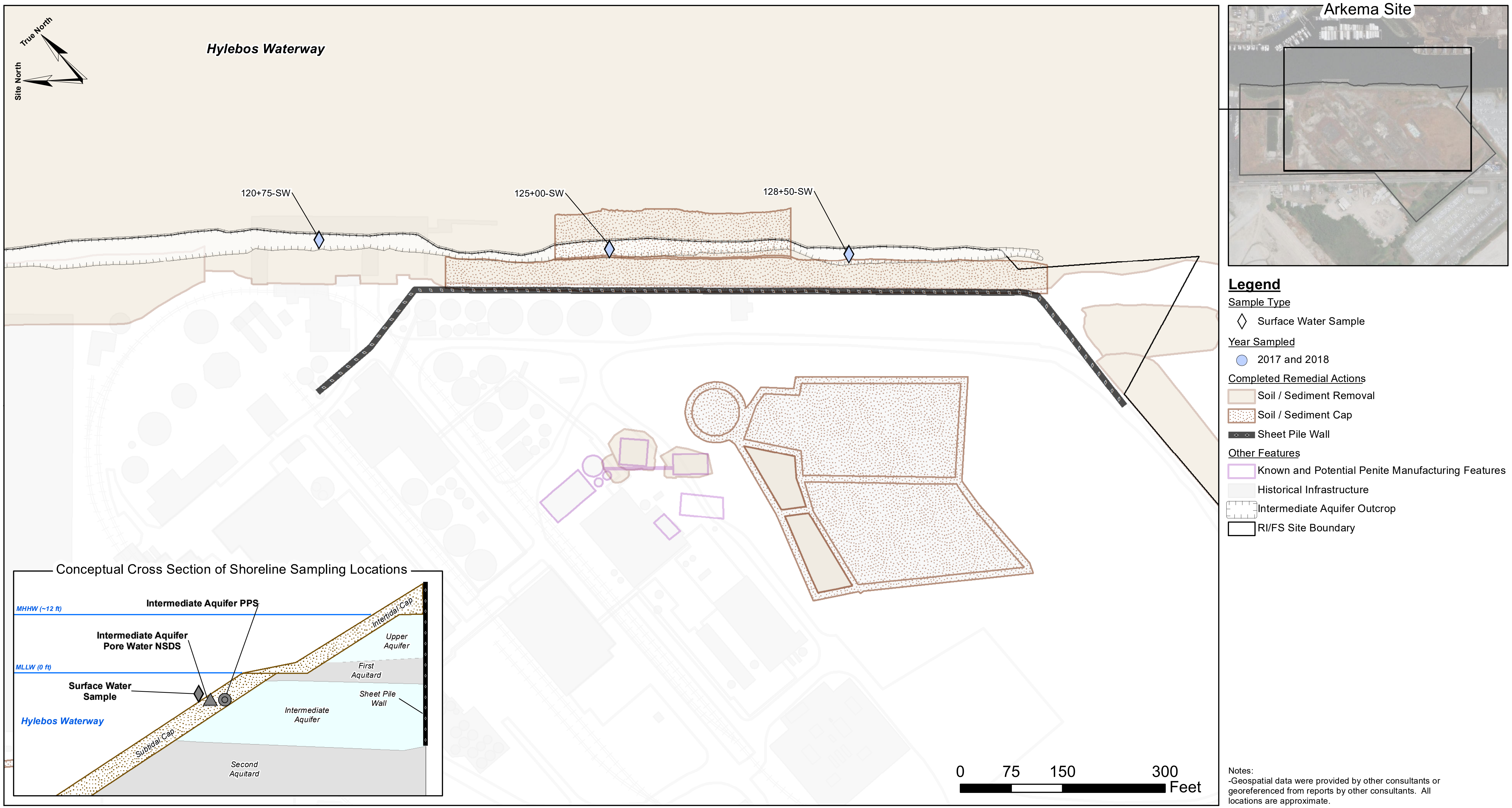
Investigation Locations for Data Gap #1B
Shoreline Concentrations (Intermediate Aquifer Pore Water NSDSs)
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 4-1B

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\4-1B_IA_PW_Locations_DG#1B.mxd; Author: VN; Date Saved: 7/19/2019



Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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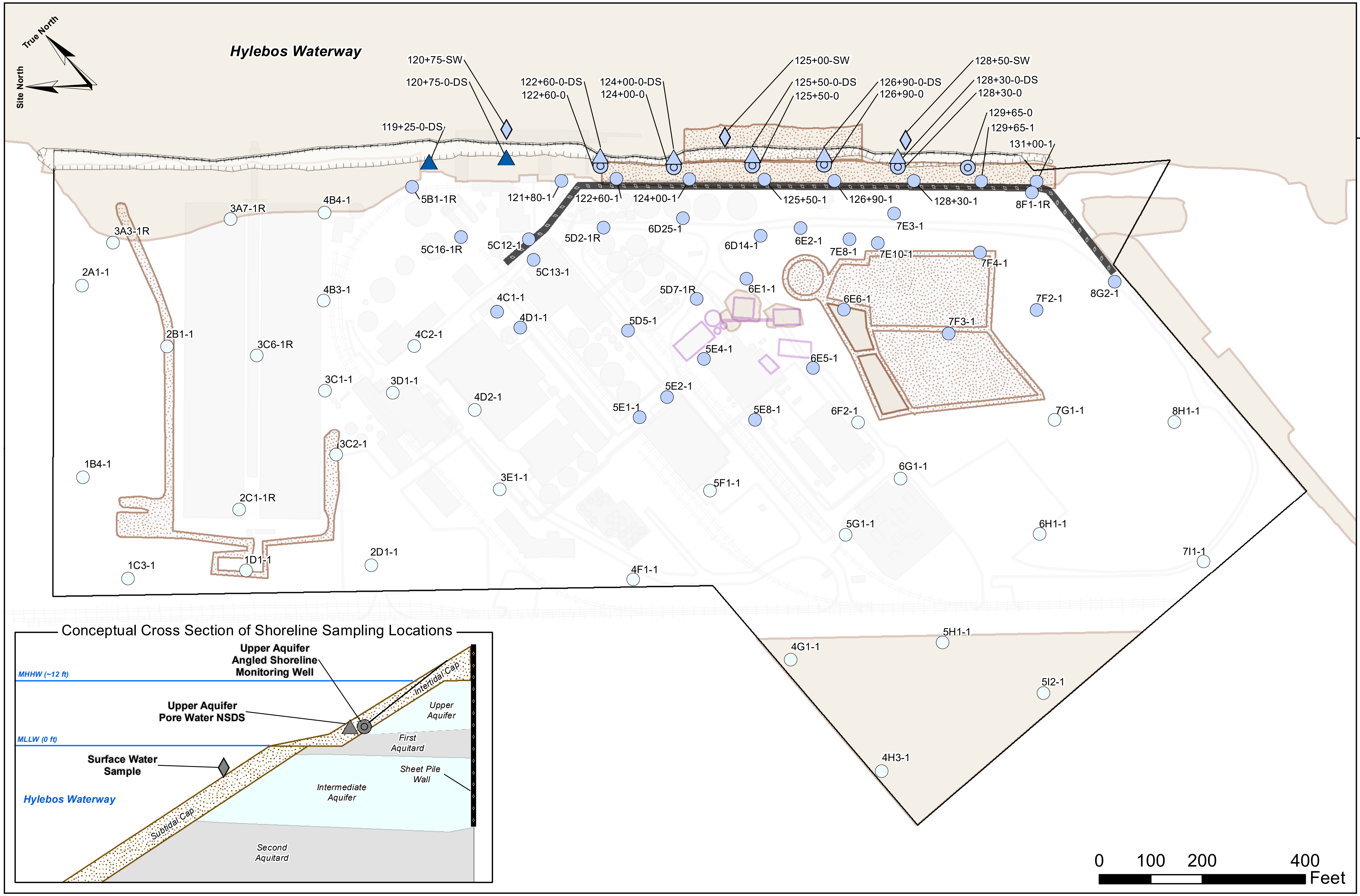
Investigation Locations for Data Gap #1C
Shoreline Concentrations (Surface Water Samples)
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 4-1C

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\4-1C_SW_Locations_DG#1C.mxd; Author: VN; Date Saved: 7/22/2019



Legend

Sample Type
- ○ Monitoring Well
- ◎ Upper Aquifer Angled Shoreline Monitoring Well
- △ Upper Aquifer Pore Water NSDS
- ◇ Surface Water Sample

Year Sampled
- ○ 2017
- ● 2017 and 2018
- ● 2018

Completed Remedial Actions
- ▭ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- ▬ Sheet Pile Wall

Other Features
- ▭ Known and Potential Penite Manufacturing Features
- ▭ Historical Infrastructure
- ▭ Intermediate Aquifer Outcrop
- ▭ RI/FS Site Boundary

Notes:
- Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.

PIONEER
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Investigation Locations for Data Gap #2A
Arsenic Plume Stability (Upper Aquifer)
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 4-2A

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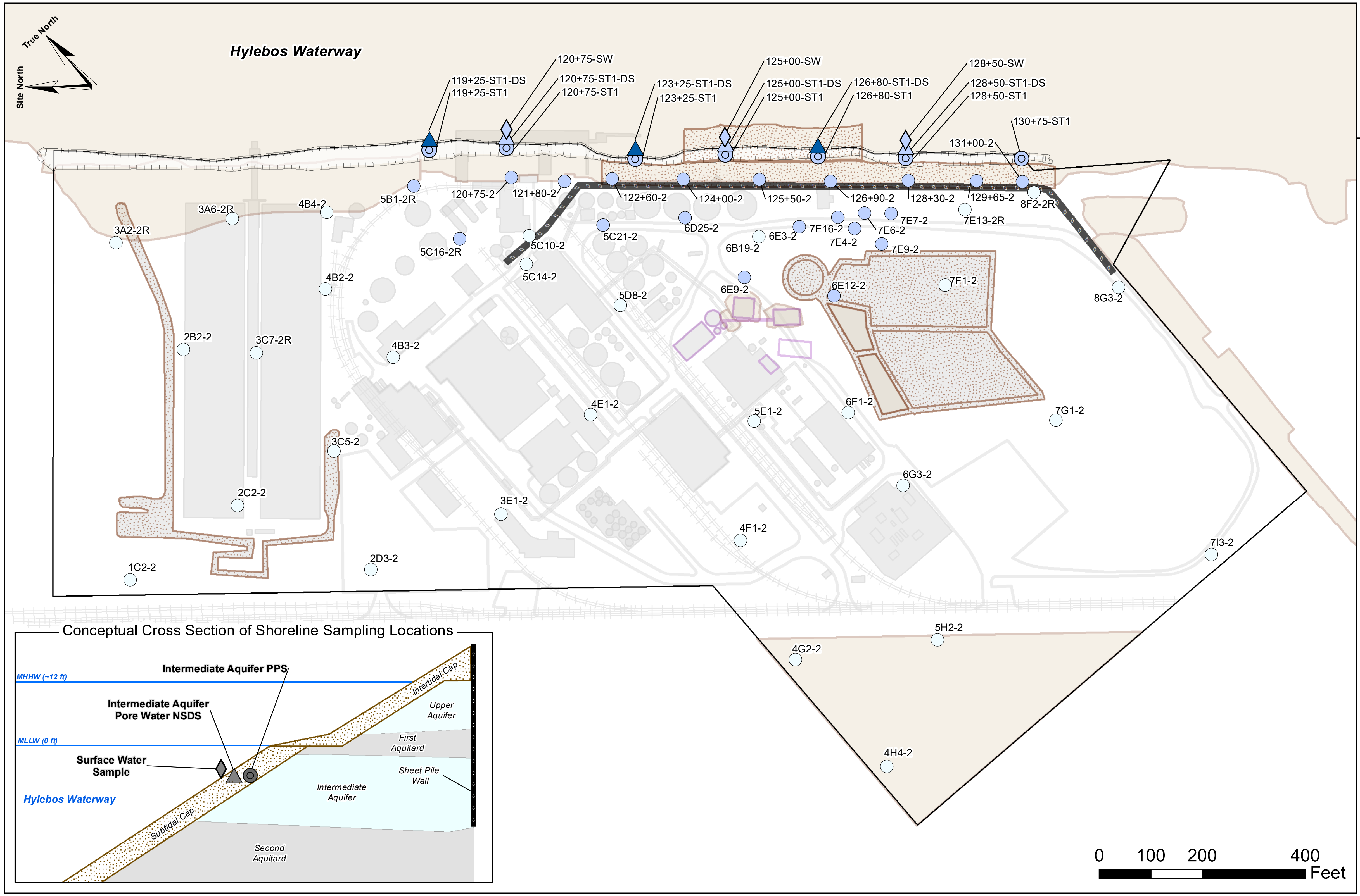

Legend

Sample Type
- ○ Monitoring Well
- ◎ Intermediate Aquifer PPS
- △ Intermediate Aquifer Pore Water NSDS
- ◇ Surface Water Sample

Year Sampled
- ○ 2017
- ● 2017 and 2018
- ● 2018

Completed Remedial Actions
- ▭ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- ▬ Sheet Pile Wall

Other Features
- ▭ Known and Potential Penite Manufacturing Features
- ▭ Historical Infrastructure
- ▭ Intermediate Aquifer Outcrop
- ▭ RI/FS Site Boundary

Notes:
- Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.

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Investigation Locations for Data Gap #2B
Arsenic Plume Stability (Intermediate Aquifer)
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 4-2B

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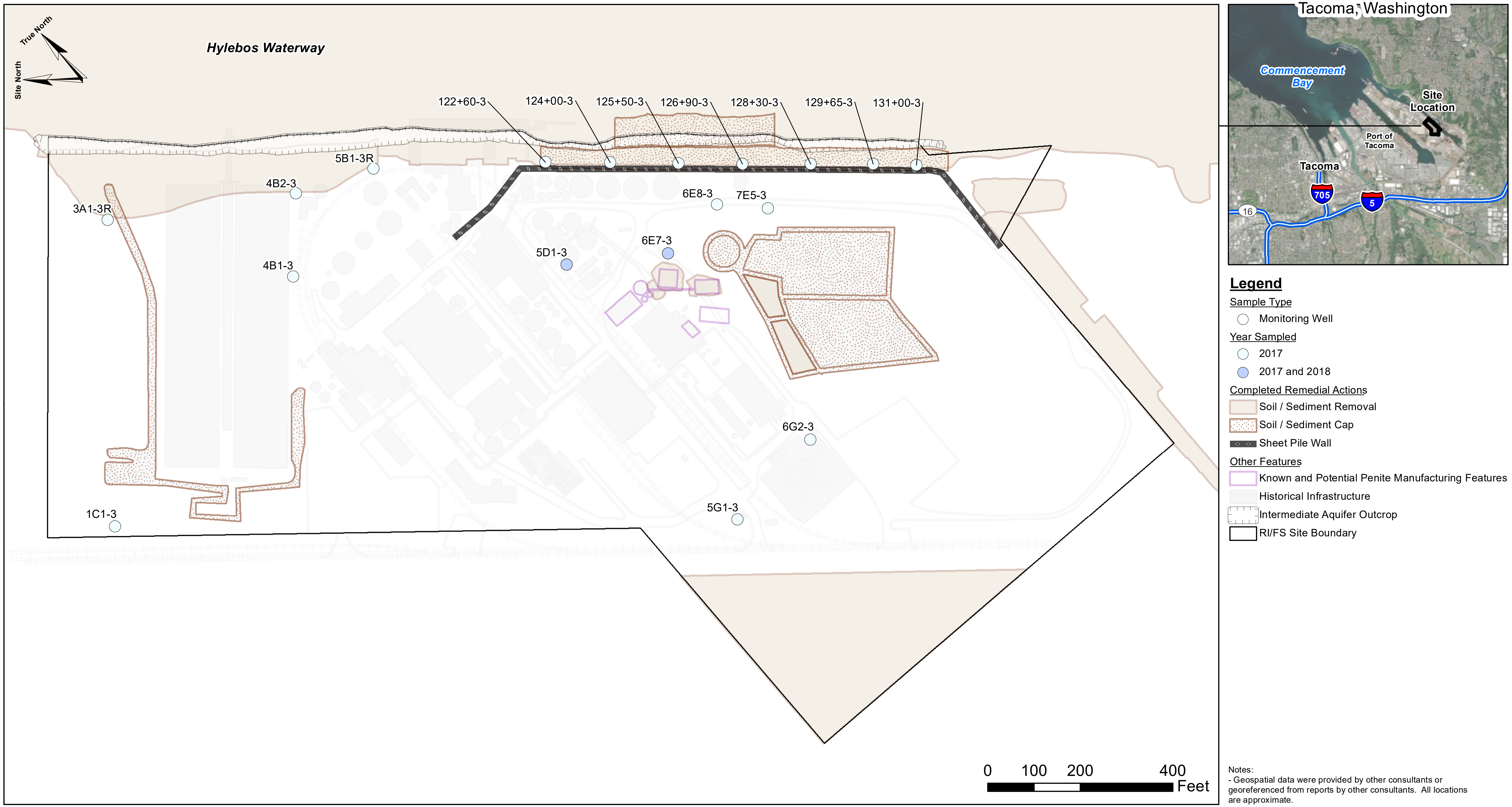

Notes:
- Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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Investigation Locations for Data Gap #2C
Arsenic Plume Stability (Deep Aquifer)
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 4-2C

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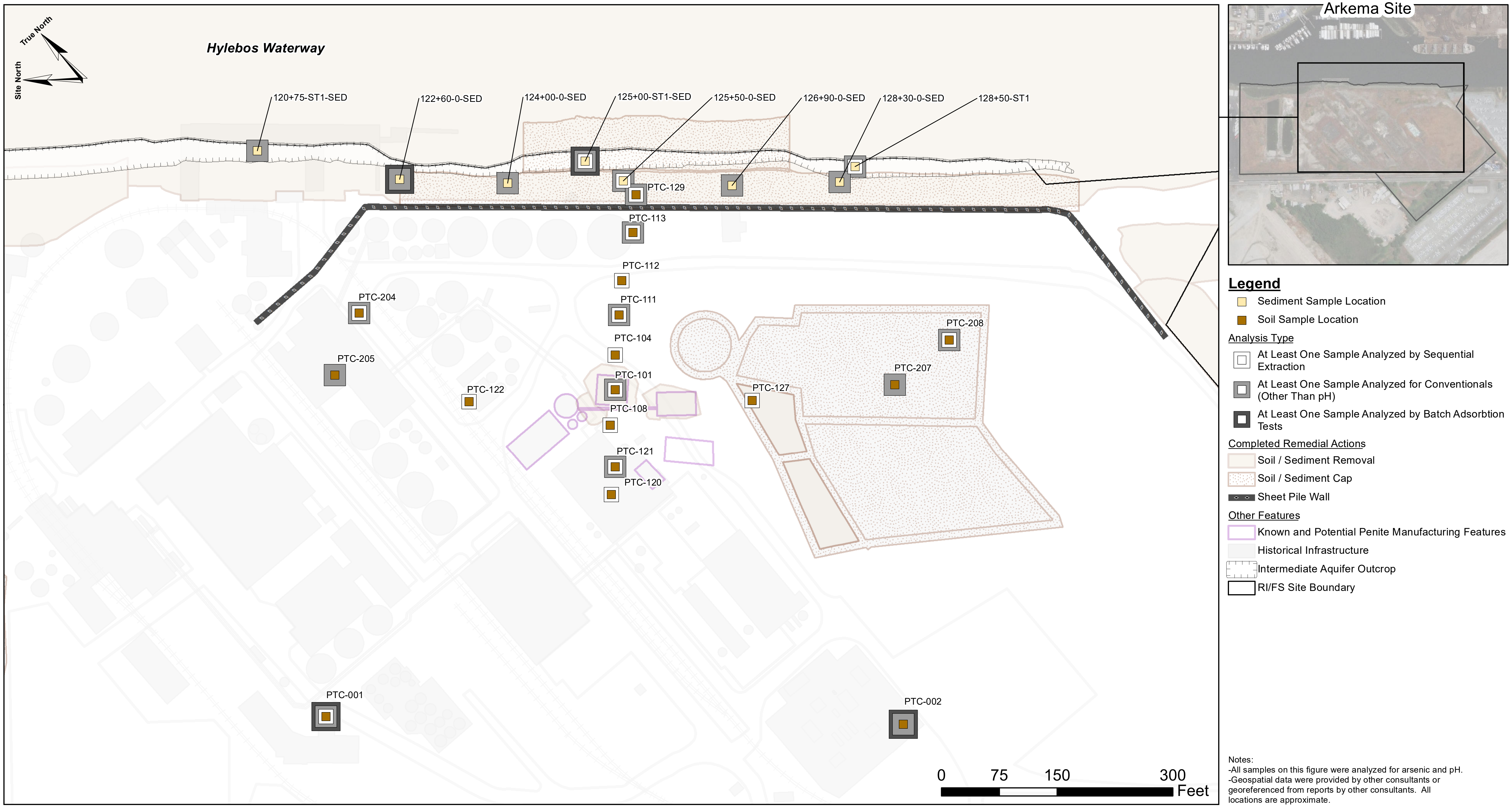

Notes:
-All samples on this figure were analyzed for arsenic and pH.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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Investigation Locations for Data Gap #2D
Arsenic Plume Stability (Soil/Sediment Geochemistry)
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 4-2D

Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\4-3_WallIntegrity_Test_Pits_DG#3.mxd; Author: VN; Date Saved: 5/15/2019

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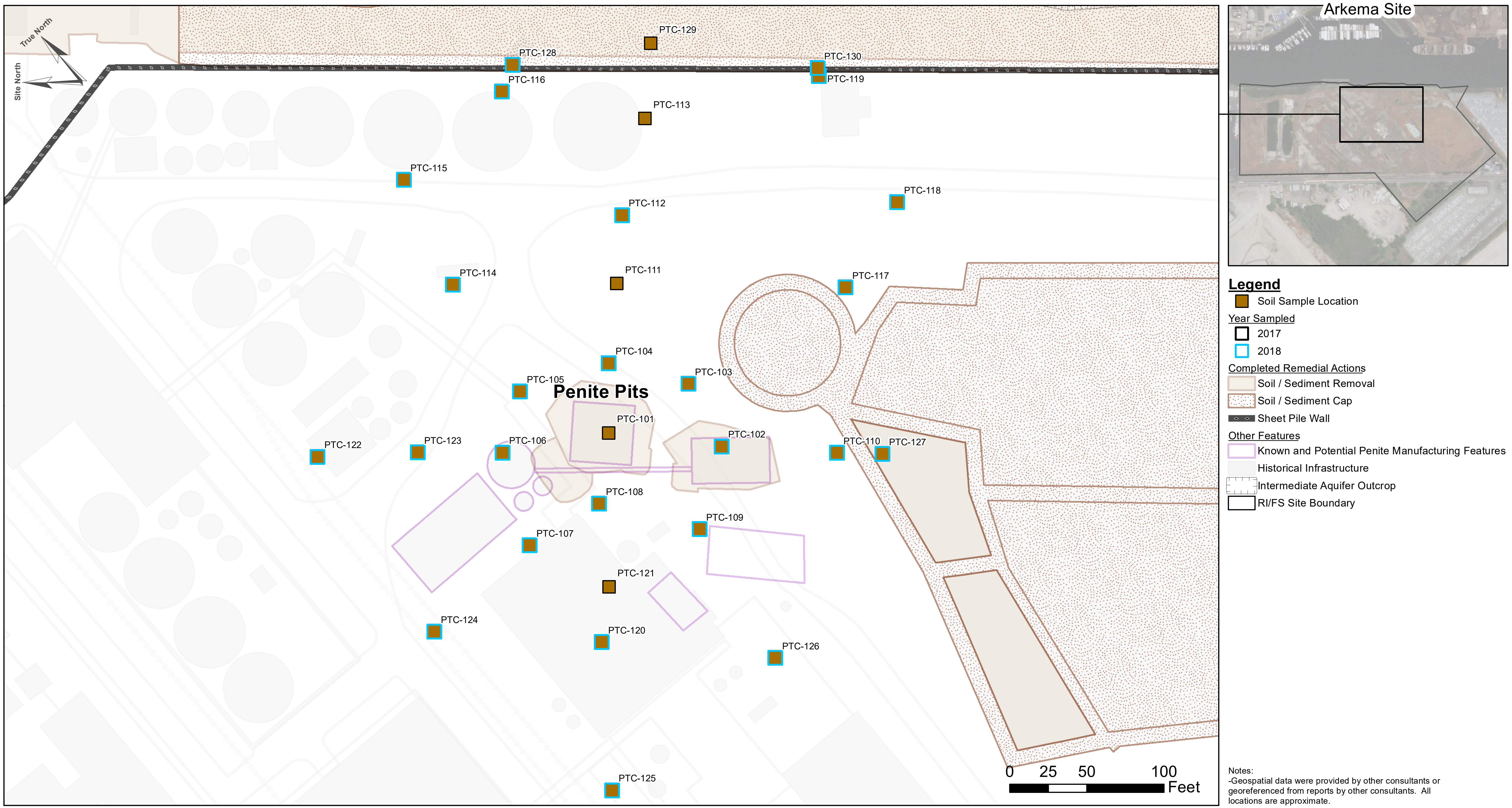
Investigation Locations for Data Gap #3
Wall Integrity
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 4-3



Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

PIONEER
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Investigation Locations for Data Gap #4A
Feasibility of Focused Soil Excavation Alternative (Arsenic)
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 4-4A

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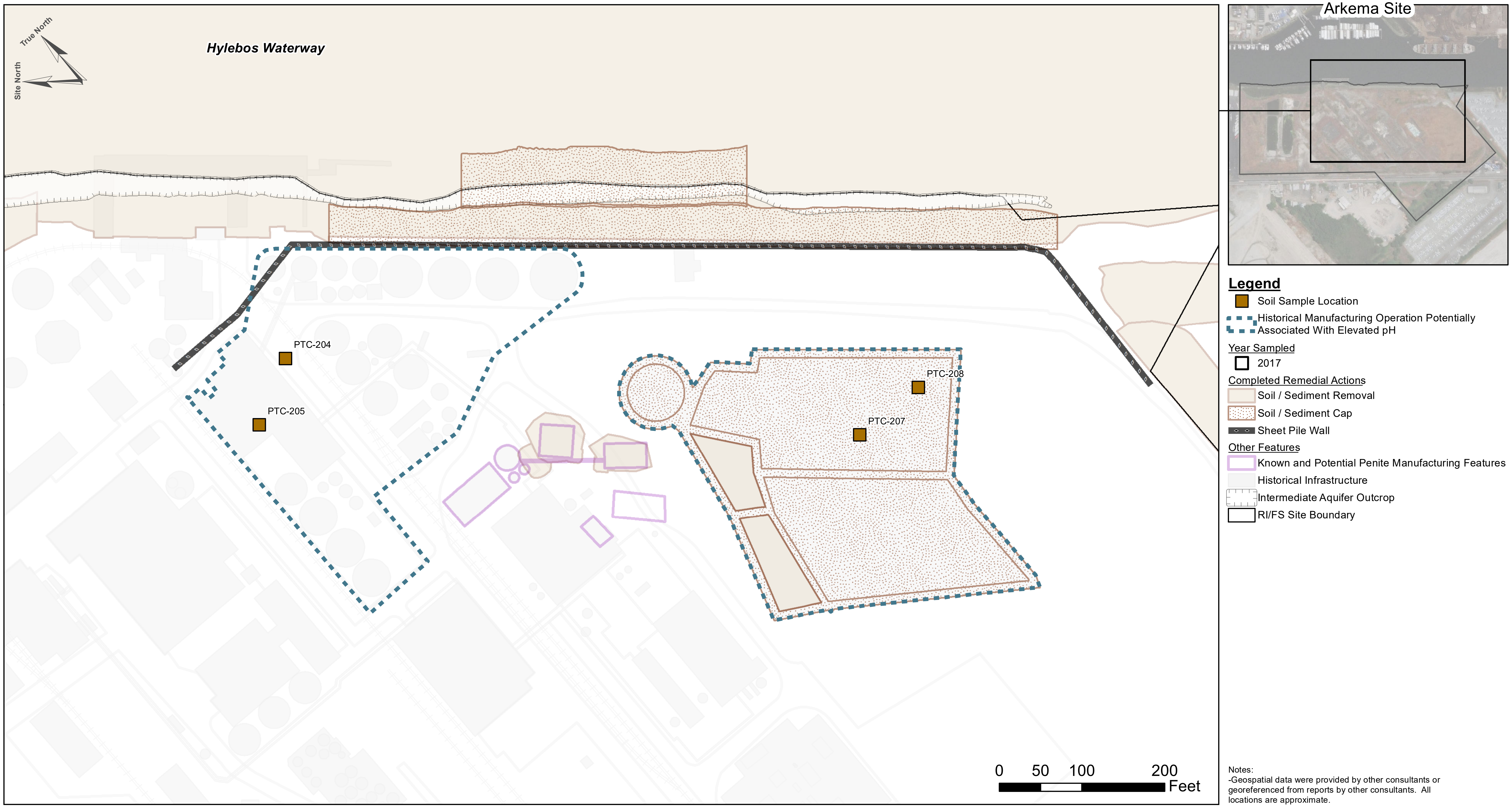

Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

PIONEER
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Investigation Locations for Data Gap #4B
Feasibility of Focused Soil Excavation Alternative (pH)
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 4-4B

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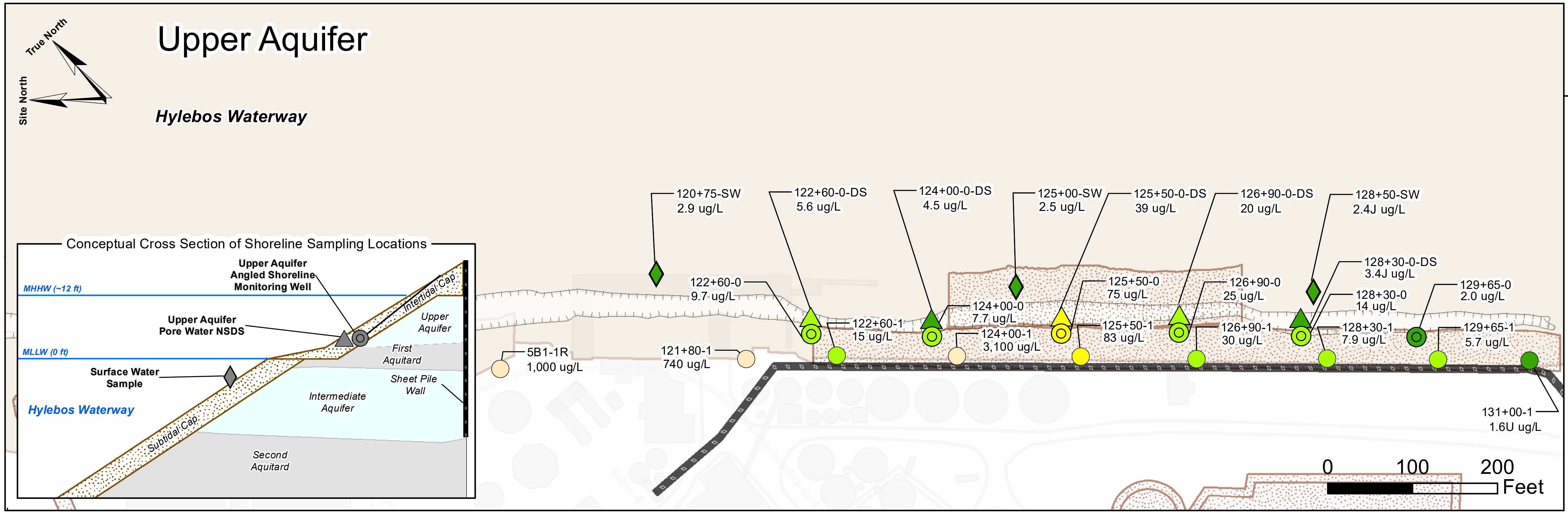

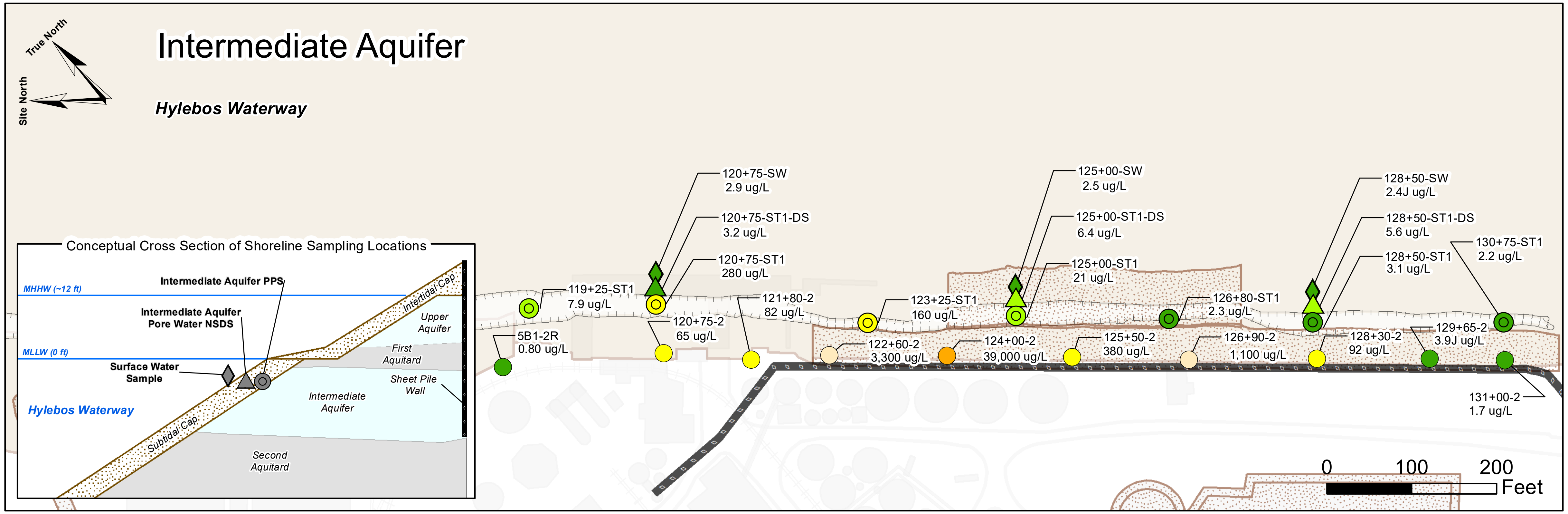

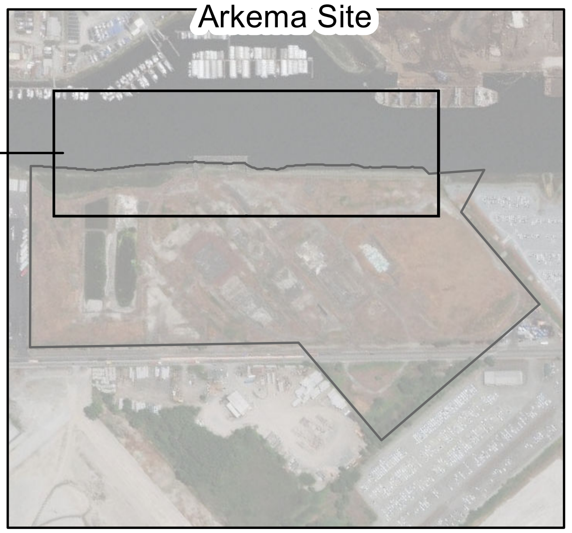

Legend

- ○ Monitoring Well
- ◎ Upper Aquifer Angled Shoreline Monitoring Well / Intermediate Aquifer PPS
- △ Upper / Intermediate Aquifer Pore Water NSDS
- ◇ Surface Water Sample

2017 Dissolved Arsenic Concentrations

- ● Dissolved Arsenic ≤ 5 ug/L (or Not Detected)
- ● 5 ug/L < Dissolved Arsenic ≤ 36 ug/L
- ● 36 ug/L < Dissolved Arsenic ≤ 500 ug/L
- ● 500 ug/L < Dissolved Arsenic ≤ 5,000 ug/L
- ● 5,000 ug/L < Dissolved Arsenic ≤ 50,000 ug/L
- ● Dissolved Arsenic > 50,000 ug/L

Completed Remedial Actions

- ▨ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- ▬ Sheet Pile Wall

Other Features

- ▨ Historical Infrastructure
- ▨ Intermediate Aquifer Outcrop
- ☐ RI/FS Site Boundary

Notes:
J: Estimated concentration
U: Constituent was not detected at the shown reporting limit
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.
-Results are shown to two significant figures.

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2017 Closeup of Shoreline Dissolved Arsenic Concentrations
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-1

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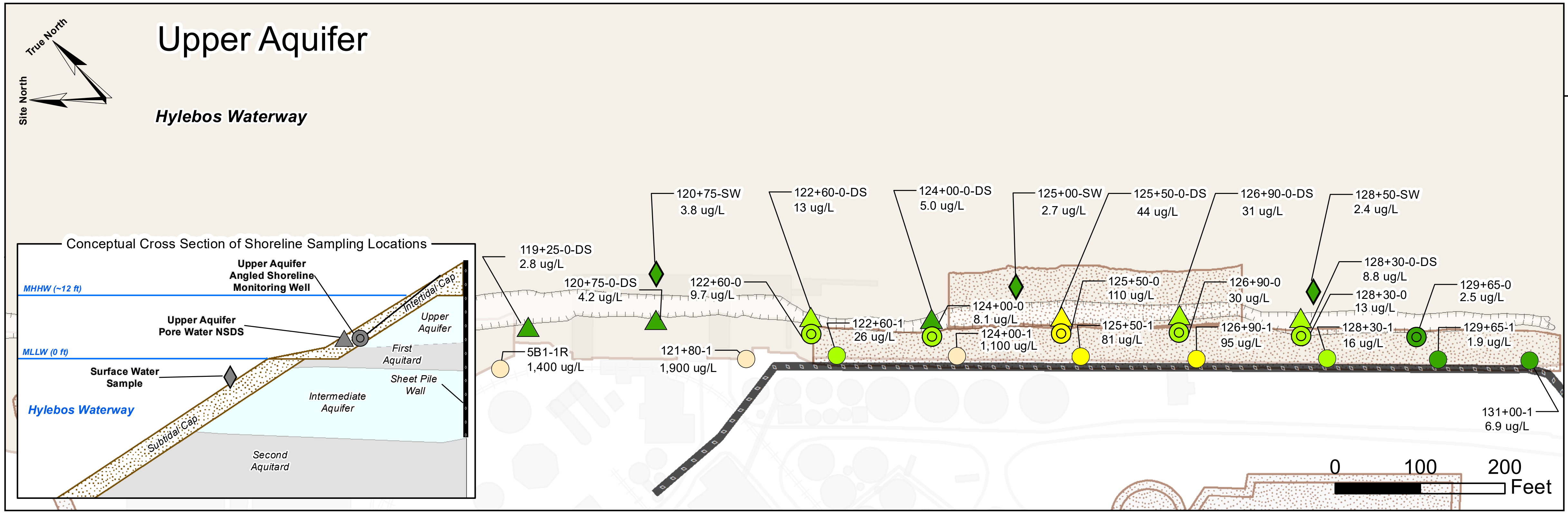

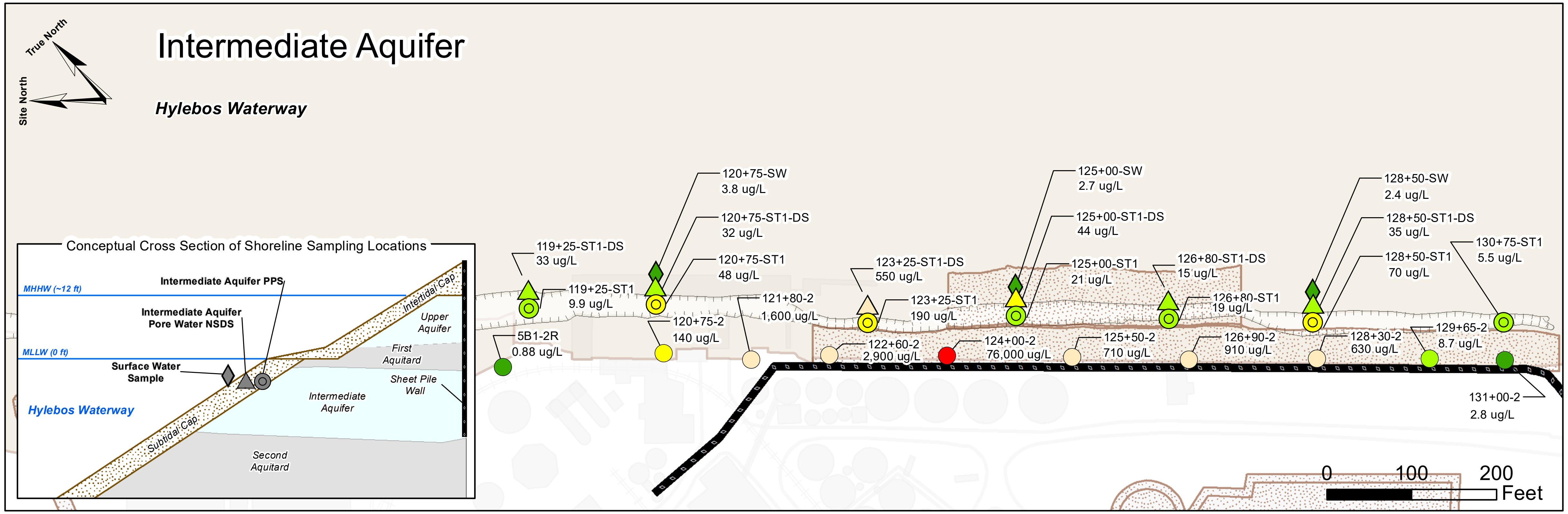

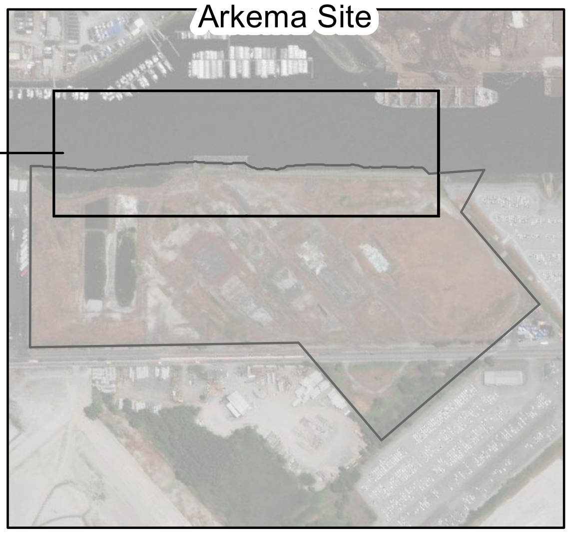

Legend

Sample Type
- ○ Monitoring Well
- ◎ Upper Aquifer Angled Shoreline Monitoring Well / Intermediate Aquifer PPS
- △ Upper / Intermediate Aquifer Pore Water NSDS
- ◇ Surface Water Sample

2018 Upper Aquifer Dissolved Arsenic
- ● Dissolved Arsenic ≤ 5 ug/L (or Not Detected)
- ● 5 ug/L < Dissolved Arsenic ≤ 36 ug/L
- ● 36 ug/L < Dissolved Arsenic ≤ 500 ug/L
- ● 500 ug/L < Dissolved Arsenic ≤ 5,000 ug/L
- ● 5,000 ug/L < Dissolved Arsenic ≤ 50,000 ug/L
- ● Dissolved Arsenic > 50,000 ug/L

Completed Remedial Actions
- ▭ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- ▬ Sheet Pile Wall

Other Features
- ▭ Historical Infrastructure
- ▭ Intermediate Aquifer Outcrop
- ▭ RI/FS Site Boundary

Notes:
J: Estimated concentration
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.
-Results are shown to two significant figures.

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-2_2018_Dis_As_Shoreline.mxd; Author: VN; Date Saved: 7/19/2019

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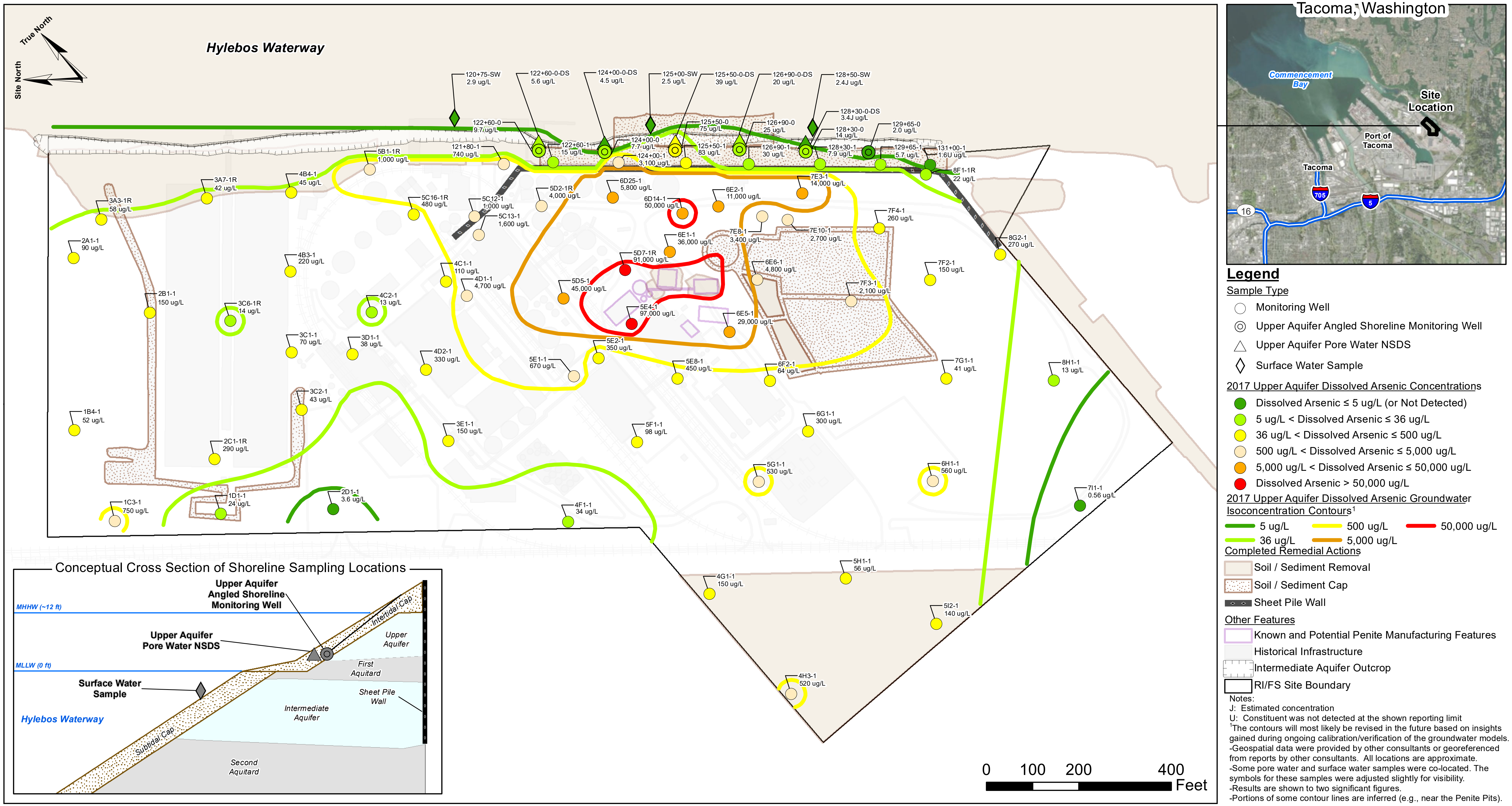
2018 Closeup of Shoreline Dissolved Arsenic Concentrations
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-2



Legend

Sample Type

○ Monitoring Well

◎ Upper Aquifer Angled Shoreline Monitoring Well

△ Upper Aquifer Pore Water NSDS

◇ Surface Water Sample

2017 Upper Aquifer Dissolved Arsenic Concentrations

● Dissolved Arsenic ≤ 5 ug/L (or Not Detected)

● 5 ug/L < Dissolved Arsenic ≤ 36 ug/L

● 36 ug/L < Dissolved Arsenic ≤ 500 ug/L

● 500 ug/L < Dissolved Arsenic ≤ 5,000 ug/L

● 5,000 ug/L < Dissolved Arsenic ≤ 50,000 ug/L

● Dissolved Arsenic > 50,000 ug/L

2017 Upper Aquifer Dissolved Arsenic Groundwater Isoconcentration Contours[1]

— 5 ug/L — 500 ug/L — 50,000 ug/L

— 36 ug/L — 5,000 ug/L

Completed Remedial Actions

▨ Soil / Sediment Removal

▨ Soil / Sediment Cap

▬ Sheet Pile Wall

Other Features

☐ Known and Potential Penite Manufacturing Features

☐ Historical Infrastructure

☐ Intermediate Aquifer Outcrop

☐ RI/FS Site Boundary

Notes:
J: Estimated concentration
U: Constituent was not detected at the shown reporting limit
[1] The contours will most likely be revised in the future based on insights gained during ongoing calibration/verification of the groundwater models.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.
-Results are shown to two significant figures.
-Portions of some contour lines are inferred (e.g., near the Penite Pits).

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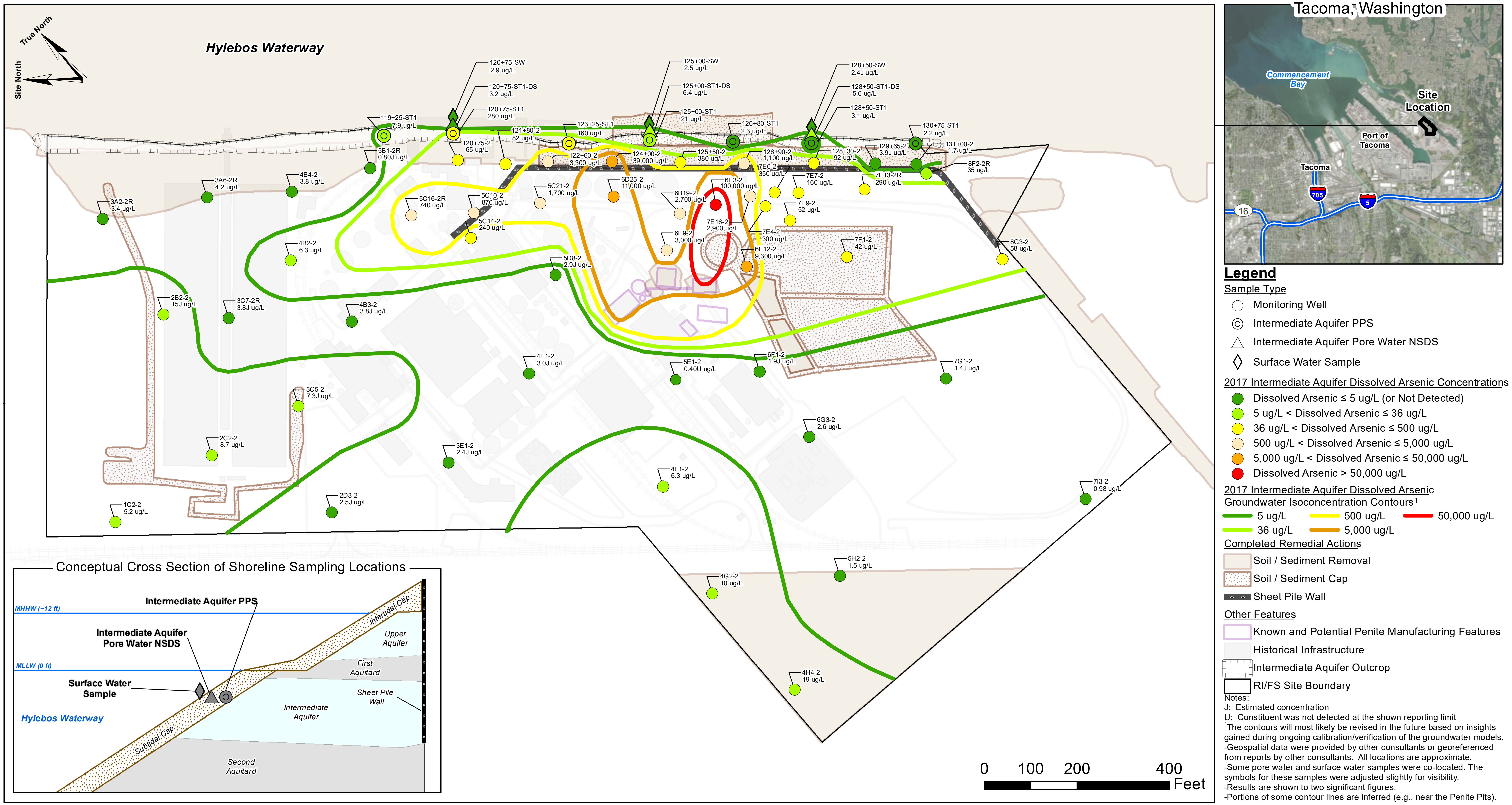
2017 Dissolved Arsenic Concentrations in the Upper Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-3



Notes:
J: Estimated concentration
U: Constituent was not detected at the shown reporting limit
[1] The contours will most likely be revised in the future based on insights gained during ongoing calibration/verification of the groundwater models.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.
-Results are shown to two significant figures.
-Portions of some contour lines are inferred (e.g., near the Penite Pits).

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-4_2017_IA_Diss_As.mxd; Author: KR; Date Saved: 7/19/2019

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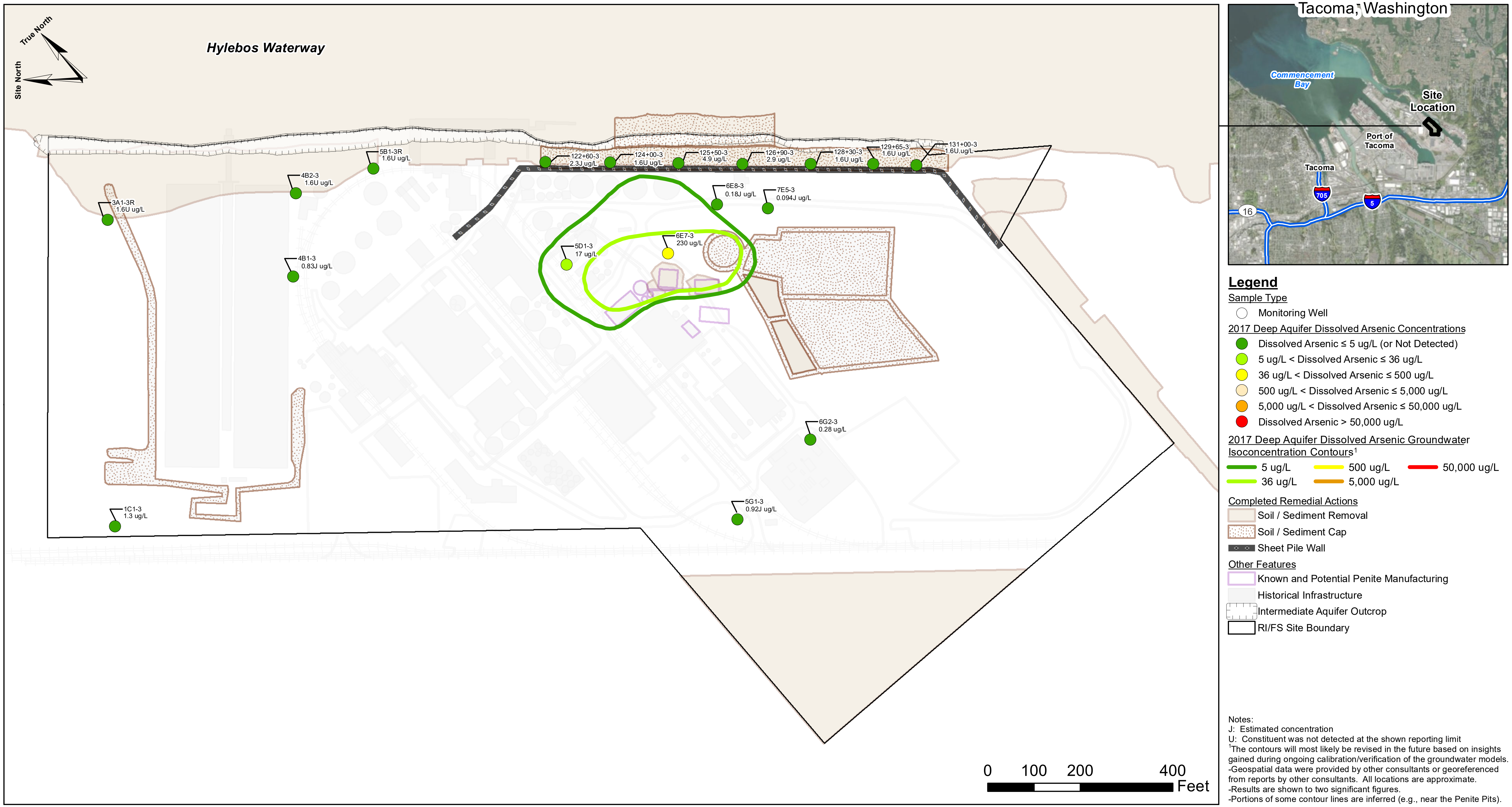
2017 Dissolved Arsenic Concentrations in the Intermediate Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-4



Notes:
J: Estimated concentration
U: Constituent was not detected at the shown reporting limit
[1] The contours will most likely be revised in the future based on insights gained during ongoing calibration/verification of the groundwater models.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Results are shown to two significant figures.
-Portions of some contour lines are inferred (e.g., near the Penite Pits).

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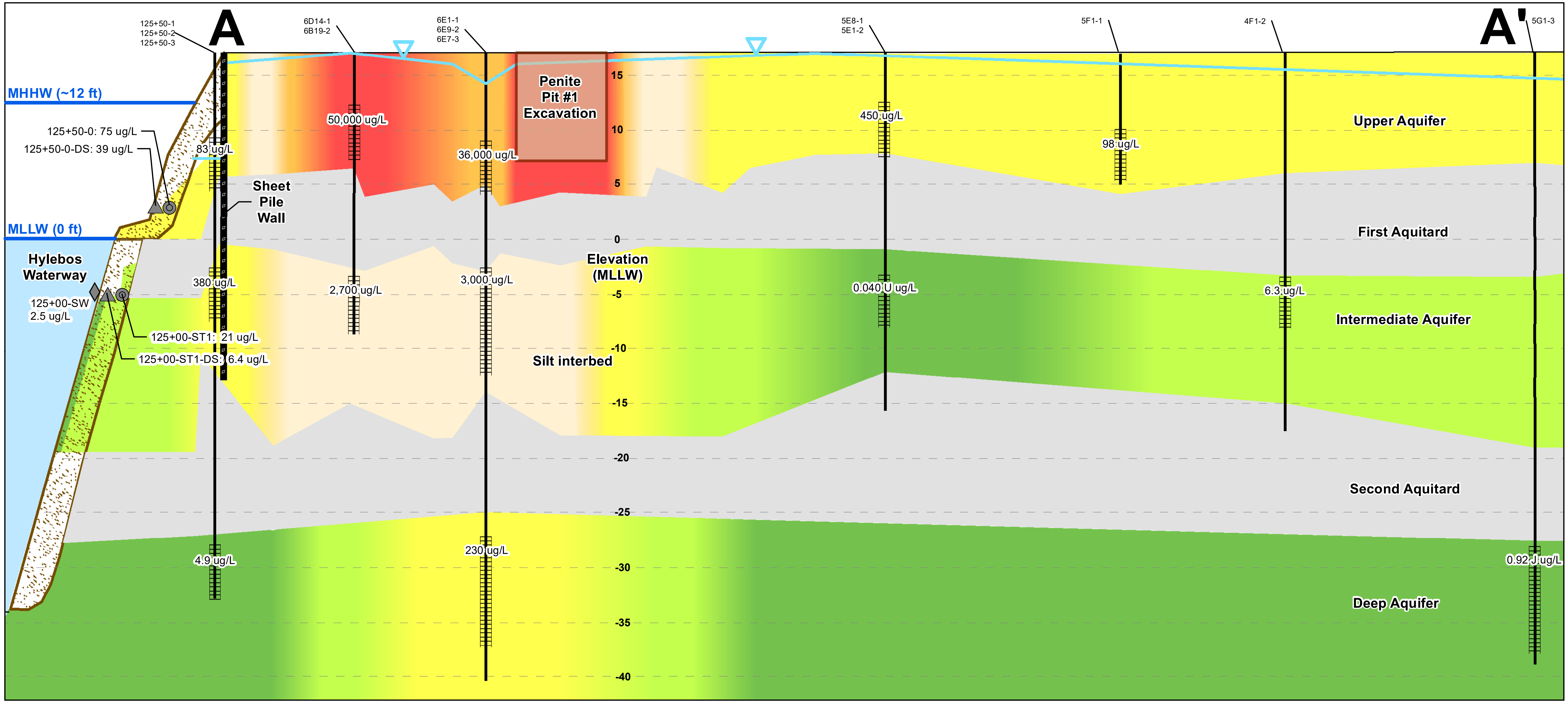
2017 Dissolved Arsenic Concentrations in the Deep Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-5

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-5_2017_DA_Diss_As.mxd; Author: KR; Date Saved: 7/19/2019

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-6_X_Section_Diss_As.mxd; Author: VN; Date Saved: 7/24/2019



Dissolved Arsenic Groundwater Concentration

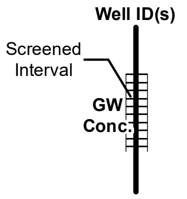
- 🟩 Arsenic ≤ 5.0 ug/L
- 🟩 5.0 ug/L < Arsenic ≤ 36 ug/L
- 🟨 36 ug/L < Arsenic ≤ 500 ug/L
- ⬜ 500 ug/L < Arsenic ≤ 5,000 ug/L
- 🟧 5,000 ug/L < Arsenic ≤ 50,000 ug/L
- 🟥 Arsenic > 50,000 ug/L

Other Features

- — March 2012 Low Tide Groundwater Elevation
- ⬜ First / Second Aquitard or Silt Interbed
- ▨ Intertidal / Subtidal Caps
- ▢ Penite Pits Excavation

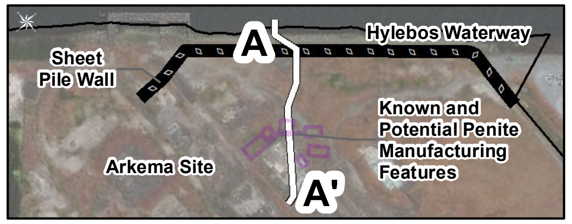
Sample Type

- ◎ Angled Shoreline Monitoring Well / PPS
- △ Pore Water NSDS
- ◊ Surface Water Sample



Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-For simplicity, a flat ground surface was assumed for the upland portion of this cross section since the upland ground surface is essentially flat along the cross section and spot elevations are not available for most boring locations.

Horizontal 0 45 90 180
Scale (ft) Vertical exaggeration is ~7x
Vertical 0 5 10 20



PIONEER
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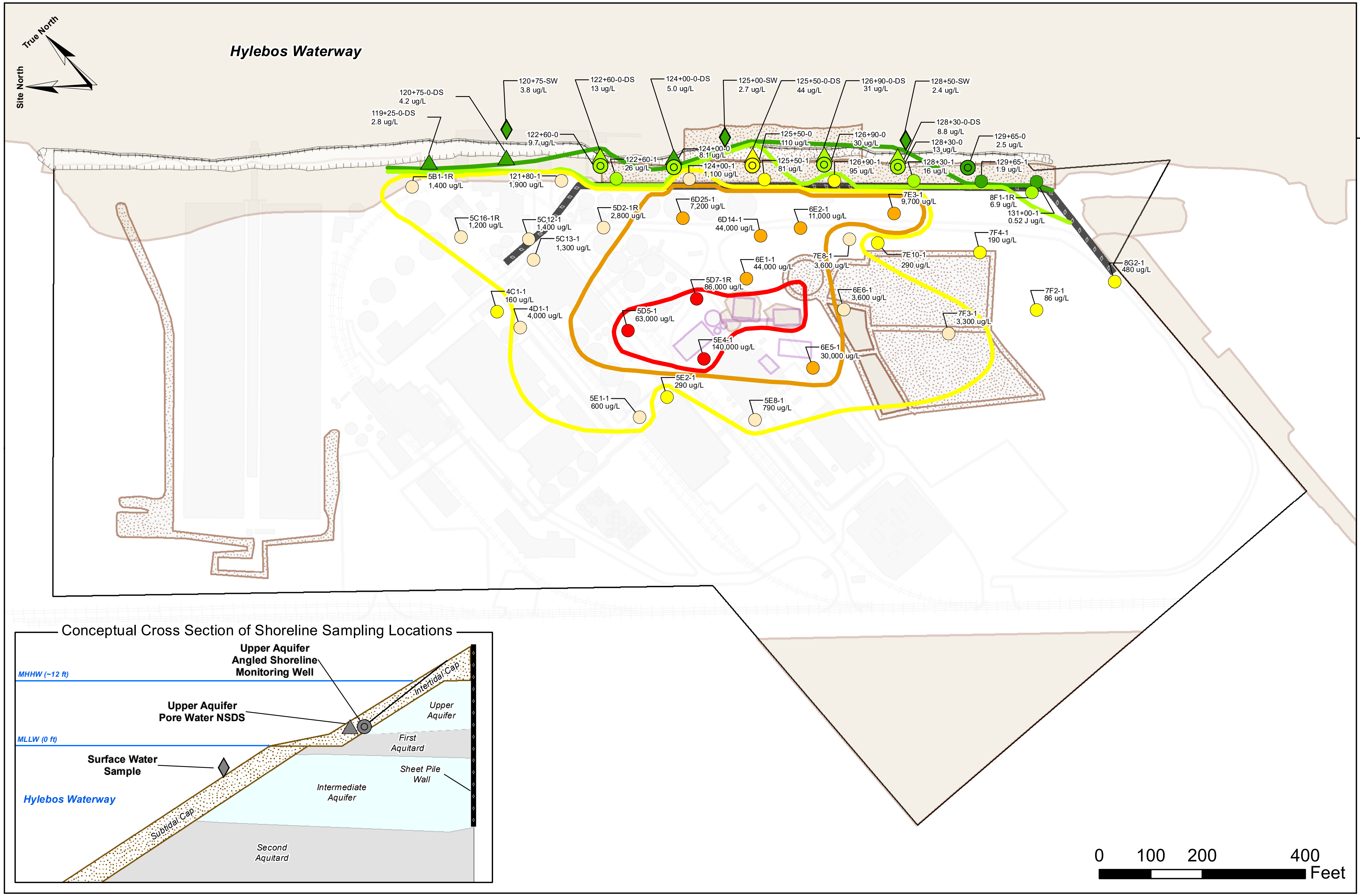
Conceptual Cross Section of 2017 Dissolved Arsenic Concentrations
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-6



Legend

Sample Type

- ○ Monitoring Well
- ◎ Upper Aquifer Angled Shoreline Monitoring Well
- △ Upper Aquifer Pore Water NSDS
- ◊ Surface Water Sample

2017 Upper Aquifer Dissolved Arsenic Concentrations

- ● Dissolved Arsenic ≤ 5 ug/L (or Not Detected)
- ● 5 ug/L < Dissolved Arsenic ≤ 36 ug/L
- ● 36 ug/L < Dissolved Arsenic ≤ 500 ug/L
- ● 500 ug/L < Dissolved Arsenic ≤ 5,000 ug/L
- ● 5,000 ug/L < Dissolved Arsenic ≤ 50,000 ug/L
- ● Dissolved Arsenic > 50,000 ug/L

2018 Intermediate Aquifer Dissolved Arsenic Groundwater Isoconcentration Contours[1]

- 5 ug/L
- 36 ug/L
- 500 ug/L
- 5,000 ug/L
- 50,000 ug/L

Completed Remedial Actions

- Soil / Sediment Removal
- Soil / Sediment Cap
- Sheet Pile Wall

Other Features

- Known and Potential Penite Manufacturing Features
- Historical Infrastructure
- Intermediate Aquifer Outcrop
- RI/FS Site Boundary

Notes:
J: Estimated concentration
[1] The contours will most likely be revised in the future based on insights gained during ongoing calibration/verification of the groundwater models.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.
-Results are shown to two significant figures.
-Portions of some contour lines are inferred (e.g., near the Penite Pits).

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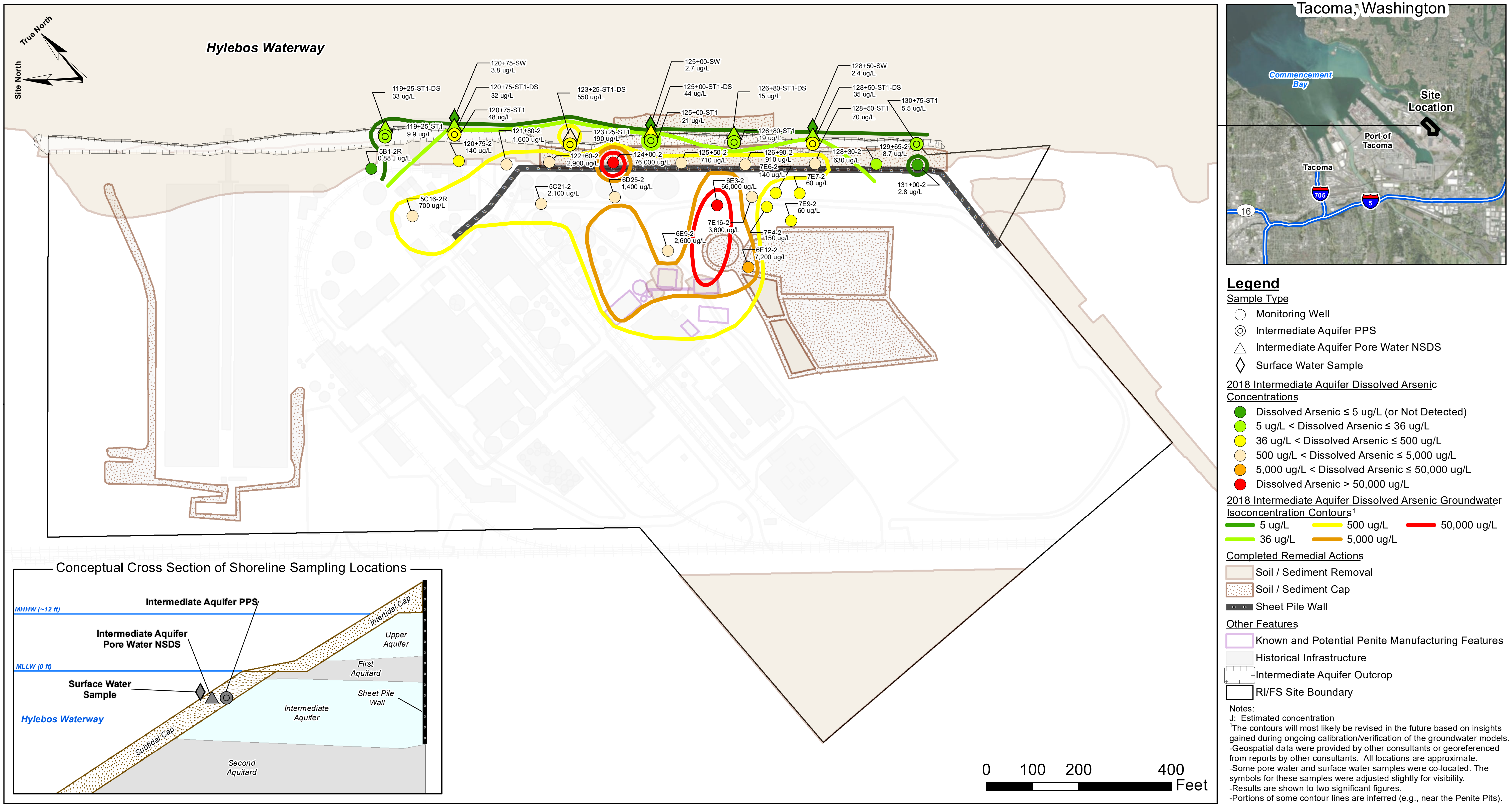
2018 Dissolved Arsenic Concentrations in the Upper Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-7

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-7_2018_UA_Diss_As.mxd; Author: VN; Date Saved: 7/19/2019



Notes:
J: Estimated concentration
¹The contours will most likely be revised in the future based on insights gained during ongoing calibration/verification of the groundwater models.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.
-Results are shown to two significant figures.
-Portions of some contour lines are inferred (e.g., near the Penite Pits).

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-8_2018_IA_Diss_As.mxd; Author: VN; Date Saved: 7/19/2019

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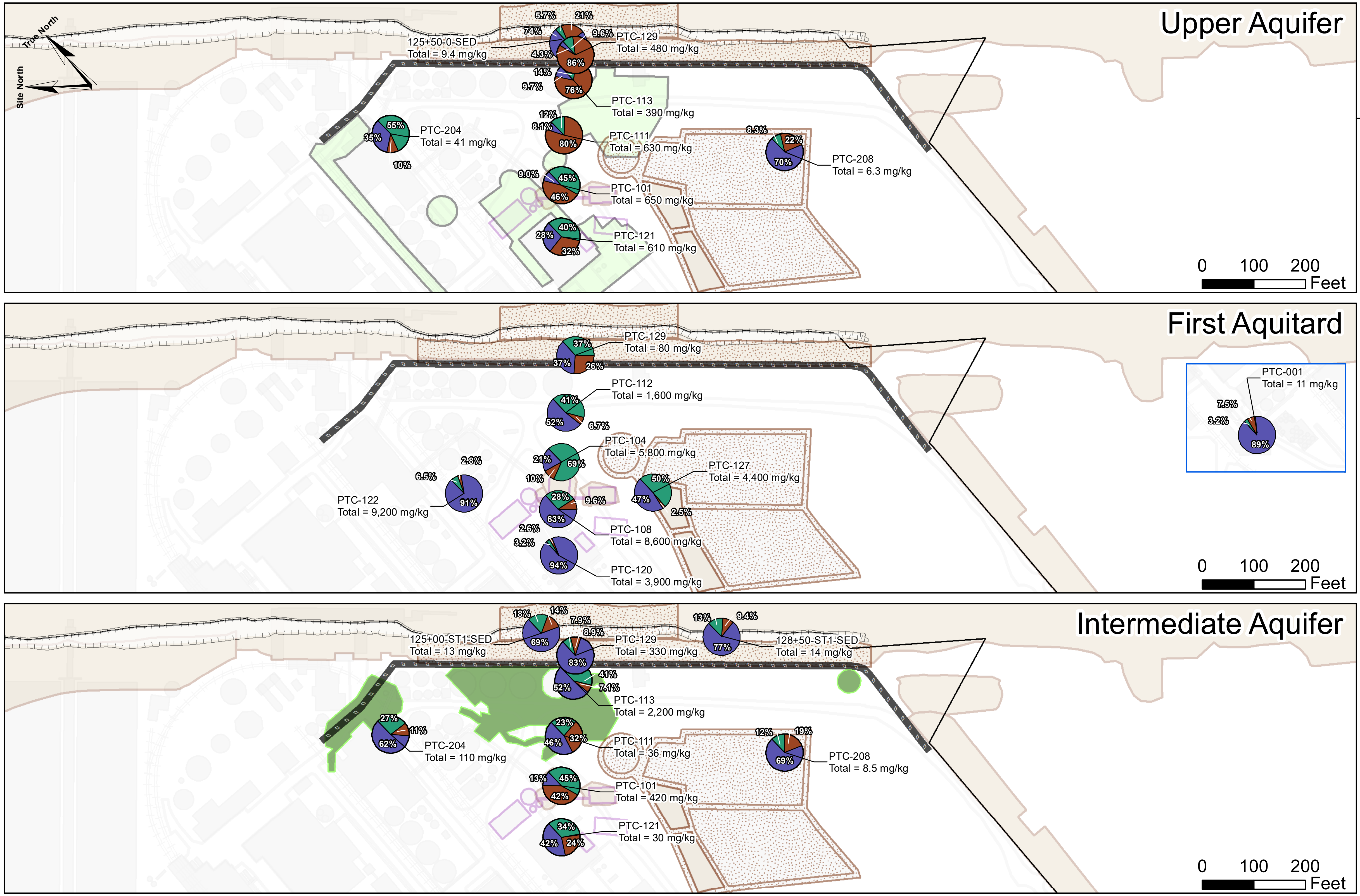
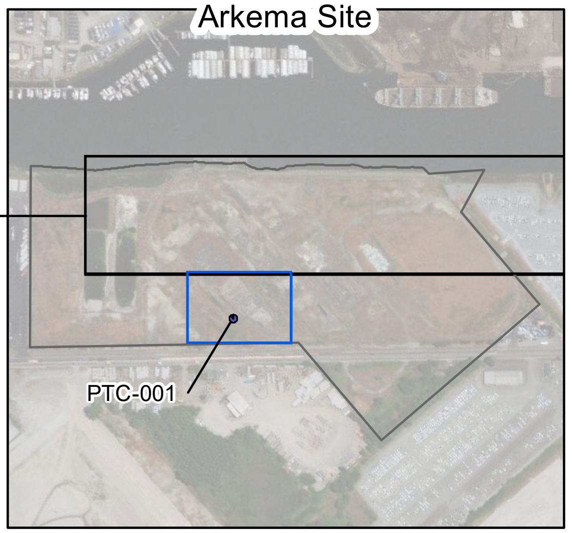
2018 Dissolved Arsenic Concentrations in the Intermediate Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-8





Legend

Sequential Extraction Arsenic

🟦 Arsenic Associated with Highly Stable Minerals
🟫 Arsenic Co-precipitated with Metal Oxides
🟩 Sorbed Arsenic

Completed Remedial Actions

▨ Soil / Sediment Removal
▨ Soil / Sediment Cap
🟩 Arsenic In-Situ Stabilization Upper Aquifer Injection Areas
🟩 Arsenic In-Situ Stabilization Intermediate Aquifer Injection Locations
▬ Sheet Pile Wall

Other Features

☐ Known and Potential Penite Manufacturing Features
☐ Historical Infrastructure
☐ Intermediate Aquifer Outcrop
☐ RI/FS Site Boundary

Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Results are shown to two significant figures.
-Non-detect results were assumed to equal half the reporting limit.

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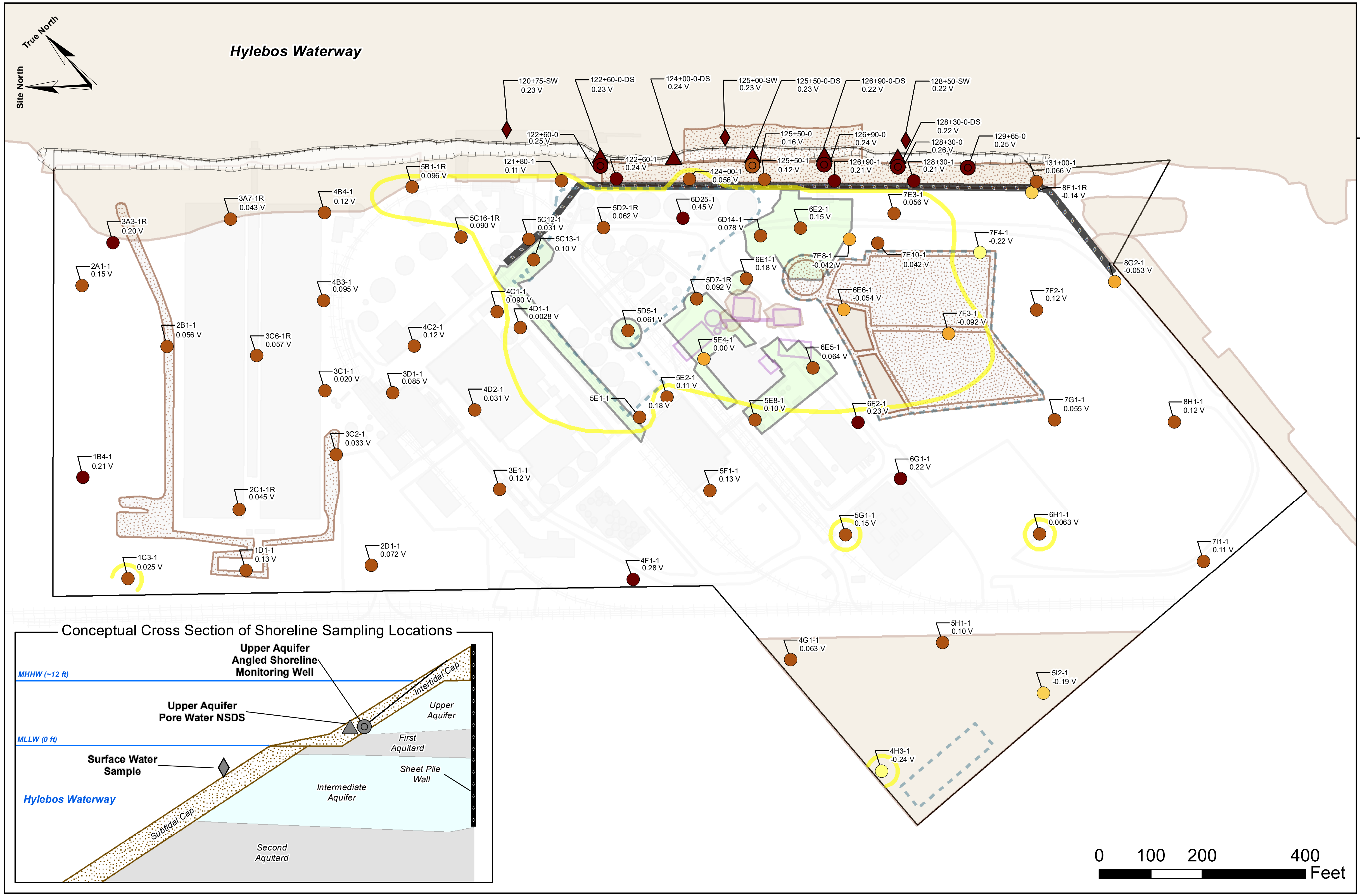
Summary of Sequential Extraction Arsenic Results for Soil and Sediment
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-9

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-9_Summary_Seq_Ext_As_SO_SED.mxd; Author: VN; Date Saved: 7/19/2019



Legend

Sample Type
- ○ Monitoring Well
- ◎ Upper Aquifer Angled Shoreline Monitoring Well
- △ Upper Aquifer Pore Water NSDS
- ◊ Surface Water Sample

2017 Upper Aquifer Eh Concentrations
- ● Eh ≤ -0.2 V
- ● -0.2 V < Eh ≤ -0.1 V
- ● -0.1 V < Eh ≤ 0.0 V
- ● 0.0 V < Eh ≤ 0.2 V
- ● Eh > 0.2 V

Completed Remedial Actions
- ▭ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- 🟩 Arsenic In-Situ Stabilization Upper Aquifer Injection Areas
- ▬ Sheet Pile Wall

Other Features
- ▭ Known and Potential Penite Manufacturing Features
- ▭ Historical Manufacturing Operation Potentially Associated With Elevated pH
- ▬ 2017 Upper Aquifer 500 ug/L Dissolved Arsenic Groundwater Isoconcentration Contour
- ▭ Historical Infrastructure
- ▭ Intermediate Aquifer Outcrop
- ▭ RI/FS Site Boundary

Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.
-Results are shown to two significant figures.

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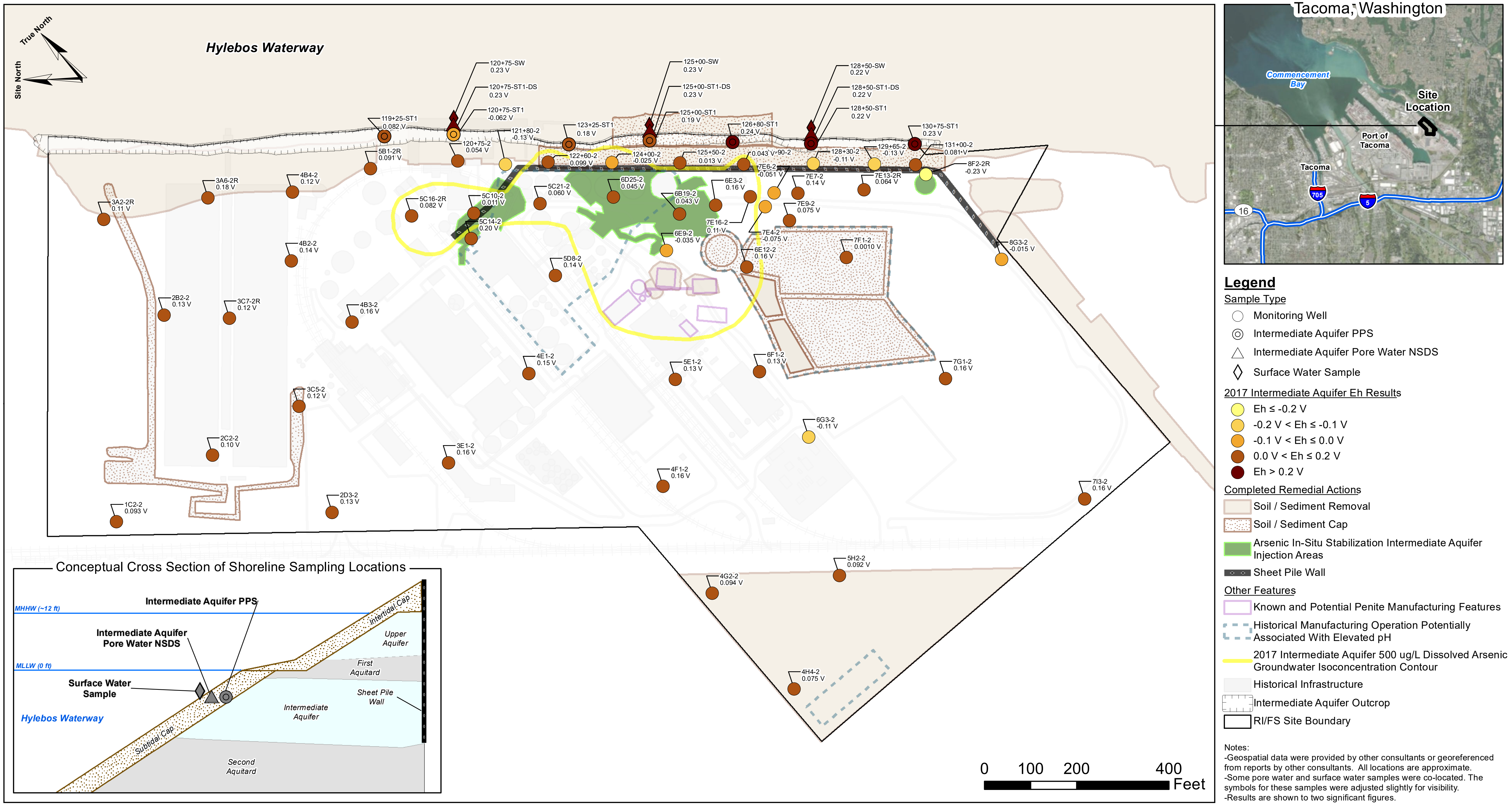
2017 Field Eh Results in the Upper Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-10

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-10_2017_UA_EH.mxd; Author: VN; Date Saved: 6/27/2019



Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.
-Results are shown to two significant figures.

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-11_2017_IA_EH.mxd; Author: VN; Date Saved: 7/19/2019

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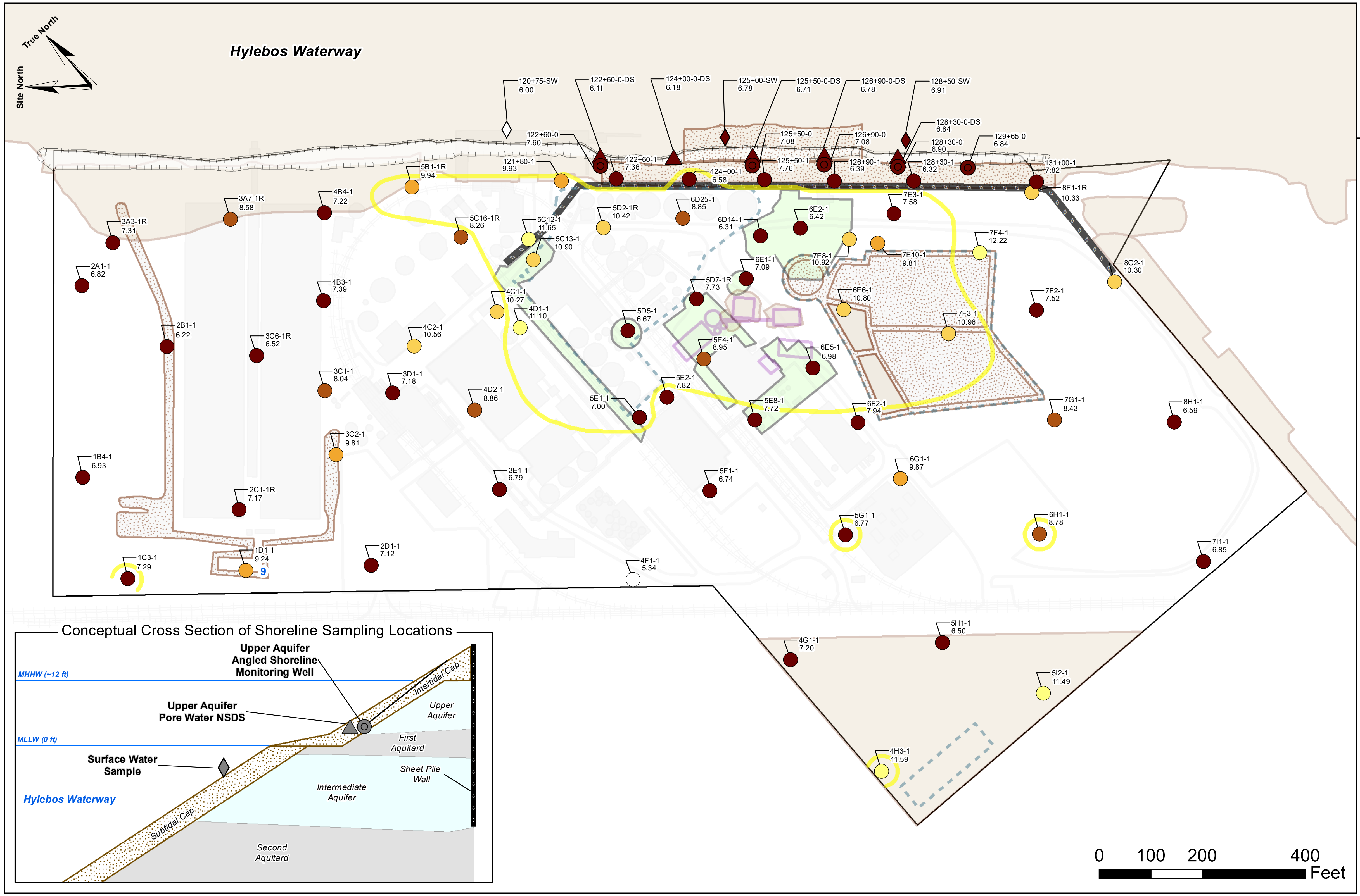
2017 Field Eh Results in the Intermediate Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-11



Conceptual Cross Section of Shoreline Sampling Locations

Legend

Sample Type

- ○ Monitoring Well
- ◎ Upper Aquifer Angled Shoreline Monitoring Well
- △ Upper Aquifer Pore Water NSDS
- ◇ Surface Water Sample

2017 Upper Aquifer Field pH Results

- ○ pH ≤ 6
- ● 6 < pH ≤ 8
- ● 8 < pH ≤ 9
- ● 9 < pH ≤ 10
- ● 10 < pH ≤ 11
- ● pH > 11

Completed Remedial Actions

- ▭ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- 🟩 Arsenic In-Situ Stabilization Upper Aquifer Injection Areas
- ▬ Sheet Pile Wall

Other Features

- ▭ Known and Potential Penite Manufacturing Features
- ▭ Historical Manufacturing Operation Potentially Associated With Elevated pH
- ▬ 2017 Upper Aquifer 500 ug/L Dissolved Arsenic Groundwater Isoconcentration Contour
- ▭ Historical Infrastructure
- ▭ Intermediate Aquifer Outcrop
- ▭ RI/FS Site Boundary

Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.
-Results are shown to two decimal places.

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2017 Field pH Results in the Upper Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-12

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-12_2017_UA_FieldpH.mxd; Author: VN; Date Saved: 6/18/2019

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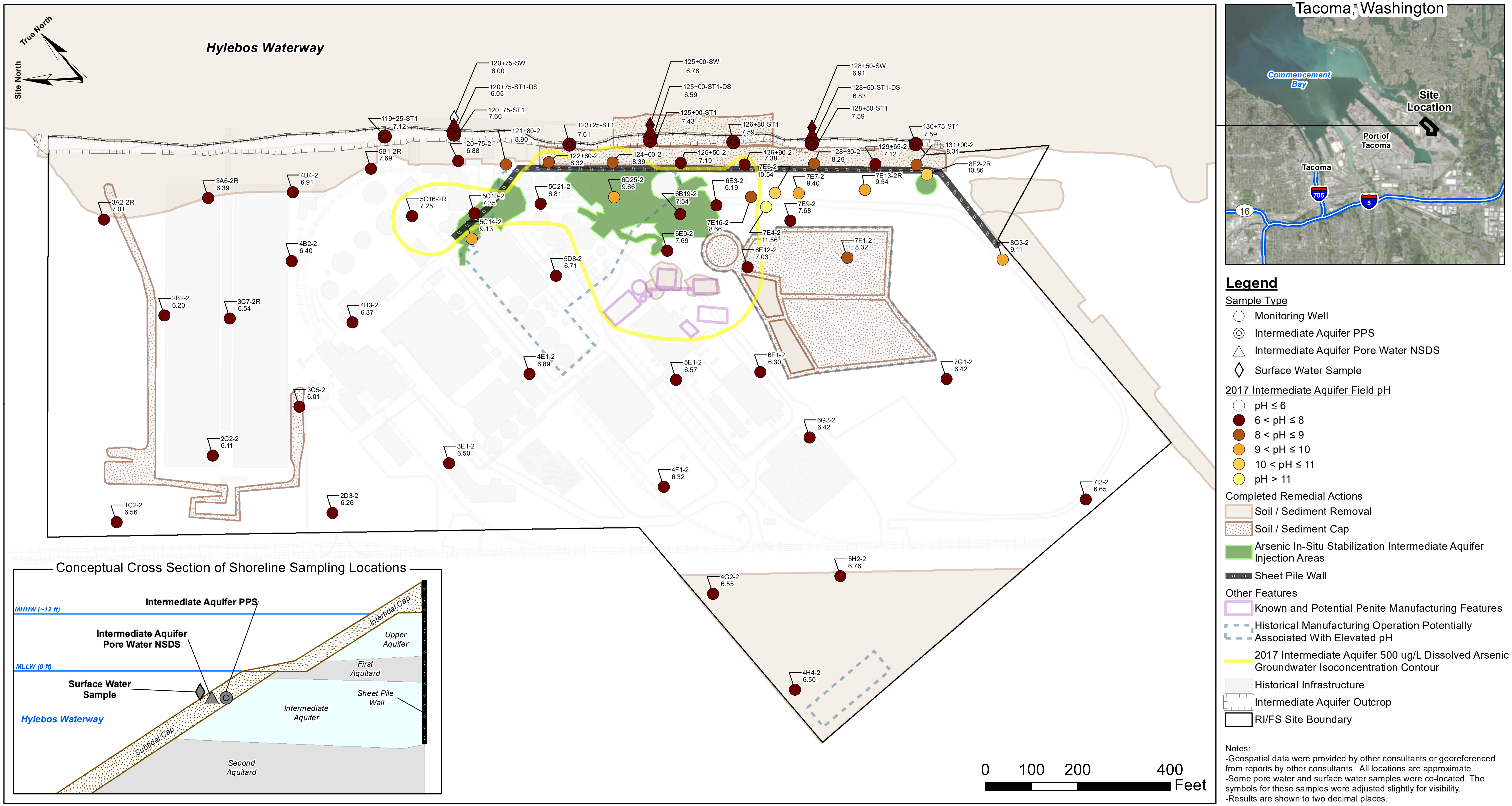

Legend

Sample Type

- ○ Monitoring Well
- ◎ Intermediate Aquifer PPS
- △ Intermediate Aquifer Pore Water NSDS
- ◊ Surface Water Sample

2017 Intermediate Aquifer Field pH

- ○ pH ≤ 6
- ● 6 < pH ≤ 8
- ● 8 < pH ≤ 9
- ● 9 < pH ≤ 10
- ● 10 < pH ≤ 11
- ● pH > 11

Completed Remedial Actions

- ▭ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- 🟩 Arsenic In-Situ Stabilization Intermediate Aquifer Injection Areas
- ▬ Sheet Pile Wall

Other Features

- ▭ Known and Potential Penite Manufacturing Features
- ▭ Historical Manufacturing Operation Potentially Associated With Elevated pH
- ▬ 2017 Intermediate Aquifer 500 ug/L Dissolved Arsenic Groundwater Isoconcentration Contour
- ▭ Historical Infrastructure
- ▭ Intermediate Aquifer Outcrop
- ▭ RI/FS Site Boundary

Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.
-Results are shown to two decimal places.

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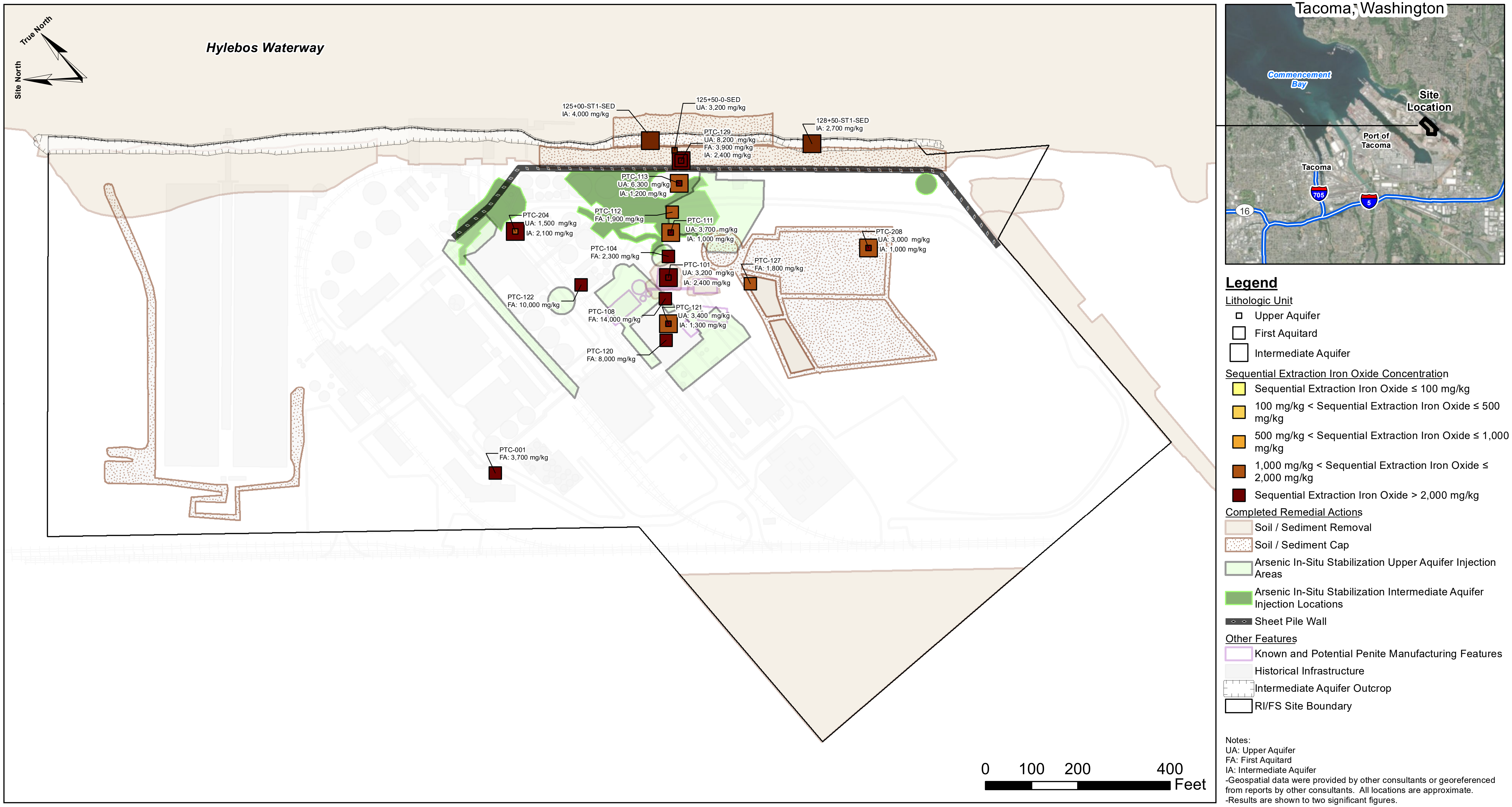
2017 Field pH Results in the Intermediate Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-13



Notes:
UA: Upper Aquifer
FA: First Aquitard
IA: Intermediate Aquifer
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Results are shown to two significant figures.

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-14_Seq_Ext_Ferric_Iron_SO_SED.mxd; Author: VN; Date Saved: 6/18/2019

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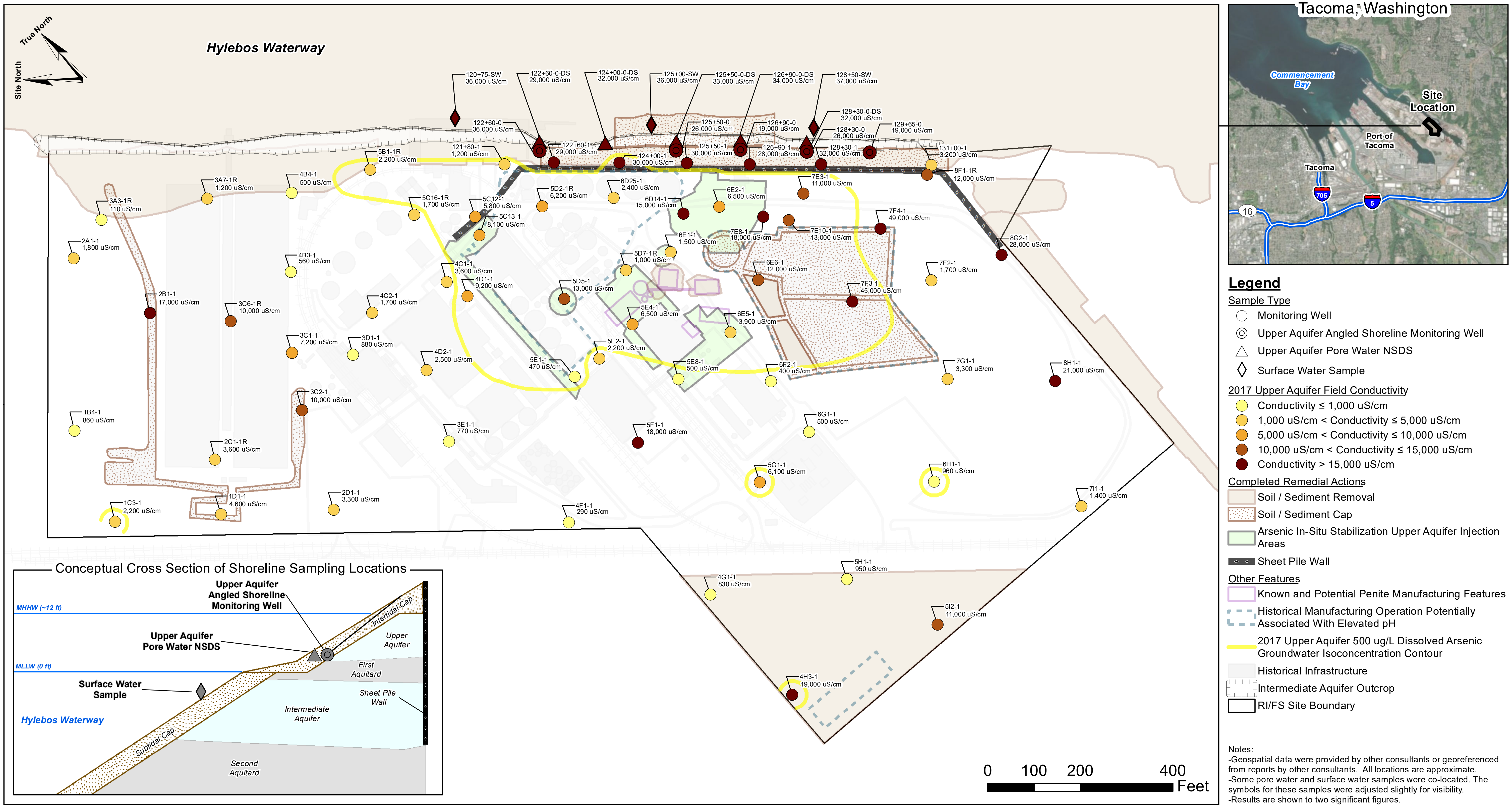
Sequential Extraction Iron Oxide (e.g., Ferric Iron Oxide) Concentrations for Soil and Sediment
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-14



Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.
-Results are shown to two significant figures.

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-15_2017_UA_FieldConductivity.mxd; Author: KR; Date Saved: 6/18/2019

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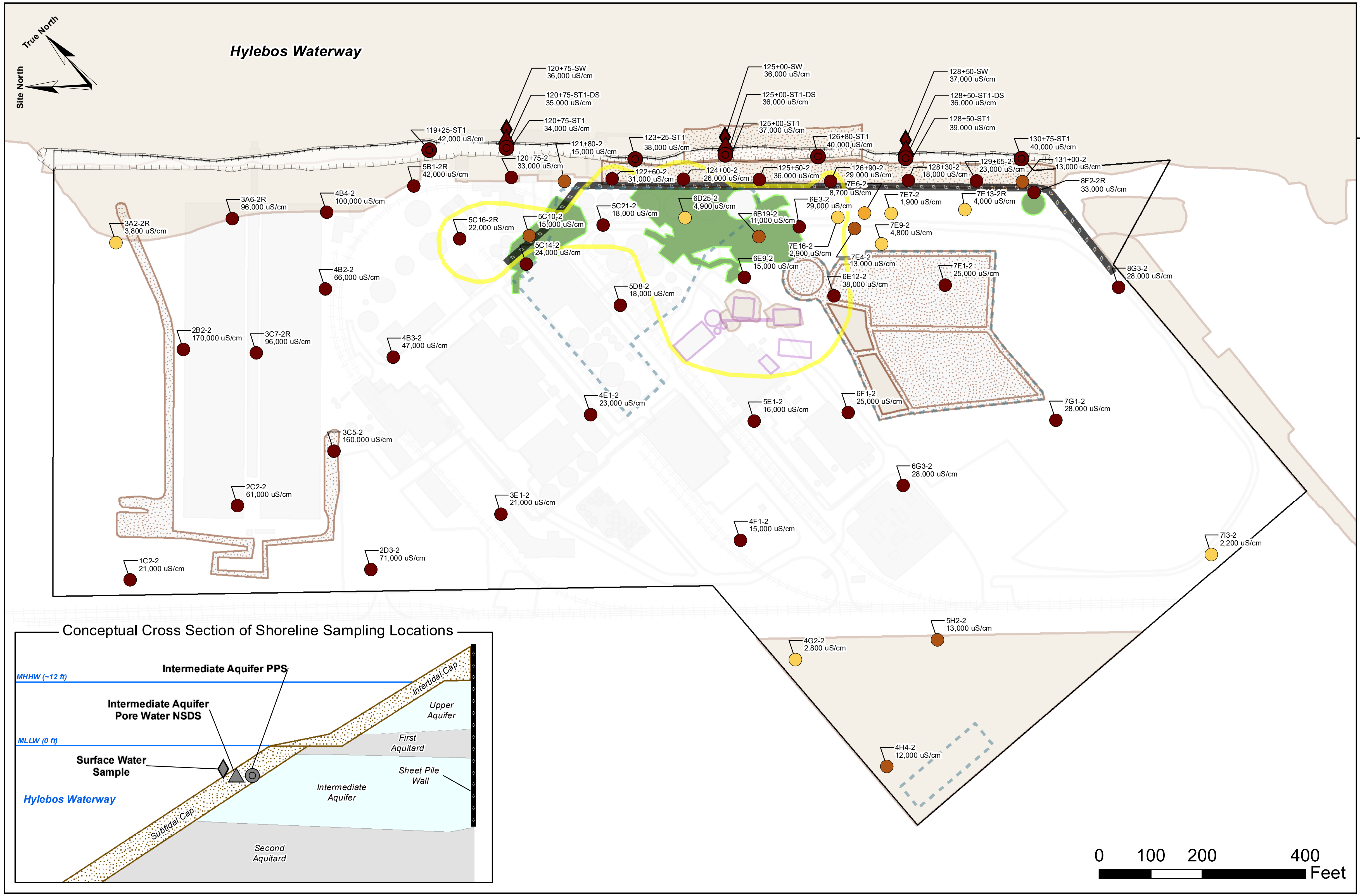
2017 Field Conductivity Results in the Upper Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-15



Legend

Sample Type

- ○ Monitoring Well
- ◎ Intermediate Aquifer PPS
- △ Intermediate Aquifer Pore Water NSDS
- ◇ Surface Water Sample

2017 Intermediate Aquifer Field Conductivity Results

- ● Conductivity ≤ 1,000 uS/cm
- ● 1,000 uS/cm < Conductivity ≤ 5,000 uS/cm
- ● 5,000 uS/cm < Conductivity ≤ 10,000 uS/cm
- ● 10,000 uS/cm < Conductivity ≤ 15,000 uS/cm
- ● Conductivity > 15,000 uS/cm

Completed Remedial Actions

- ▭ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- 🟩 Arsenic In-Situ Stabilization Intermediate Aquifer Injection Areas
- ▬ Sheet Pile Wall

Other Features

- ▭ Known and Potential Penite Manufacturing Features
- ▭ Historical Manufacturing Operation Potentially Associated With Elevated pH
- ▬ 2017 Intermediate Aquifer 500 ug/L Dissolved Arsenic Groundwater Isoconcentration Contour
- ▭ Historical Infrastructure
- ▭ Intermediate Aquifer Outcrop
- ▭ RI/FS Site Boundary

Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.
-Results are shown to two significant figures.

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-16_2017_IA_FieldConductivity.mxd; Author: VN; Date Saved: 7/19/2019

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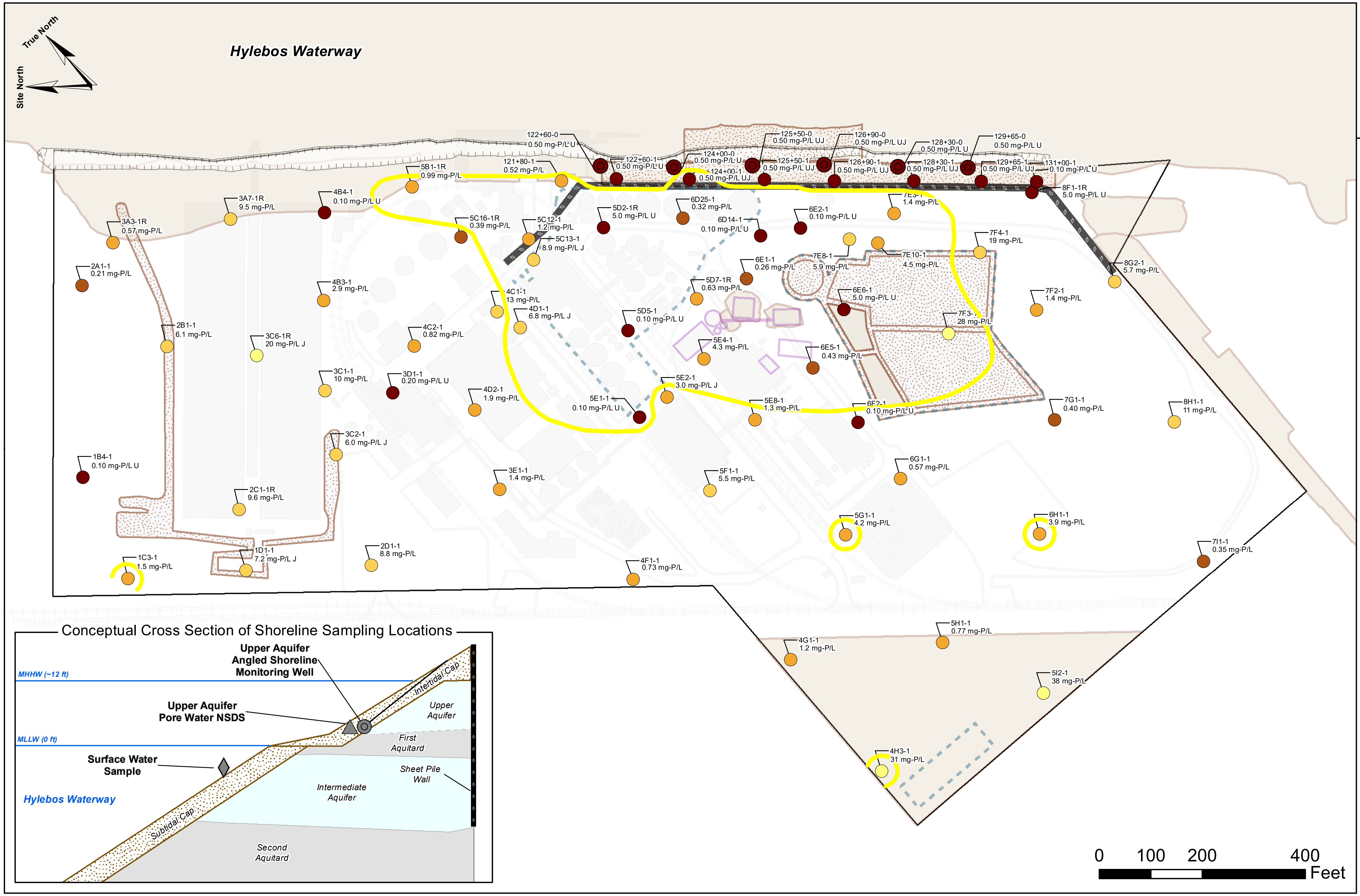
2017 Field Conductivity Results in the Intermediate Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-16



Legend

Sample Type

○ Monitoring Well

◎ Upper Aquifer Angled Shoreline Monitoring Well

2017 Upper Aquifer Ortho-phosphorus Concentrations

● Phos ≤ 0.1 mg-P/L (or Not Detected)

● 0.1 mg-P/L < Phos ≤ 0.5 mg-P/L

● 0.5 mg-P/L < Phos ≤ 5.0 mg-P/L

● 5.0 mg-P/L < Phos ≤ 20 mg-P/L

● Phos > 20 mg-P/L

Completed Remedial Actions

▭ Soil / Sediment Removal

▨ Soil / Sediment Cap

▬ Sheet Pile Wall

Other Features

▭ Known and Potential Penite Manufacturing Features

▭ Historical Manufacturing Operation Potentially Associated With Elevated pH

▬ 2017 Upper Aquifer 500 ug/L Dissolved Arsenic Groundwater Isoconcentration Contour

▭ Historical Infrastructure

▭ Intermediate Aquifer Outcrop

▭ RI/FS Site Boundary

Notes:
J: Estimated concentration
U: Constituent was not detected at the shown reporting limit
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.
-Results are shown to two significant figures.

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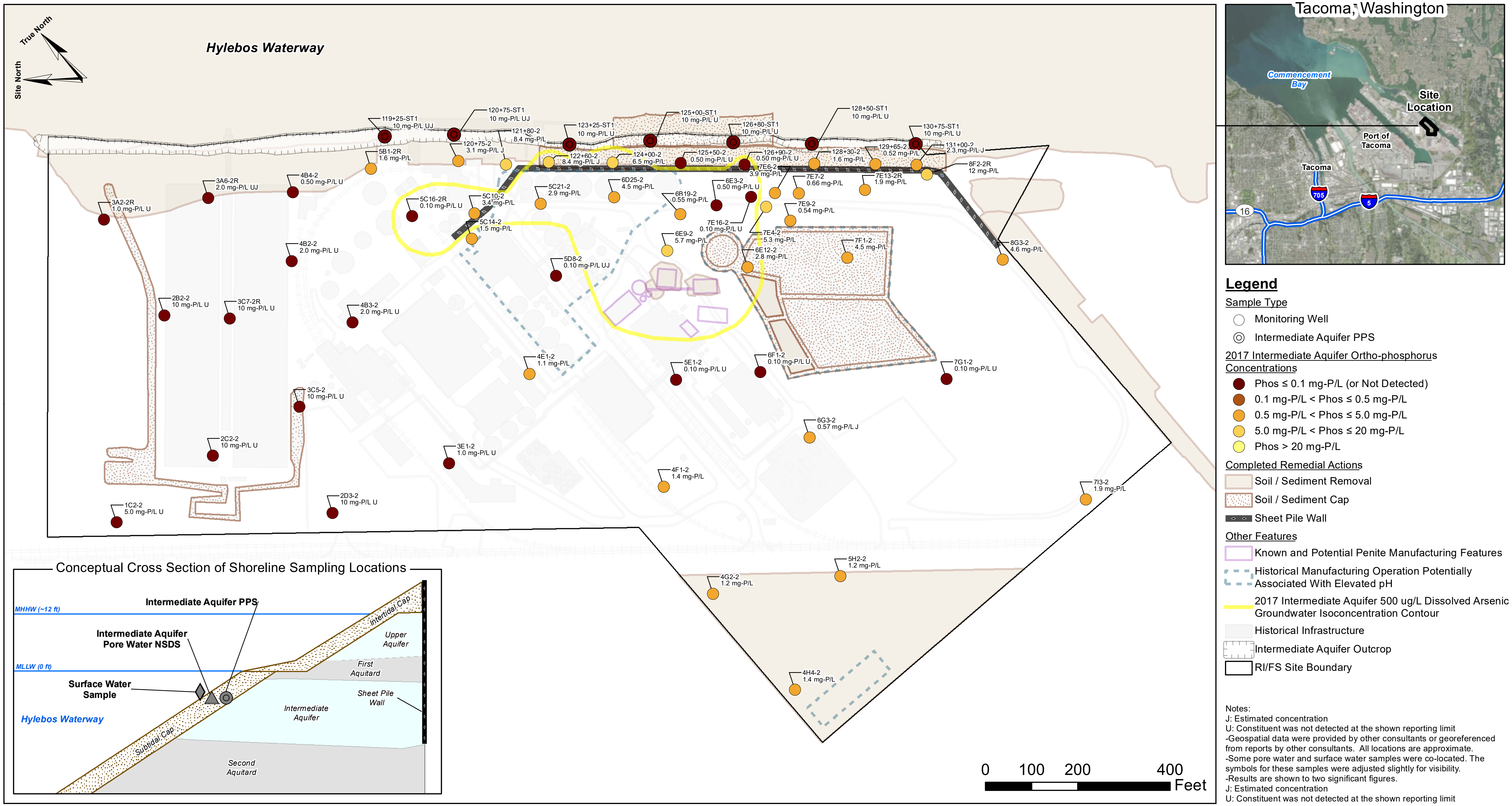
2017 Dissolved Ortho-phosphorus Concentrations in the Upper Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-17

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-17_2017_UA_OrthoPHOS.mxd; Author: VN; Date Saved: 6/27/2019



Notes:
J: Estimated concentration
U: Constituent was not detected at the shown reporting limit
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.
-Results are shown to two significant figures.
J: Estimated concentration
U: Constituent was not detected at the shown reporting limit

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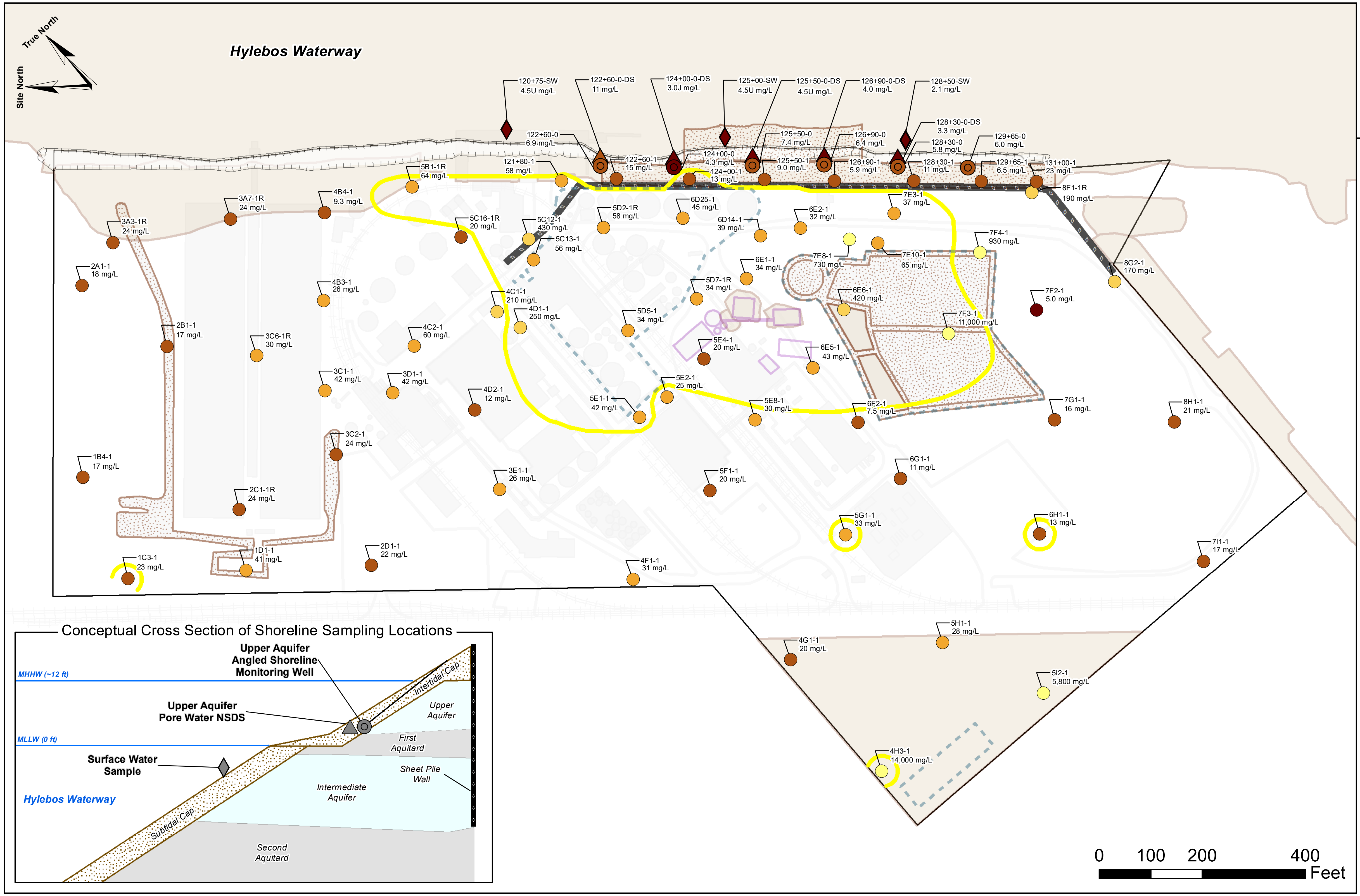
2017 Dissolved Ortho-phosphorus Concentrations in the Intermediate Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-18

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-18_2017_IA_OrthoPHOS.mxd; Author: VN; Date Saved: 7/19/2019



Legend

Sample Type
- ○ Monitoring Well
- ◎ Upper Aquifer Angled Shoreline Monitoring Well
- △ Upper Aquifer Pore Water NSDS
- ◇ Surface Water Sample

2017 Upper Aquifer Silicon Concentrations
- ● Dissolved Silicon ≤ 5 mg/L (or Not Detected)
- ● 5 mg/L < Dissolved Silicon ≤ 25 mg/L
- ● 25 mg/L < Dissolved Silicon ≤ 100 mg/L
- ● 100 mg/L < Dissolved Silicon ≤ 500 mg/L
- ● Dissolved Silicon > 500 mg/L

Completed Remedial Actions
- ▭ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- ▬ Sheet Pile Wall

Other Features
- ▭ Known and Potential Penite Manufacturing Features
- ▭ Historical Manufacturing Operation Potentially Associated With Elevated pH
- ▬ 2017 Upper Aquifer 500 ug/L Dissolved Arsenic Groundwater Isoconcentration Contour
- ▭ Historical Infrastructure
- ▭ Intermediate Aquifer Outcrop
- ▭ RI/FS Site Boundary

Notes:
J: Estimated concentration
U: Constituent was not detected at the shown reporting limit
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.
-Results are shown to two significant figures.

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-19_2017_UA_Diss_Silicon.mxd; Author: KR; Date Saved: 6/27/2019

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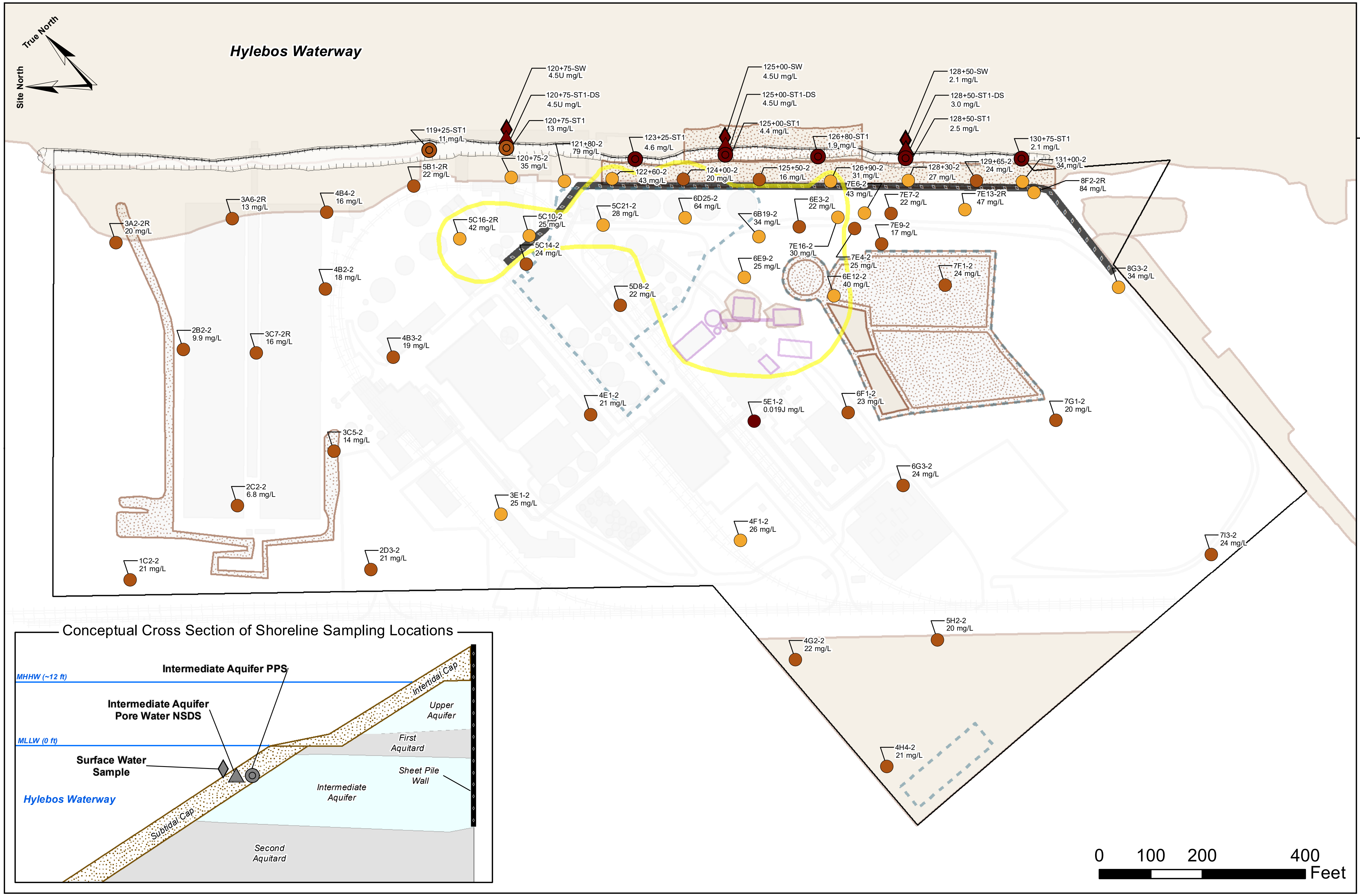
2017 Dissolved Silicon Concentrations in the Upper Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-19



Legend

Sample Type
- ○ Monitoring Well
- ◎ Intermediate Aquifer PPS
- △ Intermediate Aquifer Pore Water NSDS
- ◇ Surface Water Sample

2017 Intermediate Aquifer Silicon Concentrations
- ● Dissolved Silicon ≤ 5 mg/L (or Not Detected)
- ● 5 mg/L < Dissolved Silicon ≤ 25 mg/L
- ● 25 mg/L < Dissolved Silicon ≤ 100 mg/L
- ● 100 mg/L < Dissolved Silicon ≤ 500 mg/L
- ● Dissolved Silicon > 500 mg/L

Completed Remedial Actions
- ▭ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- ▬ Sheet Pile Wall

Other Features
- ▭ Known and Potential Penite Manufacturing Features
- ⬚ Historical Manufacturing Operation Potentially Associated With Elevated pH
- ▬ 2017 Intermediate Aquifer 500 ug/L Dissolved Arsenic Groundwater Isoconcentration Contour
- ▭ Historical Infrastructure
- ⬚ Intermediate Aquifer Outcrop
- ▭ RI/FS Site Boundary

Notes:
J: Estimated concentration
U: Constituent was not detected at the shown reporting limit
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Some pore water and surface water samples were co-located. The symbols for these samples were adjusted slightly for visibility.
-Results are shown to two significant figures.

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-20_2017_IA_Diss_Silicon.mxd; Author: VN; Date Saved: 7/19/2019

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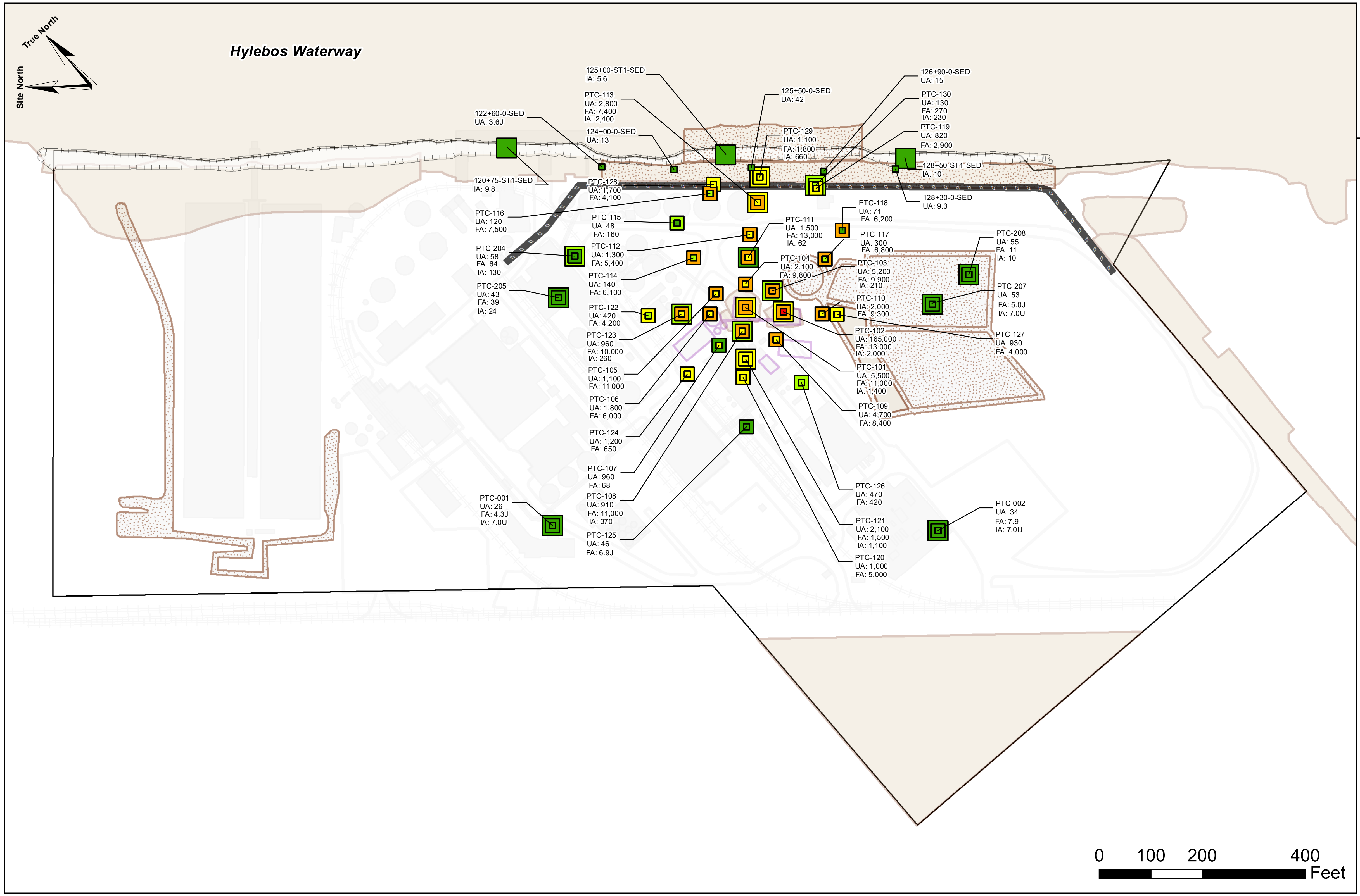
2017 Dissolved Silicon Concentrations in the Intermediate Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-20



Legend

Lithologic Unit

- ▫ Upper Aquifer
- ☐ First Aquitard
- ☐ Intermediate Aquifer

Arsenic Soil or Sediment Concentration

- 🟩 Arsenic ≤ 88 mg/kg (or Not Detected)
- 🟩 88 mg/kg < Arsenic ≤ 590 mg/kg
- 🟨 590 mg/kg < Arsenic ≤ 5,000 mg/kg
- 🟧 5,000 mg/kg < Arsenic ≤ 20,000 mg/kg
- 🟥 Arsenic > 20,000 mg/kg

Completed Remedial Actions

- ▭ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- ▬ Sheet Pile Wall

Other Features

- ▭ Known and Potential Penite Manufacturing Features
- ▭ Historical Infrastructure
- ▭ Intermediate Aquifer Outcrop
- ☐ RI/FS Site Boundary

Notes:
J: Estimated concentration
U: Constituent was not detected at the shown reporting limit
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-The maximum concentration is shown if multiple sample intervals were collected from the same lithologic unit in a given boring.
-Both laboratory and field x-ray fluorescence sample results were included.
-Results are shown to two significant figures.

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-21_As_SO_2017-2018_Litho.mxd; Author: VN; Date Saved: 6/27/2019

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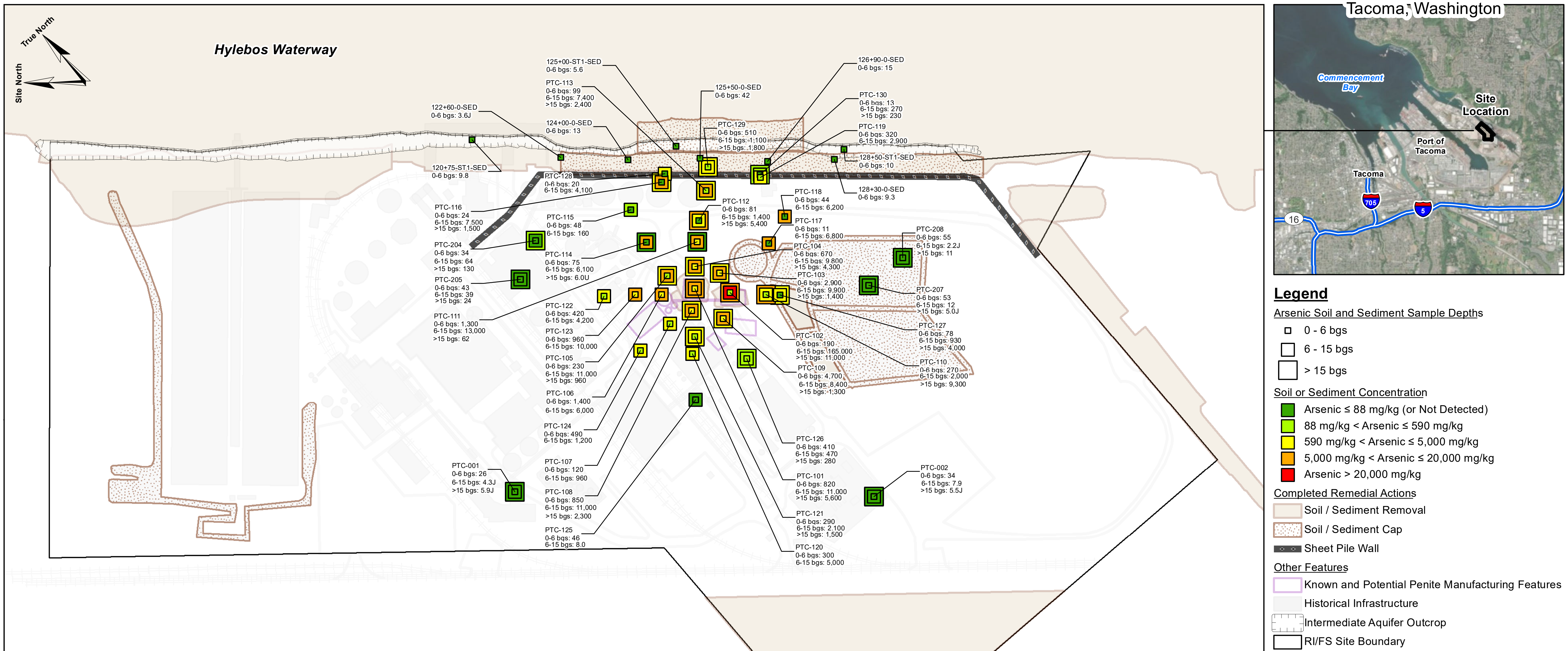
Arsenic Soil Concentrations in 2017 and 2018 Borings
(By Lithologic Unit)
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-21



Legend

Arsenic Soil and Sediment Sample Depths
- ▫ 0 - 6 bgs
- ☐ 6 - 15 bgs
- ☐ > 15 bgs

Soil or Sediment Concentration
- 🟩 Arsenic ≤ 88 mg/kg (or Not Detected)
- 🟩 88 mg/kg < Arsenic ≤ 590 mg/kg
- 🟨 590 mg/kg < Arsenic ≤ 5,000 mg/kg
- 🟧 5,000 mg/kg < Arsenic ≤ 20,000 mg/kg
- 🟥 Arsenic > 20,000 mg/kg

Completed Remedial Actions
- ▭ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- ▬ Sheet Pile Wall

Other Features
- ☐ Known and Potential Penite Manufacturing Features
- ▭ Historical Infrastructure
- ☐ Intermediate Aquifer Outcrop
- ☐ RI/FS Site Boundary

Notes:
J: Estimated concentration
U: Constituent was not detected at the shown reporting limit
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-The maximum concentration is shown if multiple sample intervals were collected from the same lithologic unit in a given boring.
-Both laboratory and field x-ray fluorescence sample results were included.
-Results are shown to two significant figures.

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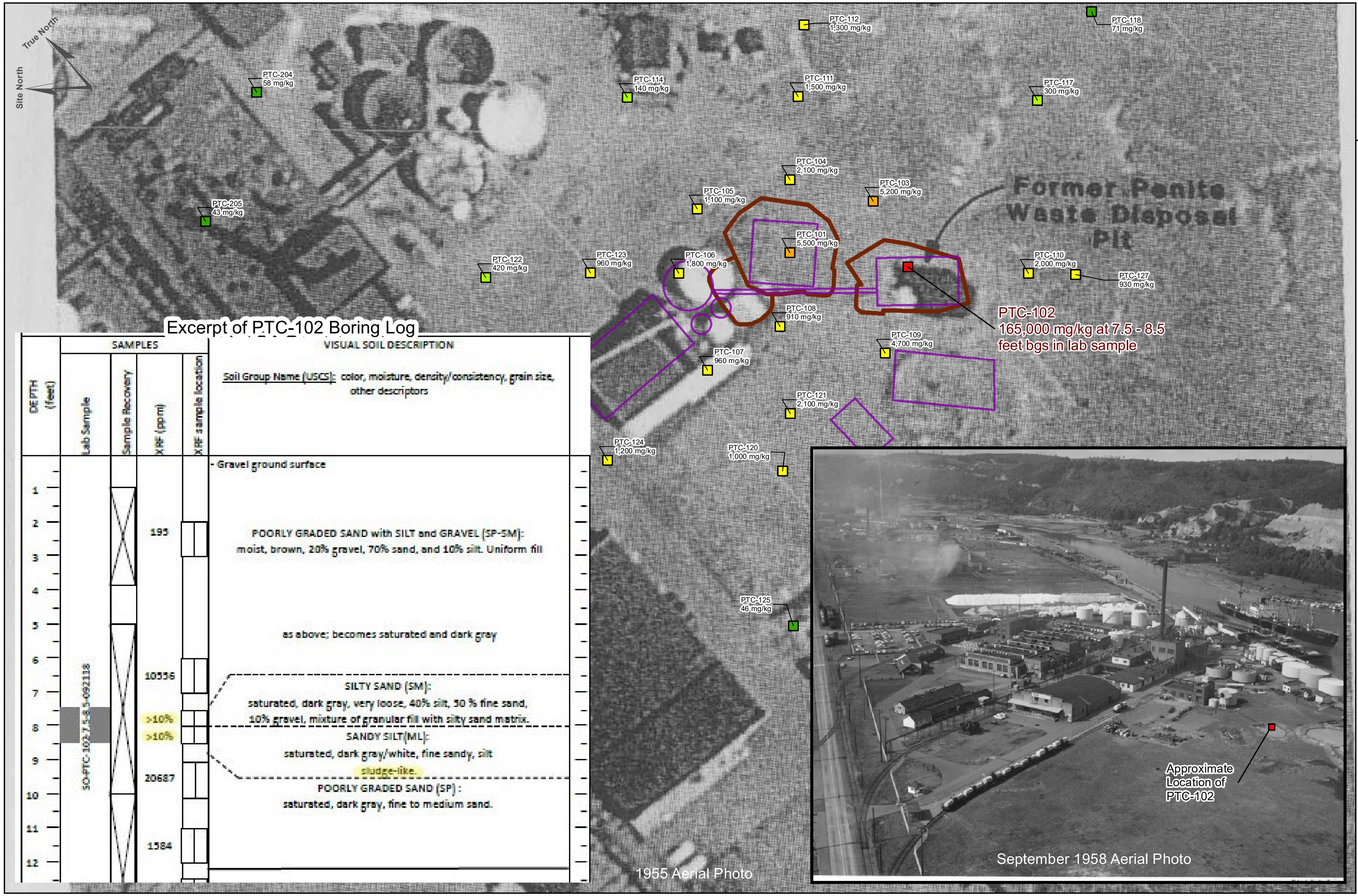
Arsenic Soil Concentrations in 2017 and 2018 Borings
(By Depth)
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-22

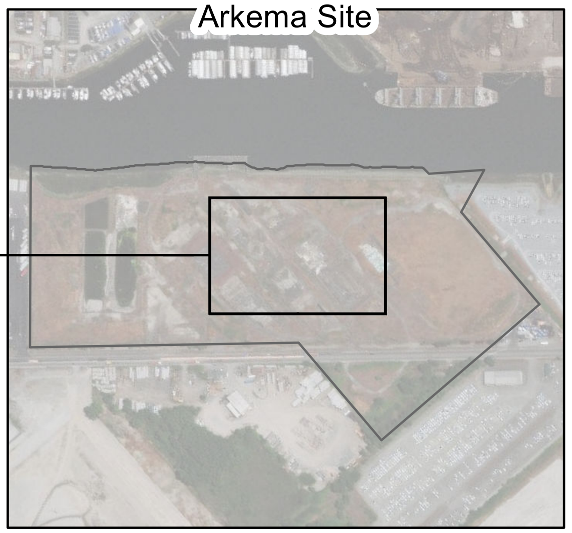
Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-22_As_SO_2017-2018_Depth.mxd; Author: VN; Date Saved: 6/27/2019

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-23_Penite_Pit2_Remaining_Source.mxd; Author: VN; Date Saved: 6/27/2019



Excerpt of PTC-102 Boring Log

DEPTH (feet)	SAMPLES: Lab Sample	Sample Recovery	XRF (ppm)	XRF sample location	VISUAL SOIL DESCRIPTION Soil Group Name (USCS): color, moisture, density/consistency, grain size, other descriptors
0					- Gravel ground surface
2–3			195		POORLY GRADED SAND with SILT and GRAVEL (SP-SM): moist, brown, 20% gravel, 70% sand, and 10% silt. Uniform fill
5					as above; becomes saturated and dark gray
6–7			10536		
7–8	SO-PTC-102-7.5-8.5-092118		>10% >10%		SILTY SAND (SM): saturated, dark gray, very loose, 40% silt, 50 % fine sand, 10% gravel, mixture of granular fill with silty sand matrix.
8–9					SANDY SILT(ML): saturated, dark gray/white, fine sandy, silt sludge-like.
9–10			20687		POORLY GRADED SAND (SP): saturated, dark gray, fine to medium sand.
11			1584		
12					



Legend

Maximum Upper Aquifer Arsenic Soil Concentration in 2017 and 2018 Soil Borings

- 🟩 Arsenic ≤ 88 mg/kg (or Not Detected)
- 🟩 88 mg/kg < Arsenic ≤ 590 mg/kg
- 🟨 590 mg/kg < Arsenic ≤ 5,000 mg/kg
- 🟧 5,000 mg/kg < Arsenic ≤ 20,000 mg/kg
- 🟥 Arsenic > 20,000 mg/kg

Other Features

- ☐ Known and Potential Penite Manufacturing Features
- ☐ Soil / Sediment Removal

Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-The maximum concentration is shown if multiple sample intervals were collected from the same lithologic unit in a given boring.
-Both laboratory and field x-ray fluorescence sample results were included.
-Results are shown to two significant figures.

0 25 50 100
Feet

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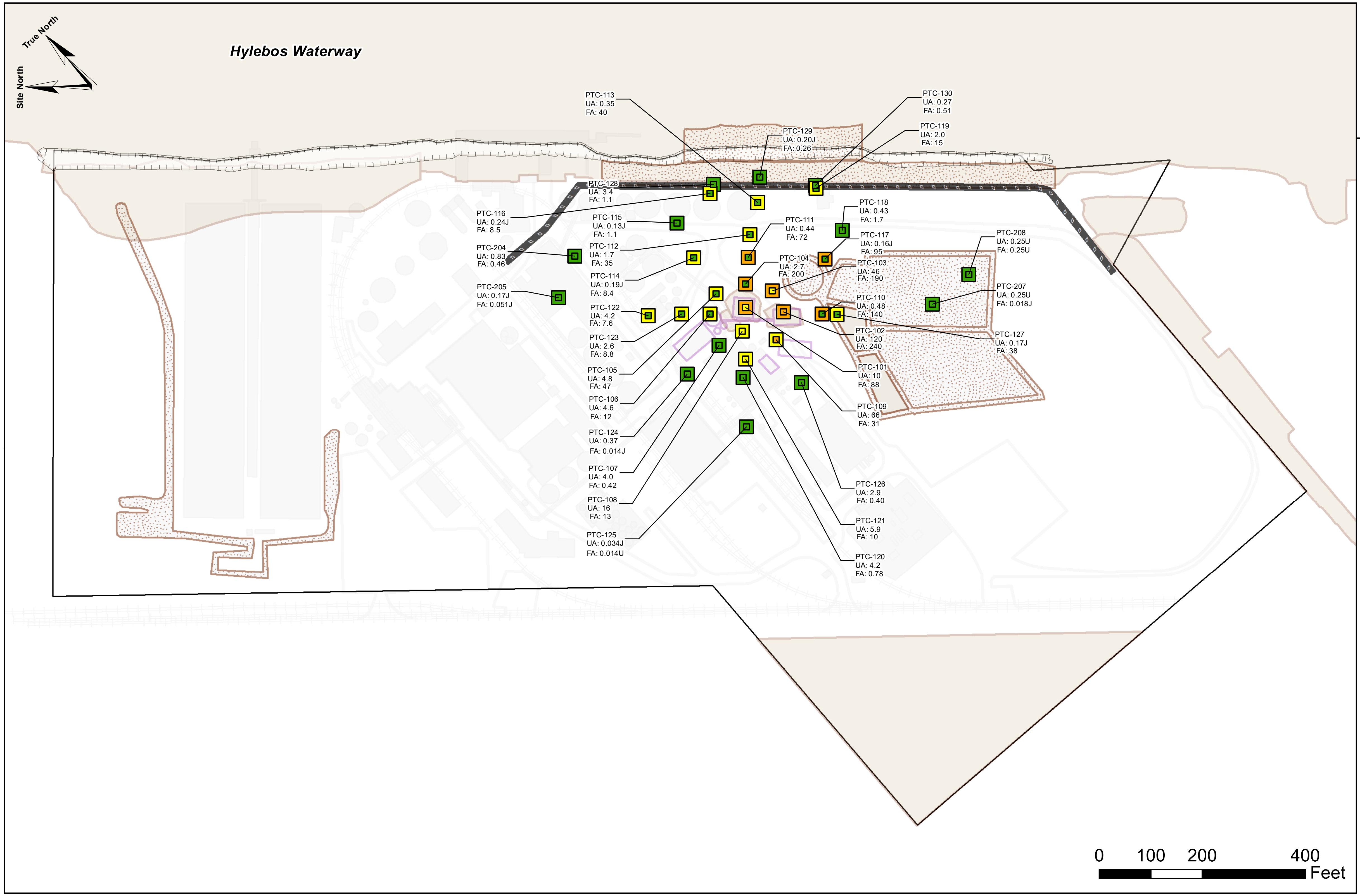
Remaining Source in Former Penite Pit #2
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-23



Legend

Lithologic Unit
- ▫ Upper Aquifer
- ☐ First Aquitard

Arsenic TCLP Concentration
- 🟩 Arsenic ≤ 5 mg/L (or Not Detected)
- 🟨 5 mg/L < Arsenic ≤ 50 mg/L
- 🟧 Arsenic > 50 mg/L

Completed Remedial Actions
- ▭ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- ▬ Sheet Pile Wall

Other Features
- ▭ Known and Potential Penite Manufacturing Features
- ▭ Historical Infrastructure
- ▭ Intermediate Aquifer Outcrop
- ☐ RI/FS Site Boundary

Notes:
J: Estimated concentration
U: Constituent was not detected at the shown reporting limit
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Results are shown to two significant figures.

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-24_As_TCLP_SO_2017-2018_Litho.mxd; Author: VN; Date Saved: 6/27/2019

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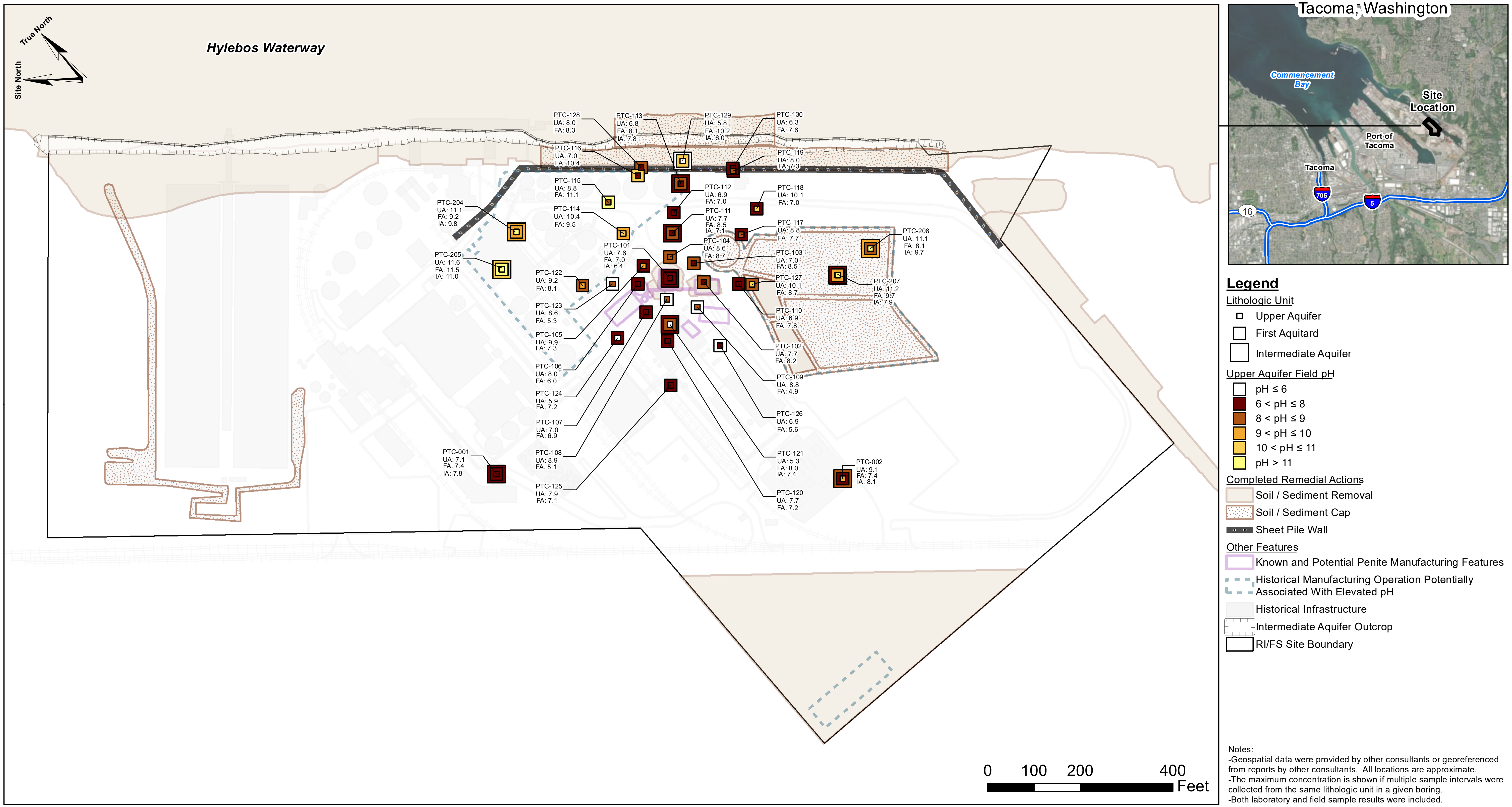
Arsenic TCLP Concentrations in 2017 and 2018 Borings (By Lithologic Unit)
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-24



Legend

Lithologic Unit
- ▫ Upper Aquifer
- ☐ First Aquitard
- ☐ Intermediate Aquifer

Upper Aquifer Field pH
- ☐ pH ≤ 6
- ■ 6 < pH ≤ 8
- ■ 8 < pH ≤ 9
- ■ 9 < pH ≤ 10
- ■ 10 < pH ≤ 11
- ■ pH > 11

Completed Remedial Actions
- ▨ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- ▬ Sheet Pile Wall

Other Features
- ☐ Known and Potential Penite Manufacturing Features
- ☐ Historical Manufacturing Operation Potentially Associated With Elevated pH
- ▨ Historical Infrastructure
- ☐ Intermediate Aquifer Outcrop
- ☐ RI/FS Site Boundary

Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-The maximum concentration is shown if multiple sample intervals were collected from the same lithologic unit in a given boring.
-Both laboratory and field sample results were included.

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\5-25_pH_SO_2017-2018_Litho.mxd; Author: VN; Date Saved: 6/27/2019

PTC™
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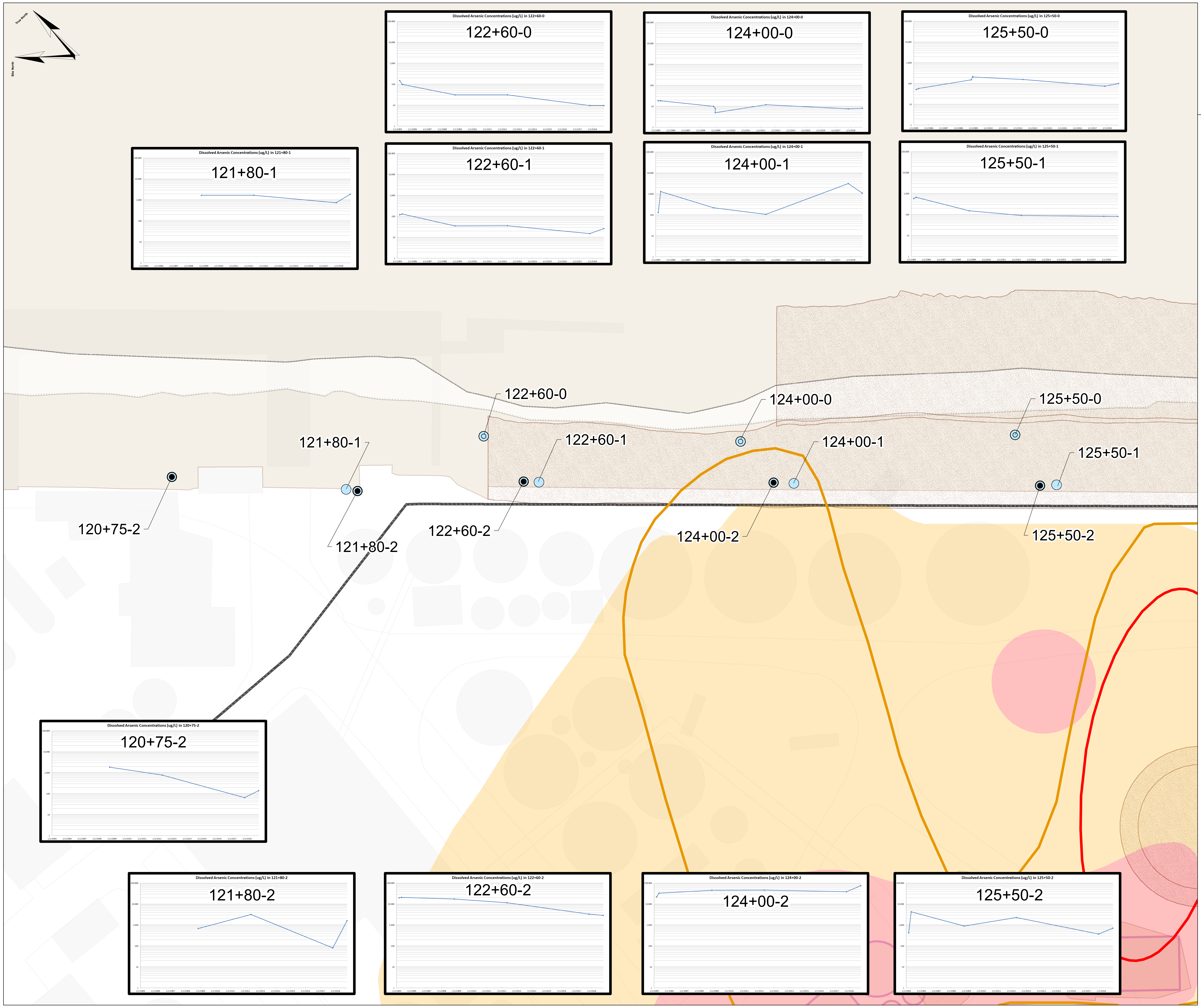
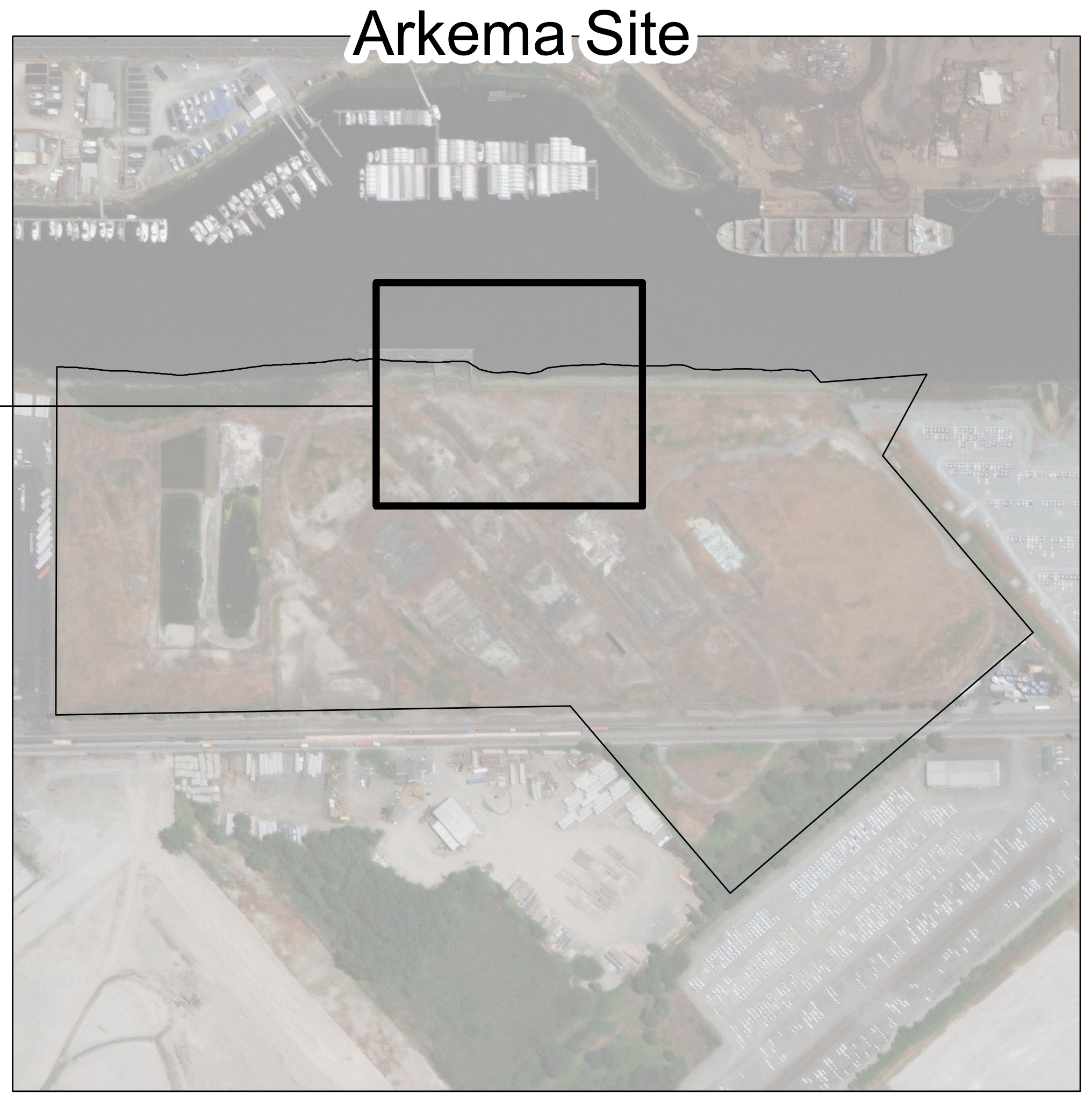
pH Soil Results in 2017 and 2018 Borings
(By Lithologic Unit)
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 5-25





Legend

◎ Upper Aquifer Angled Shoreline Monitoring Well
● Upper Aquifer Monitoring Well
◉ Intermediate Aquifer Monitoring Well

2017 Upper Aquifer Dissolved Arsenic Groundwater Isoconcentration

🟨 5,000 ug/L 🟥 50,000 ug/L

2017 Intermediate Aquifer Dissolved Arsenic Groundwater Isoconcentration Contours

— 5,000 ug/L — 50,000 ug/L

Completed Remedial Actions

▨ Soil / Sediment Removal
▨ Soil / Sediment Cap
— Sheet Pile Wall

Other Features

☐ Known and Potential Penite Manufacturing Features
▨ Historical Infrastructure
☐ Intermediate Aquifer Outcrop
☐ RI/FS Site Boundary

Notes:
-Non-detect results were assumed to equal half the reporting limit in the trend analysis.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

0 25 50 75
Feet

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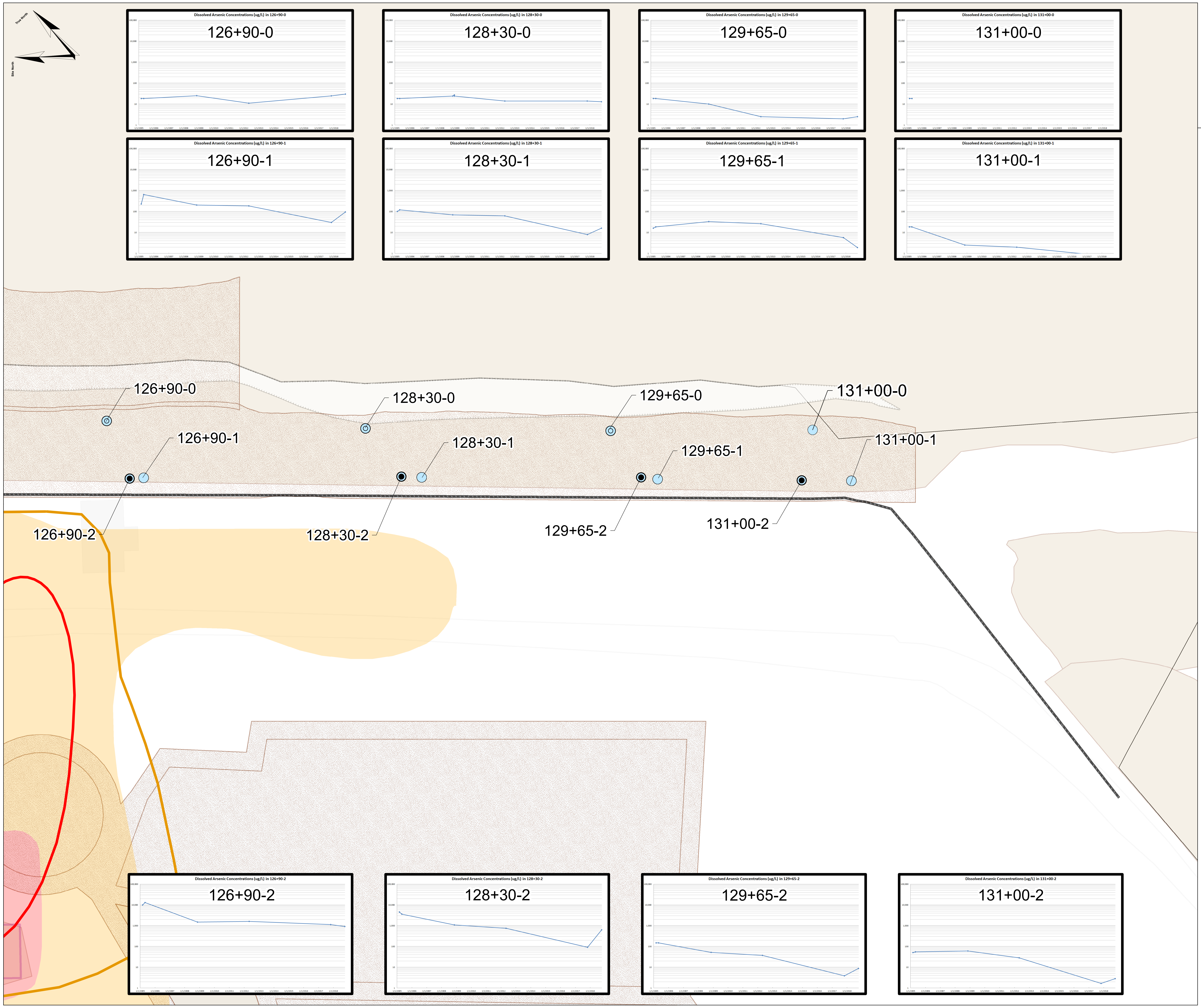
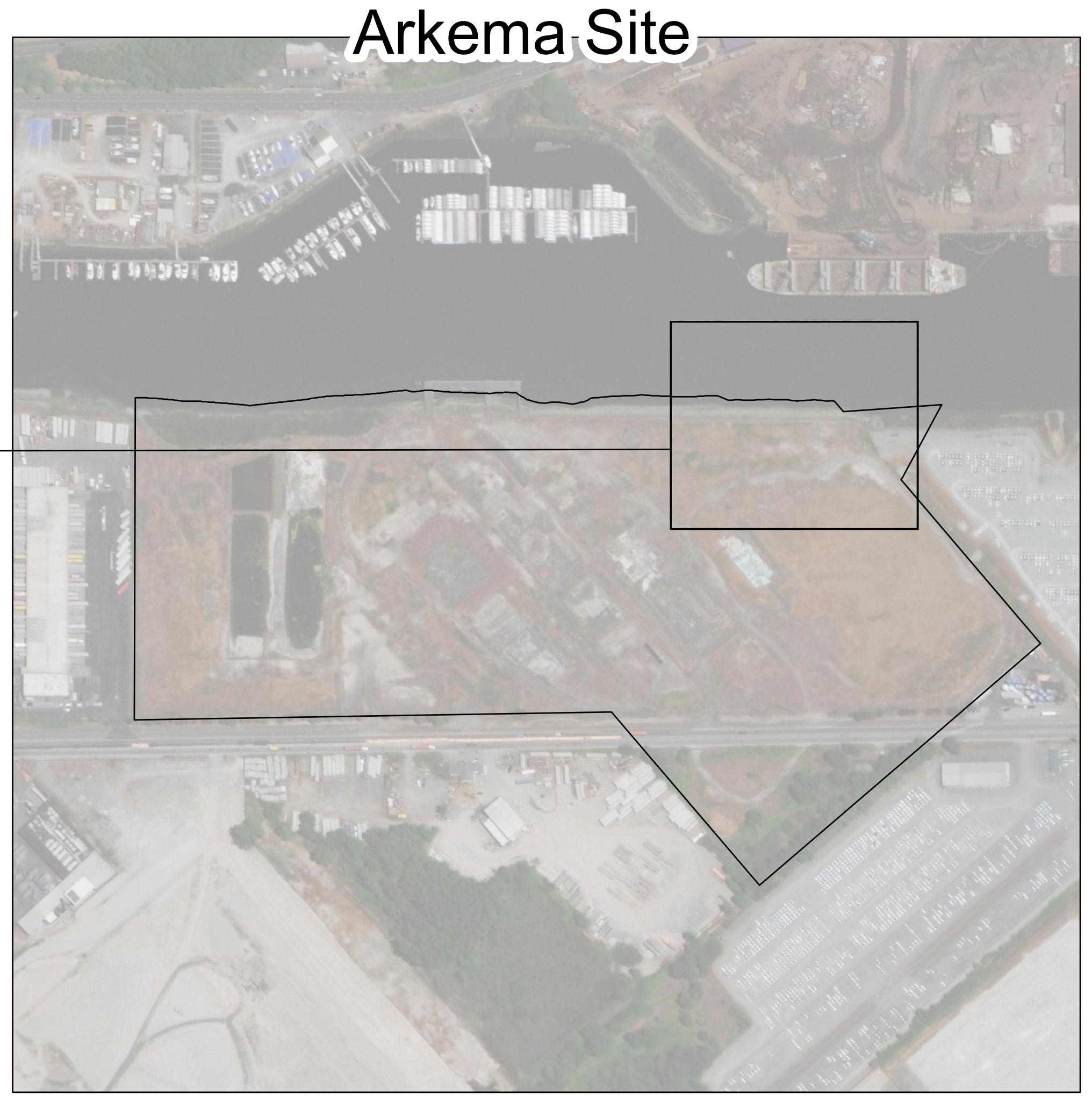
Dissolved Arsenic Time-Series Plots for Near Shore Monitoring Wells (Northern Portion)
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-1A

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-1A_Near_Shore_Diss_As_Time-Series_Plots.mxd; Author: VN; Date Saved: 5/30/2019



Arkema Site



Legend

◎ Upper Aquifer Angled Shoreline Monitoring Well
○ Upper Aquifer Monitoring Well
● Intermediate Aquifer Monitoring Well

2017 Upper Aquifer Dissolved Arsenic Groundwater Isoconcentration
🟨 5,000 ug/L 🟥 50,000 ug/L

2017 Intermediate Aquifer Dissolved Arsenic Groundwater Isoconcentration Contours
— 5,000 ug/L — 50,000 ug/L

Completed Remedial Actions
▭ Soil / Sediment Removal
▨ Soil / Sediment Cap
— Sheet Pile Wall

Other Features
☐ Known and Potential Penite Manufacturing Features
☐ Historical Infrastructure
☐ Intermediate Aquifer Outcrop
☐ RI/FS Site Boundary

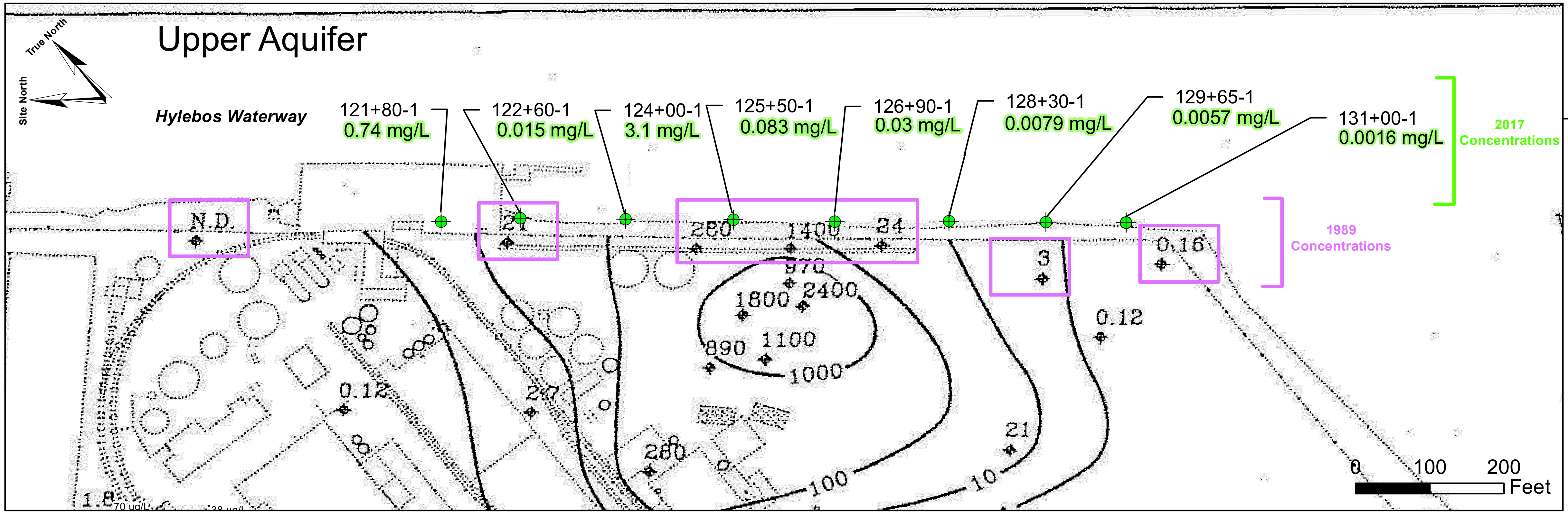
Notes:
-Non-detect results were assumed to equal half the reporting limit in the trend analysis.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

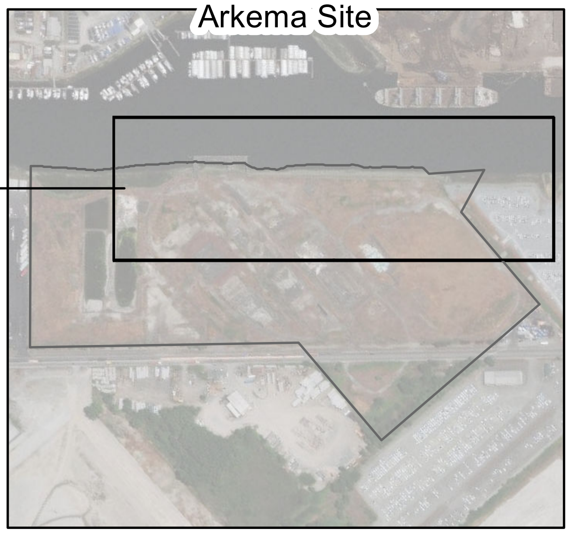
0 25 50 75 Feet

PIONEER
TECHNOLOGIES CORPORATION

Dissolved Arsenic Time-Series Plots for Near Shore Monitoring Wells (Southern Portion)
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

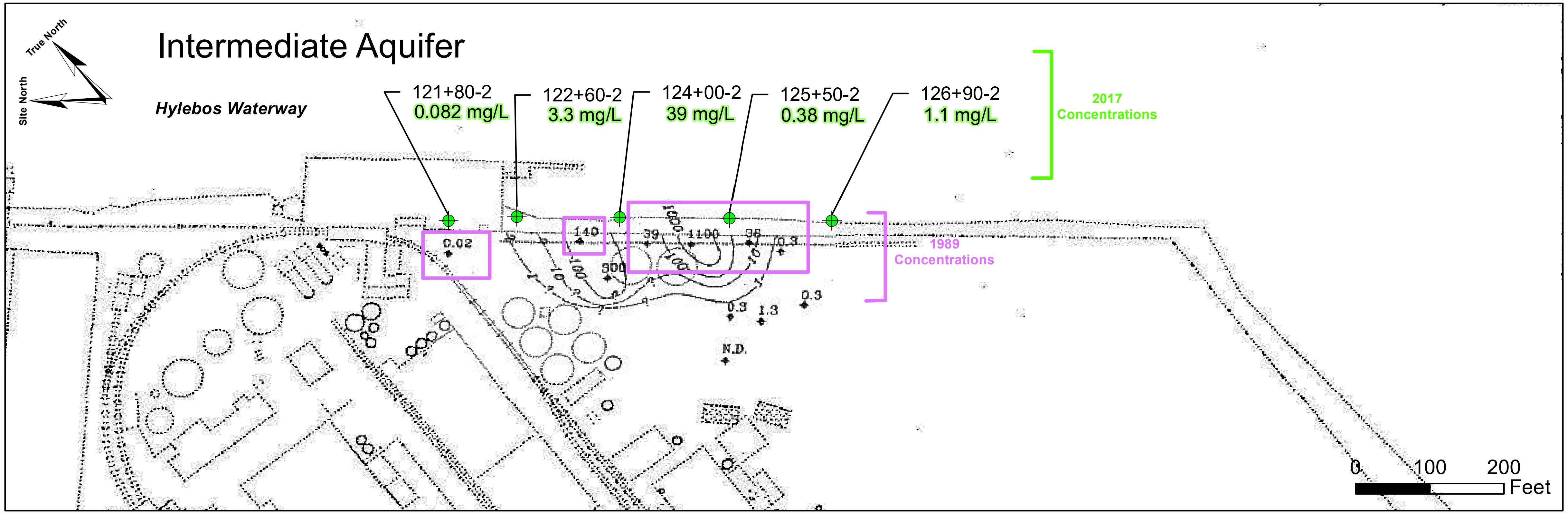
Figure 6-1B





Legend

- 2017 Arsenic Concentrations (mg/L) in Near Shore Monitoring Wells
- 1989 Arsenic Concentrations (mg/L) in Near Shore Monitoring Wells



Notes:
J: Estimated concentration
-Historical concentrations are from the July 1989 event.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Results are shown to two significant figures.

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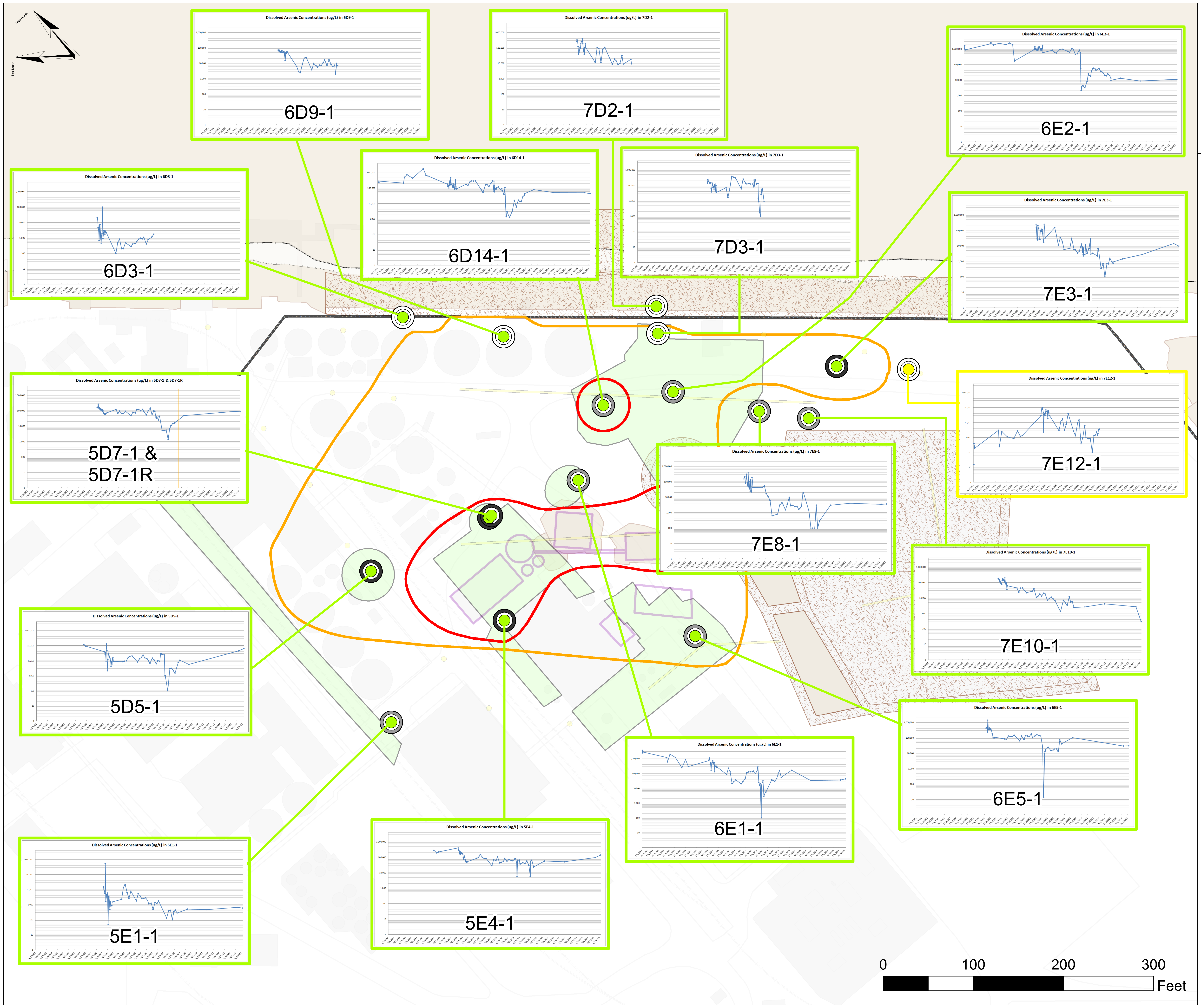
Comparison of 1989 and 2017 Near Shore Arsenic Concentrations
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-2

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-2_Comp_of_His_and_Current_NS_As_MK.mxd; Author: VN; Date Saved: 3/27/2019



Tacoma, Washington

Legend

Interpretation From 1980s or Early 1990s Through 2004
- ● Decreasing Concentration
- ● Initial Concentration Increase Due to SPW Instalation, then Decreasing Concentration
- ● Increasing Concentration
- ○ No Interpretation

Interpretation of Potential Post-2004 Rebound
- ◎ Negligible Rebound
- ◯ Potential Rebound
- ◎ No Post-2004 Data

2017 Upper Aquifer Dissolved Arsenic Groundwater Isoconcentration Contours
- 🟥 50,000 ug/L
- 🟧 5,000 ug/L

Completed Remedial Actions
- ○ Arsenic P&T Upper Aquifer Extraction Well Location
- ▬ Arsenic P&T Upper Aquifer Extraction Trench Location
- ▨ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- 🟩 Arsenic In-Situ Stabilization Upper Aquifer Injection Locations
- ▬ Sheet Pile Wall

Other Features
- ☐ Known and Potential Penite Manufacturing Features
- ▨ Historical Infrastructure
- ☐ Intermediate Aquifer Outcrop
- ☐ RI/FS Site Boundary

Notes:
-MWs within a maximum concentration greater than 50,000 ug/L and more than 5 post-1990 results spanning a duration of at least 8 years are shown.
-Non-detect results were assumed to equal half the reporting limit in the trend analysis.
-Results from a replacement MW were combined with results from the original decommissioned MW. MW IDs for the replacement MW are shown on this figure. Vertical orange line indicates the timing of the transition from the original decommissioned MW to the replacement MW.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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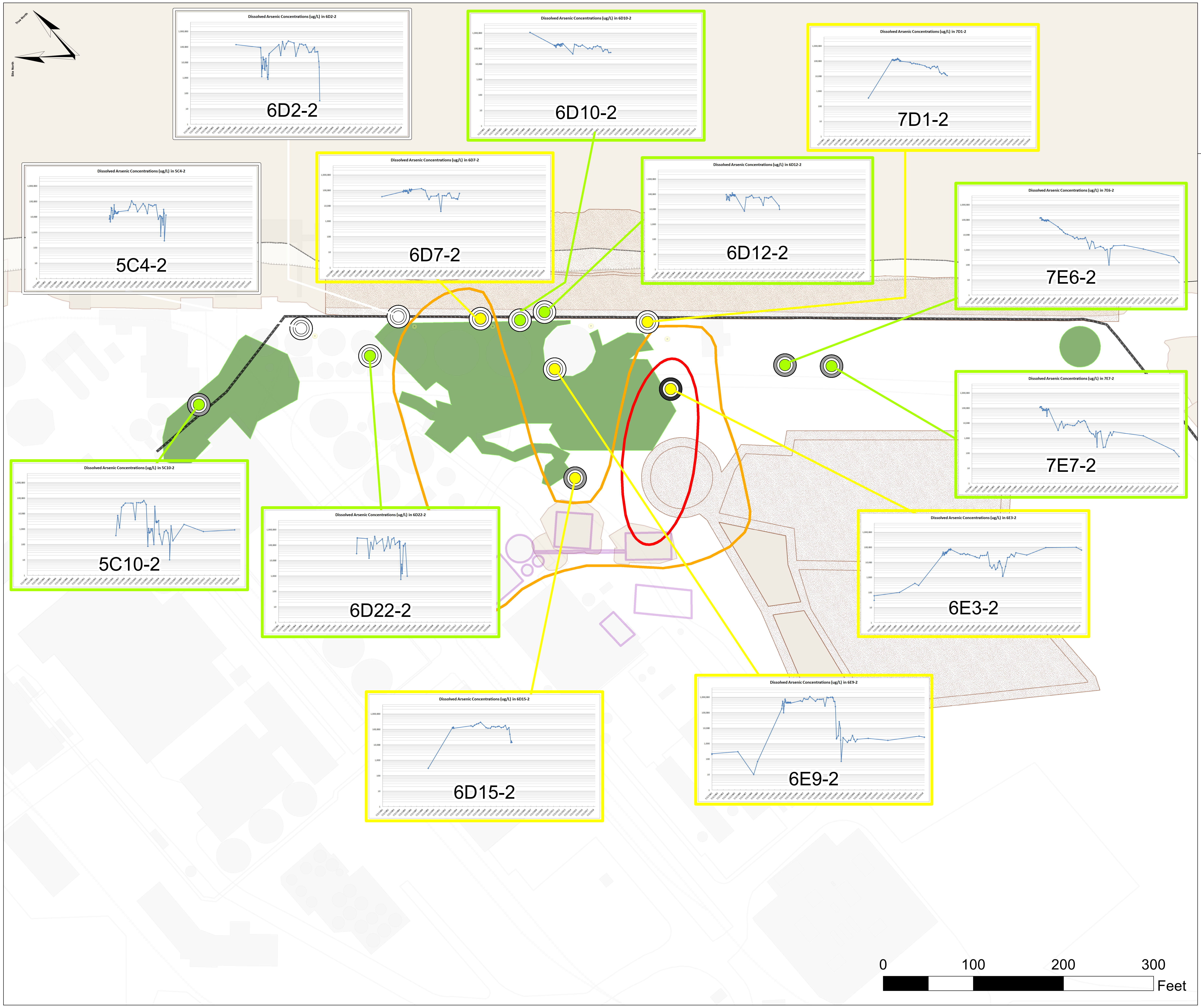
Key Dissolved Arsenic Time-Series Plots for the Upper Aquifer Plume Core
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-3

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-3_UA_Key_Diss_As_Time-Series_Plots.mxd; Author: VN; Date Saved: 7/17/2019



Tacoma, Washington

Legend

Interpretation From 1980s or Early 1990s Through 2004

- ● Decreasing Concentration
- ● Initial Concentration Increase Due to SPW Instalation, then Decreasing Concentration
- ● Increasing Concentration
- ○ No Interpretation

Interpretation of Potential Post-2004 Rebound

- ◯ Negligible Rebound
- ◯ Potential Rebound
- ◯ No Post-2004 Data

2017 Intermediate Aquifer Dissolved Arsenic Groundwater Isoconcentration Contours

- — 50,000 ug/L
- — 5,000 ug/L

Completed Remedial Activities

- • Arsenic P&T Intermediate Aquifer Extraction Well Location
- ■ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- ■ Arsenic In-Situ Stabilization Intermediate Aquifer Injection Locations
- — Sheet Pile Wall

Other Features

- ☐ Known and Potential Penite Manufacturing Features
- ■ Historical Infrastructure
- ☐ Intermediate Aquifer Outcrop
- ☐ RI/FS Site Boundary

Notes:
-MWs within a maximum concentration greater than 50,000 ug/L and more than 5 post-1990 results spanning a duration of at least 8 years are shown.
-Non-detect results were assumed to equal half the reporting limit in the trend analysis.
-Results from a replacement MW were combined with results from the original decommissioned MW. MW IDs for the replacement MW are shown on this figure.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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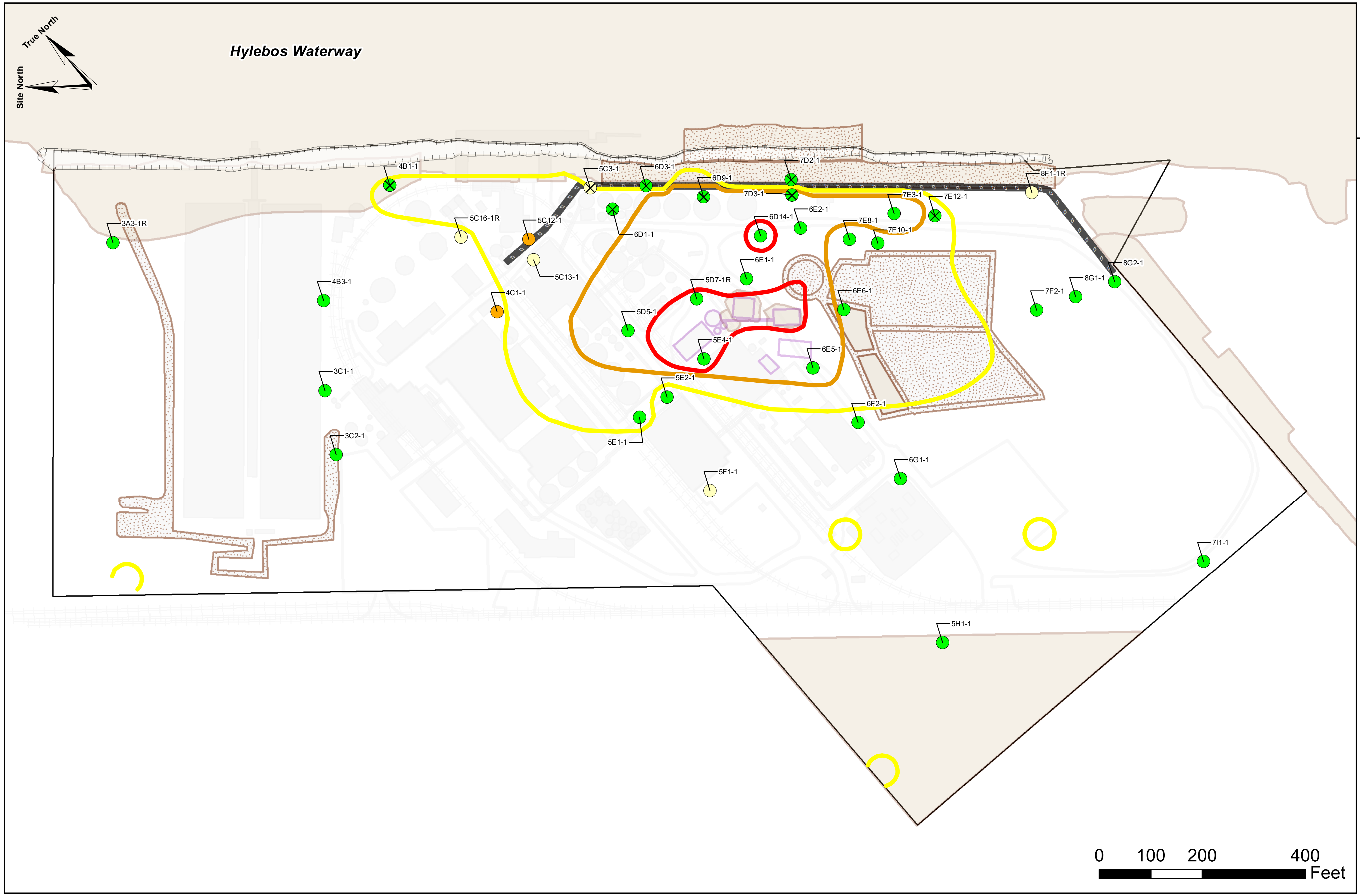
Key Dissolved Arsenic Time-Series Plots for the Intermediate Aquifer Plume Core
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-4

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-4_IA_Key_Diss_As_Time-Series_Plots.mxd; Author: KR; Date Saved: 7/17/2019



Legend

Sample Type

○ Monitoring Well

Upper Aquifer Dissolved Arsenic Mann-Kendall

● Decreasing Trend

○ Insufficient Evidence of Trend

● Increasing Trend

× Decommissioned Wells

2017 Upper Aquifer Dissolved Arsenic Groundwater Isoconcentration Contours

— 500 ug/L — 5,000 ug/L — 50,000 ug/L

Completed Remedial Actions

▭ Soil / Sediment Removal

▨ Soil / Sediment Cap

▬ Sheet Pile Wall

Other Features

▭ Known and Potential Penite Manufacturing Features

▭ Historical Infrastructure

▭ Intermediate Aquifer Outcrop

▭ RI/FS Site Boundary

Notes:
-A Mann-Kendall trend test on post-1990 results was performed for each MW that had greater than 5 results spanning a duration of at least 8 years.
-Non-detect results were assumed to equal half the reporting limit in the trend analysis.
-Results from a replacement MW were combined with results from the original decommissioned MW. MW IDs for the replacement MW are shown on this figure.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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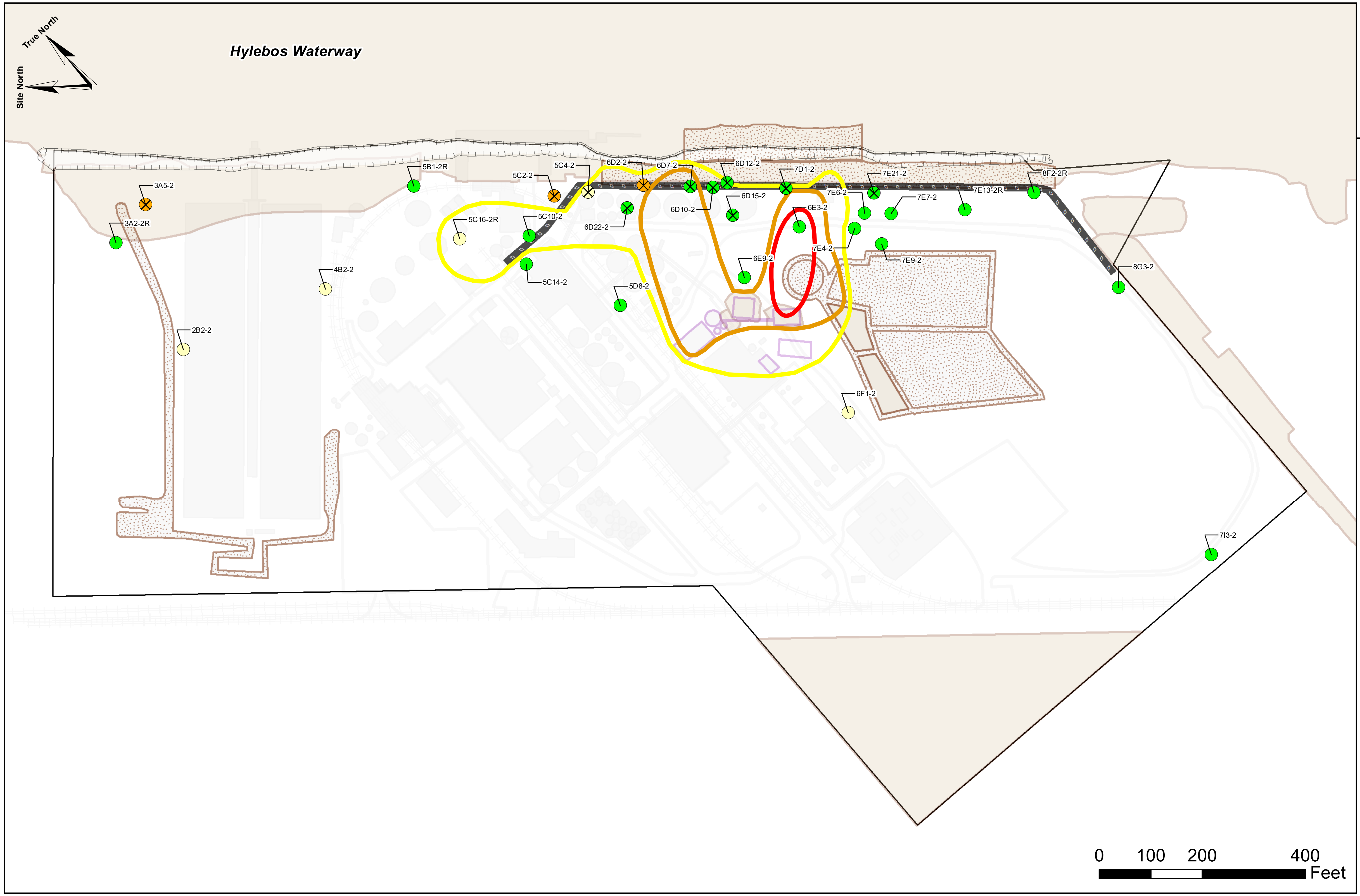
Summary of Mann-Kendall Trend Analysis (1993 – 2017) for the Upper Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-5



Legend

Sample Type

○ Monitoring Well

Intermediate Aquifer Dissolved Arsenic Mann-Kendall

● Decreasing Trend

○ Insufficient Evidence of Trend

● Increasing Trend

× Decommissioned Wells

2017 Intermediate Aquifer Dissolved Arsenic Groundwater Isoconcentration Contours

500 ug/L 5,000 ug/L 50,000 ug/L

Completed Remedial Actions

▭ Soil / Sediment Removal

▨ Soil / Sediment Cap

▬ Sheet Pile Wall

Other Features

▭ Known and Potential Penite Manufacturing Features

▭ Historical Infrastructure

▭ Intermediate Aquifer Outcrop

▭ RI/FS Site Boundary

Notes:
-A Mann-Kendall trend test on post-1990 results was performed for each MW that had greater than 5 results spanning a duration of at least 8 years.
-Non-detect results were assumed to equal half the reporting limit in the trend analysis.
-Results from a replacement MW were combined with results from the original decommissioned MW. MW IDs for the replacement MW are shown on this figure.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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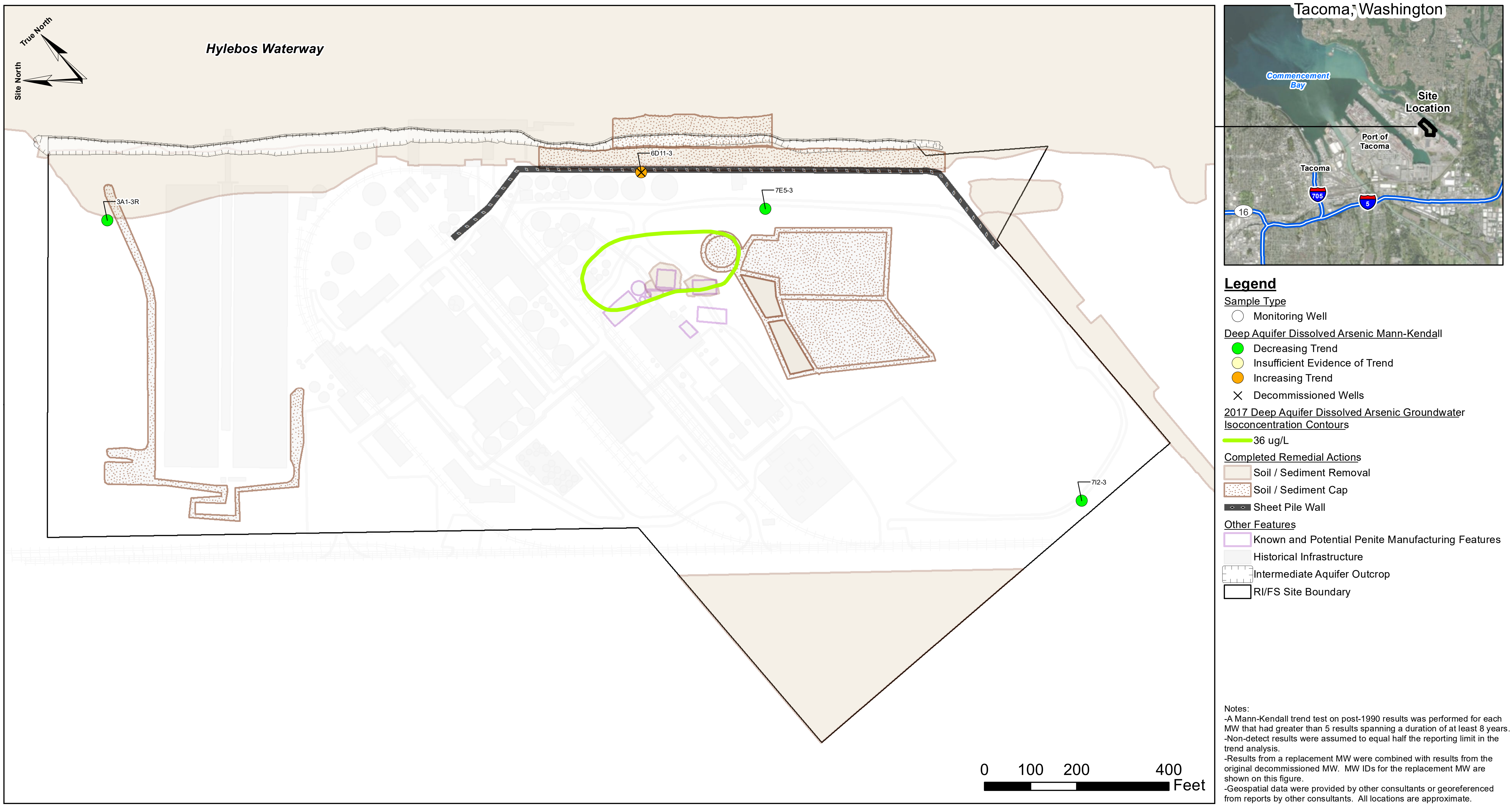
Summary of Mann-Kendall Trend Analysis (1993 – 2017) for the Intermediate Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-6

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-6_IA_MK_Summary_1992-2017.mxd; Author: KR; Date Saved: 7/19/2019

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-7_DA_MK_Summary_1992-2017.mxd; Author: KR; Date Saved: 7/19/2019



Notes:
-A Mann-Kendall trend test on post-1990 results was performed for each MW that had greater than 5 results spanning a duration of at least 8 years.
-Non-detect results were assumed to equal half the reporting limit in the trend analysis.
-Results from a replacement MW were combined with results from the original decommissioned MW. MW IDs for the replacement MW are shown on this figure.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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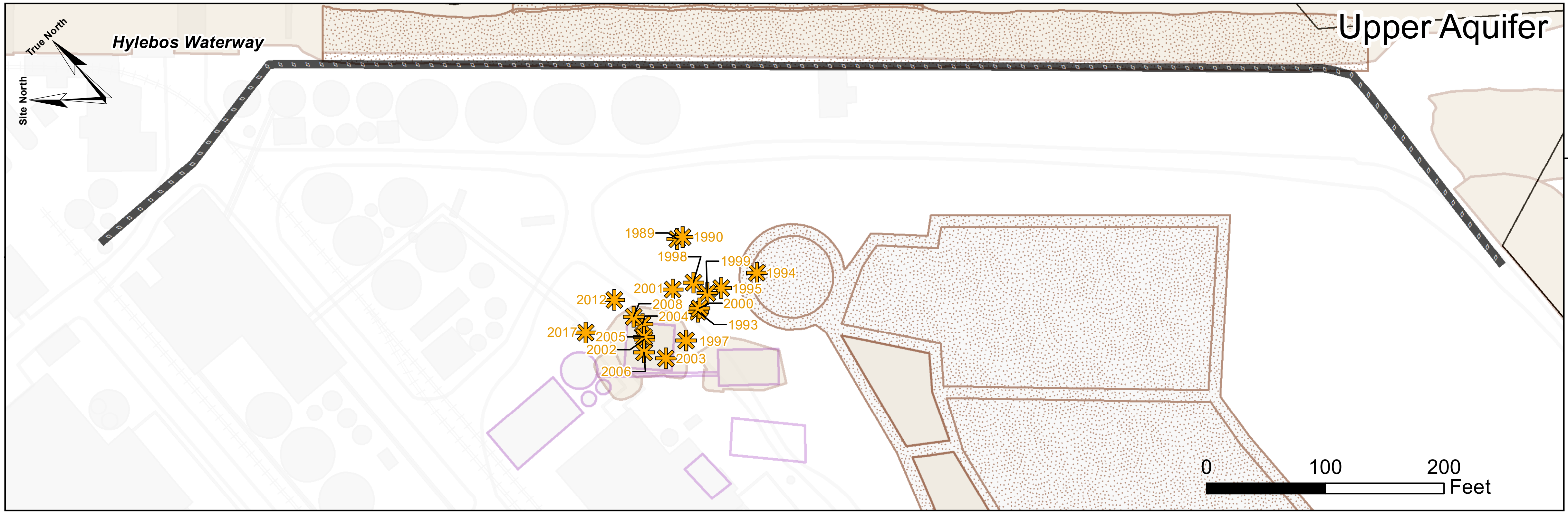
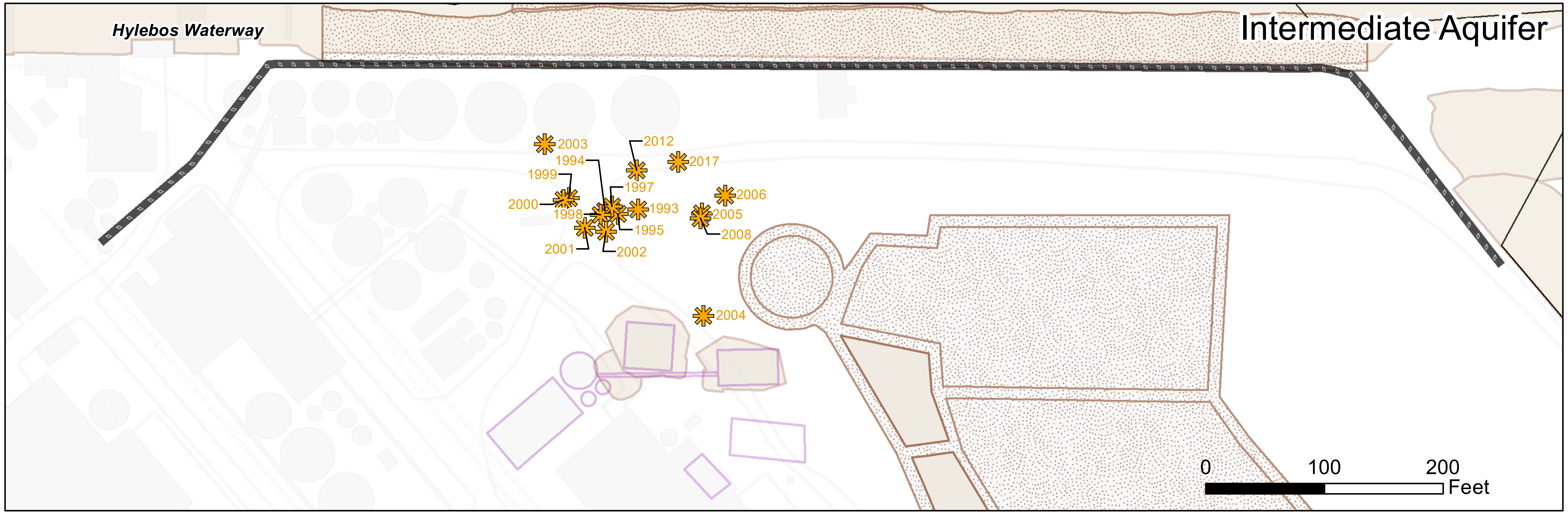
Summary of Mann-Kendall Trend Analysis (1993 – 2017) for the Deep Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-7





Legend

✳ Ricker Center of Mass

Completed Remedial Actions

▭ Soil / Sediment Removal

▨ Soil / Sediment Cap

▬ Sheet Pile Wall

Other Features

▭ Known and Potential Penite Manufacturing Features

▭ Historical Infrastructure

▭ RI/FS Site Boundary

Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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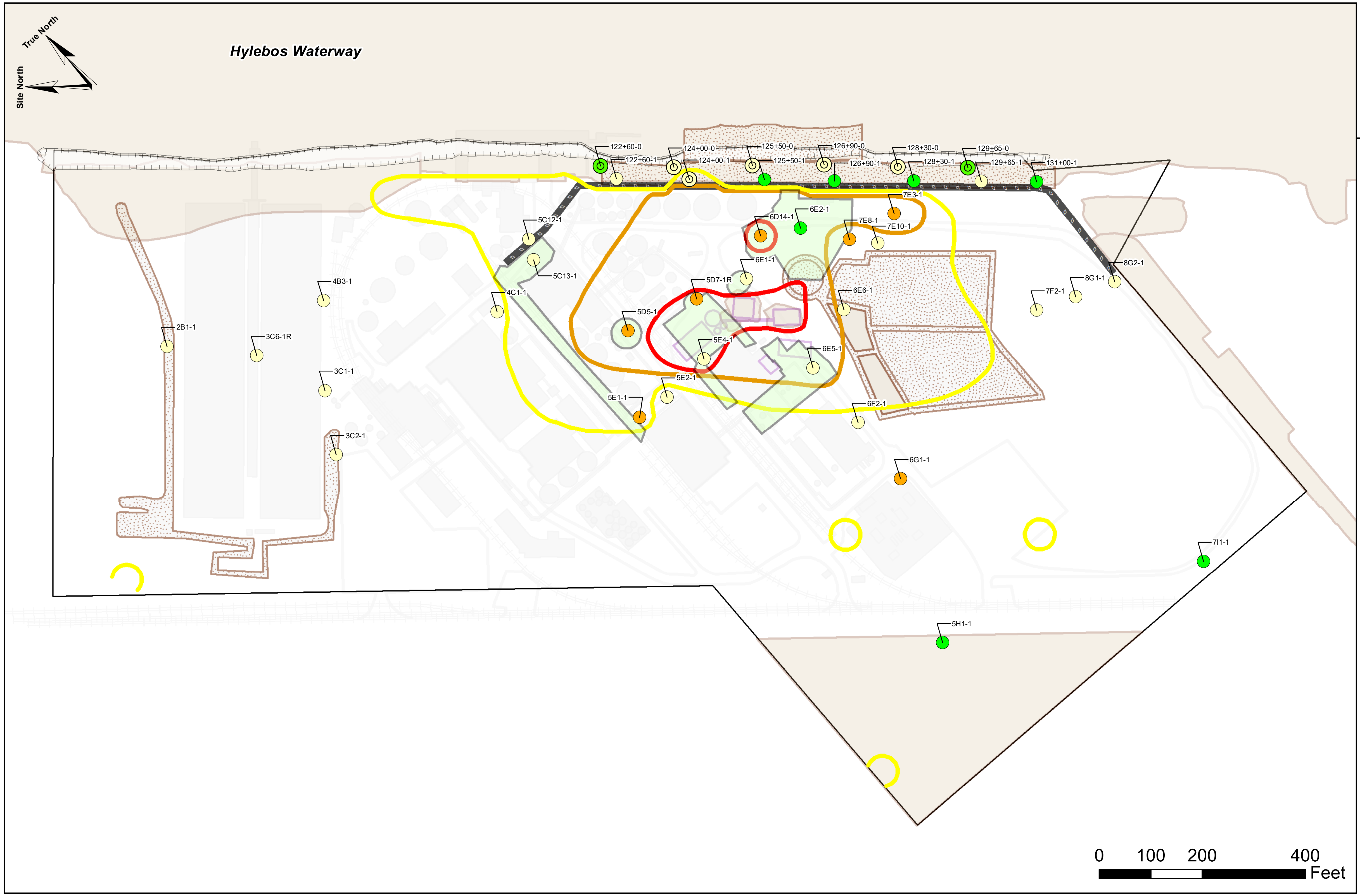
Ricker Center of Mass Results
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-8

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-8_Ricker_Center_of_Mass.mxd; Author: KR; Date Saved: 6/27/2019

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-9_UA_MK_Summary_2005-2017.mxd; Author: KR; Date Saved: 7/19/2019



Legend

Sample Type

- ○ Monitoring Well
- ◎ Upper Aquifer Angled Shoreline Monitoring

Upper Aquifer Dissolved Arsenic Mann-Kendall

- ● Decreasing Trend
- ● Insufficient Evidence of Trend
- ● Increasing Trend

2017 Upper Aquifer Dissolved Arsenic Groundwater Isoconcentration Contours

- 500 ug/L
- 5,000 ug/L
- 50,000 ug/L

Completed Remedial Actions

- ▭ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- ▬ Sheet Pile Wall

Other Features

- ▭ Known and Potential Penite Manufacturing Features
- ▭ Historical Infrastructure
- ▭ Intermediate Aquifer Outcrop
- ▭ RI/FS Site Boundary

Notes:
-A Mann-Kendall trend test was performed for each MW that had at least four post-2004 results.
-Non-detect results were assumed to equal half the reporting limit in the trend analysis.
-Results from a replacement MW were combined with results from the original decommissioned MW. MW IDs for the replacement MW are shown on this figure.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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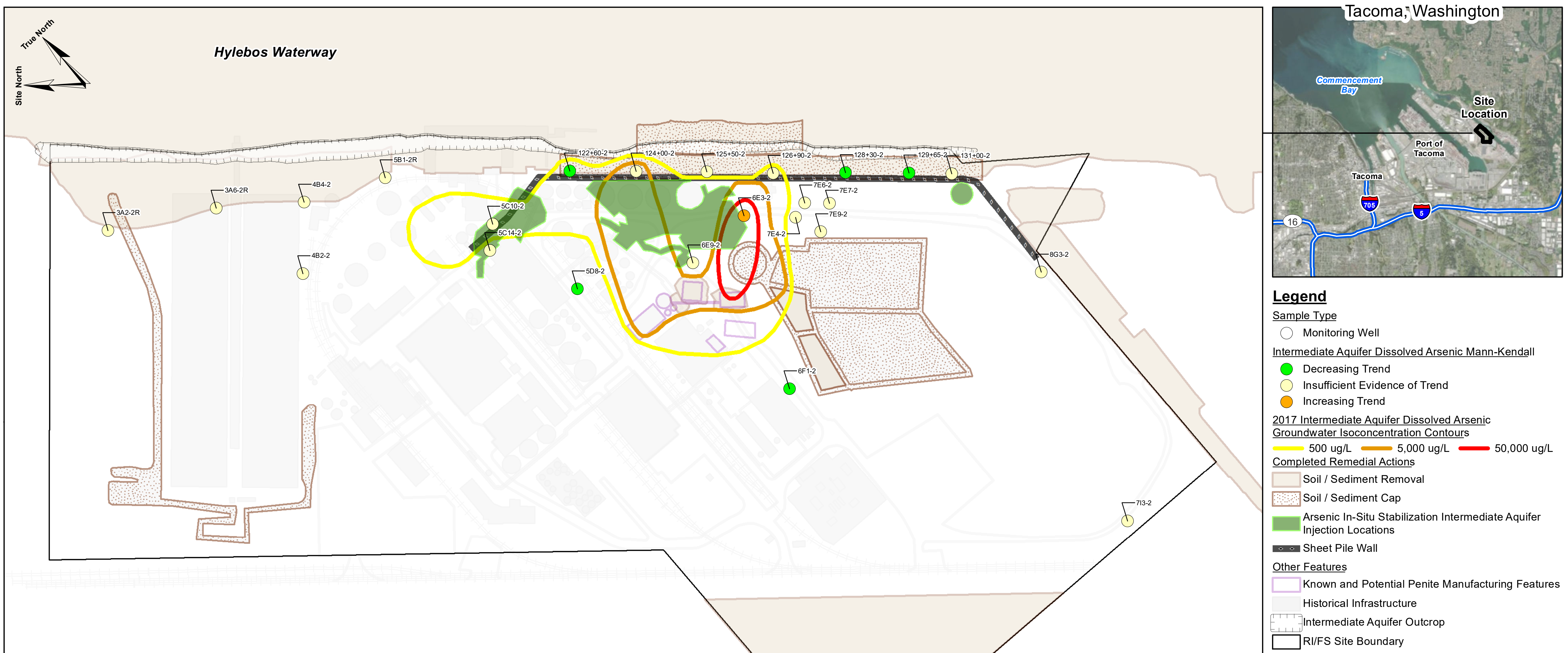
Summary of Mann-Kendall Trend Analysis (2005 – 2017) for the Upper Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-9



Notes:
-A Mann-Kendall trend test was performed for each MW that had at least four post-2004 results.
-Non-detect results were assumed to equal half the reporting limit in the trend analysis.
-Results from a replacement MW were combined with results from the original decommissioned MW. MW IDs for the replacement MW are shown on this figure.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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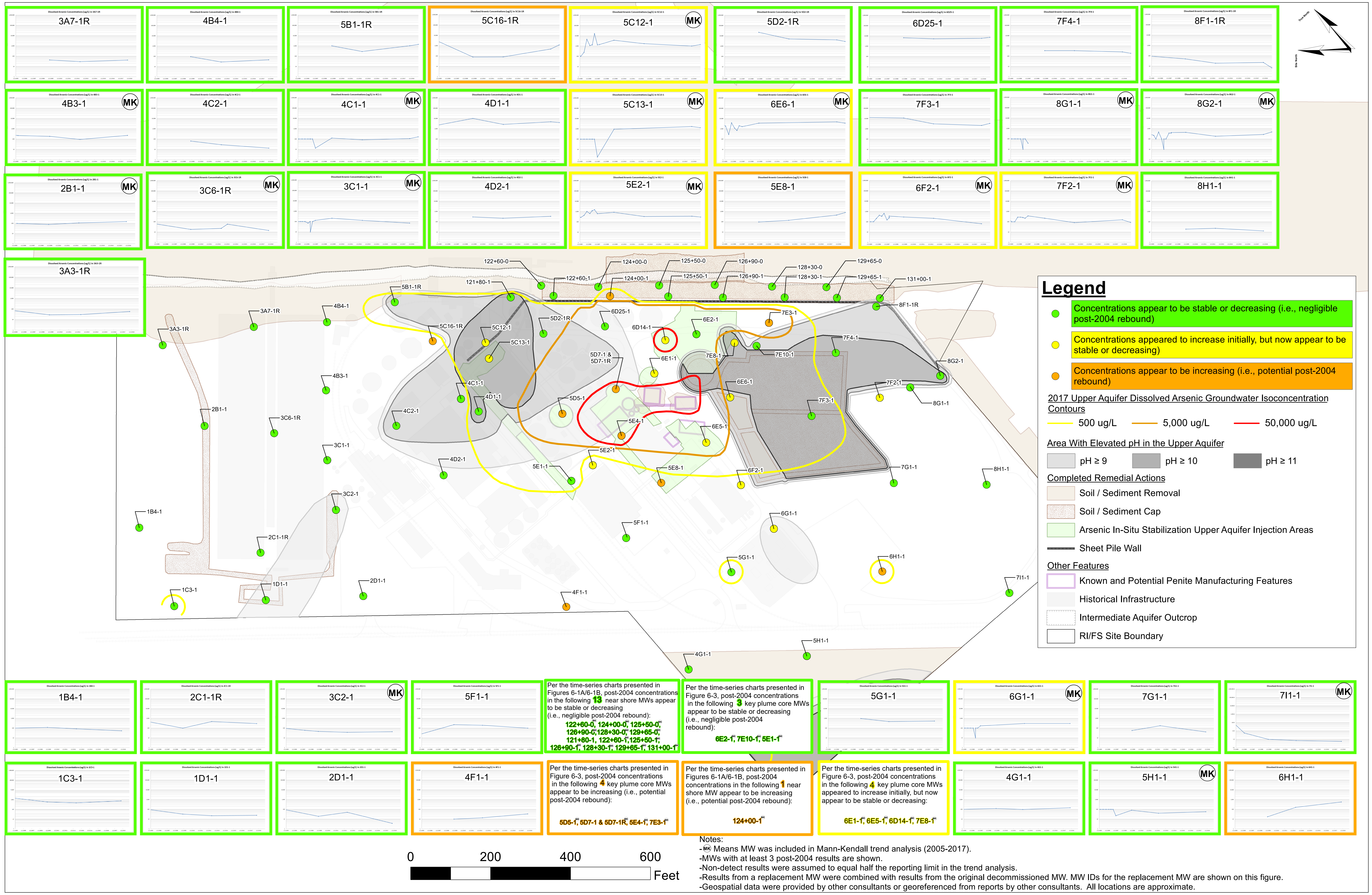
Summary of Mann-Kendall Trend Analysis (2005 – 2017) for the Intermediate Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-10

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-10_IA_MK_Summary_2005-2017.mxd; Author: KR; Date Saved: 7/19/2019



Per the time-series charts presented in Figures 6-1A/6-1B, post-2004 concentrations in the following **13** near shore MWs appear to be stable or decreasing (i.e., negligible post-2004 rebound):

122+60-0ᴹᴷ, 124+00-0ᴹᴷ, 125+50-0ᴹᴷ, 126+90-0ᴹᴷ, 128+30-0ᴹᴷ, 129+65-0ᴹᴷ, 121+80-1, 122+60-1ᴹᴷ, 125+50-1ᴹᴷ, 126+90-1ᴹᴷ, 128+30-1ᴹᴷ, 129+65-1ᴹᴷ, 131+00-1ᴹᴷ

Per the time-series charts presented in Figure 6-3, post-2004 concentrations in the following **3** key plume core MWs appear to be stable or decreasing (i.e., negligible post-2004 rebound):

6E2-1ᴹᴷ, 7E10-1ᴹᴷ, 5E1-1ᴹᴷ

Per the time-series charts presented in Figure 6-3, post-2004 concentrations in the following **4** key plume core MWs appear to be increasing (i.e., potential post-2004 rebound):

5D5-1ᴹᴷ, 5D7-1 & 5D7-1Rᴹᴷ, 5E4-1ᴹᴷ, 7E3-1ᴹᴷ

Per the time-series charts presented in Figures 6-1A/6-1B, post-2004 concentrations in the following **1** near shore MW appear to be increasing (i.e., potential post-2004 rebound):

124+00-1ᴹᴷ

Per the time-series charts presented in Figure 6-3, post-2004 concentrations in the following **4** key plume core MWs appeared to increase initially, but now appear to be stable or decreasing:

6E1-1ᴹᴷ, 6E5-1ᴹᴷ, 6D14-1ᴹᴷ, 7E8-1ᴹᴷ

Legend

- ● Concentrations appear to be stable or decreasing (i.e., negligible post-2004 rebound)
- ● Concentrations appeared to increase initially, but now appear to be stable or decreasing)
- ● Concentrations appear to be increasing (i.e., potential post-2004 rebound)

2017 Upper Aquifer Dissolved Arsenic Groundwater Isoconcentration Contours

- — 500 ug/L
- — 5,000 ug/L
- — 50,000 ug/L

Area With Elevated pH in the Upper Aquifer

- ▨ pH ≥ 9
- ▨ pH ≥ 10
- ▨ pH ≥ 11

Completed Remedial Actions

- ▨ Soil / Sediment Removal
- ▨ Soil / Sediment Cap
- ▨ Arsenic In-Situ Stabilization Upper Aquifer Injection Areas
- — Sheet Pile Wall

Other Features

- ☐ Known and Potential Penite Manufacturing Features
- ▨ Historical Infrastructure
- ☐ Intermediate Aquifer Outcrop
- ☐ RI/FS Site Boundary

Notes:
- ⓂⓀ Means MW was included in Mann-Kendall trend analysis (2005-2017).
-MWs with at least 3 post-2004 results are shown.
-Non-detect results were assumed to equal half the reporting limit in the trend analysis.
-Results from a replacement MW were combined with results from the original decommissioned MW. MW IDs for the replacement MW are shown on this figure.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-11_UA_As_Time-Series_Plots_2005-2017.mxd; Author: VN; Date Saved: 5/30/2019

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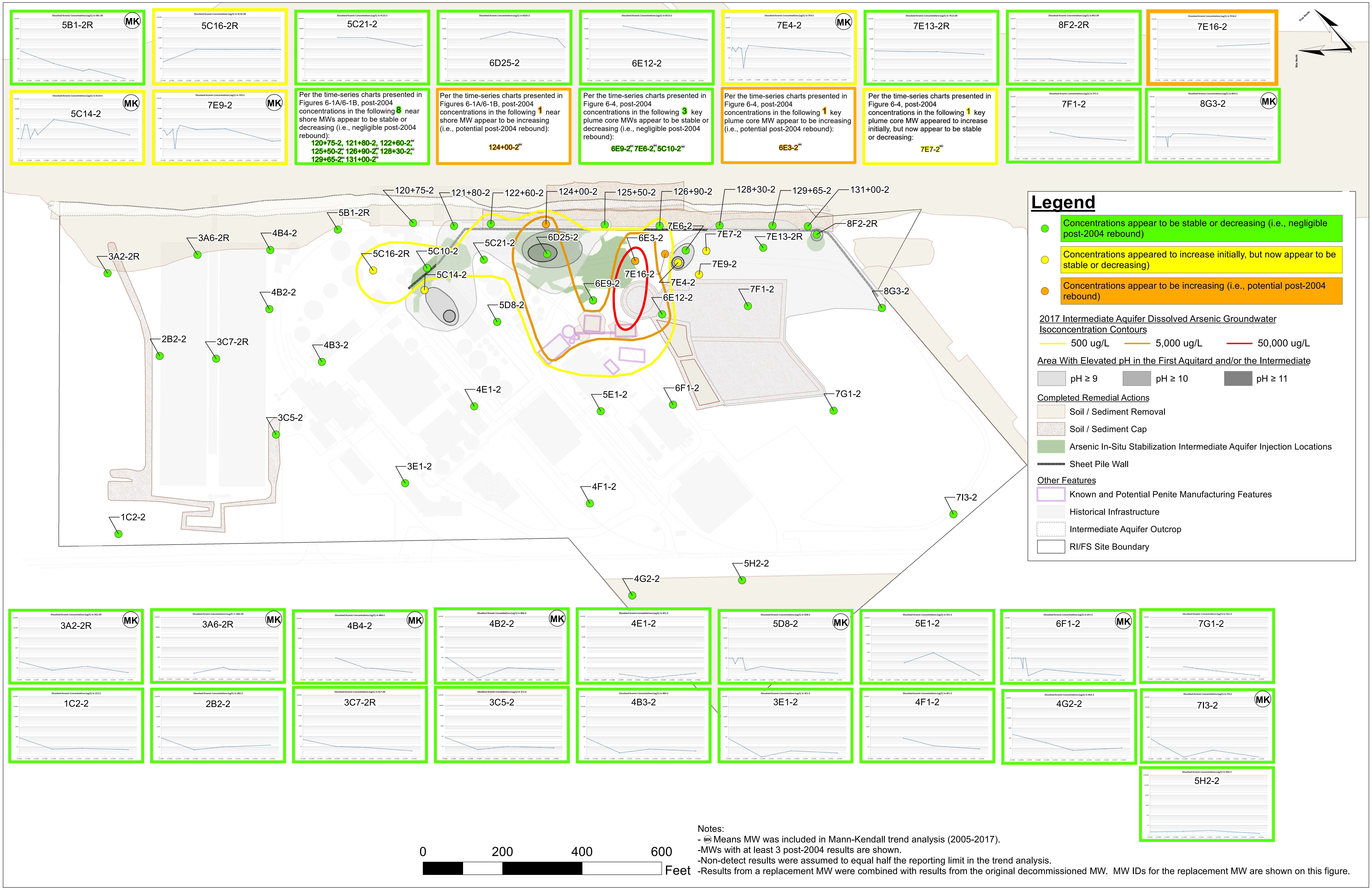
2005 - 2018 Arsenic Time-Series Plots for the Upper Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-11



Per the time-series charts presented in Figures 6-1A/6-1B, post-2004 concentrations in the following 8 near shore MWs appear to be stable or decreasing (i.e., negligible post-2004 rebound):

120+75-2, 121+80-2, 122+60-2, 125+50-2, 126+90-2, 128+30-2, 129+65-2, 131+00-2

Per the time-series charts presented in Figures 6-1A/6-1B, post-2004 concentrations in the following 1 near shore MW appear to be increasing (i.e., potential post-2004 rebound):

124+00-2

Per the time-series charts presented in Figure 6-4, post-2004 concentrations in the following 3 key plume core MWs appear to be stable or decreasing (i.e., negligible post-2004 rebound):

6E9-2, 7E6-2, 5C10-2

Per the time-series charts presented in Figure 6-4, post-2004 concentrations in the following 1 key plume core MW appear to be increasing (i.e., potential post-2004 rebound):

6E3-2

Per the time-series charts presented in Figure 6-4, post-2004 concentrations in the following 1 key plume core MW appeared to increase initially, but now appear to be stable or decreasing:

7E7-2

Legend

- 🟢 Concentrations appear to be stable or decreasing (i.e., negligible post-2004 rebound)
- 🟡 Concentrations appeared to increase initially, but now appear to be stable or decreasing)
- 🟠 Concentrations appear to be increasing (i.e., potential post-2004 rebound)

2017 Intermediate Aquifer Dissolved Arsenic Groundwater Isoconcentration Contours

500 ug/L
5,000 ug/L
50,000 ug/L

Area With Elevated pH in the First Aquitard and/or the Intermediate

pH ≥ 9
pH ≥ 10
pH ≥ 11

Completed Remedial Actions

Soil / Sediment Removal
Soil / Sediment Cap
Arsenic In-Situ Stabilization Intermediate Aquifer Injection Locations
Sheet Pile Wall

Other Features

Known and Potential Penite Manufacturing Features
Historical Infrastructure
Intermediate Aquifer Outcrop
RI/FS Site Boundary

Notes:
- MK Means MW was included in Mann-Kendall trend analysis (2005-2017).
-MWs with at least 3 post-2004 results are shown.
-Non-detect results were assumed to equal half the reporting limit in the trend analysis.
-Results from a replacement MW were combined with results from the original decommissioned MW. MW IDs for the replacement MW are shown on this figure.

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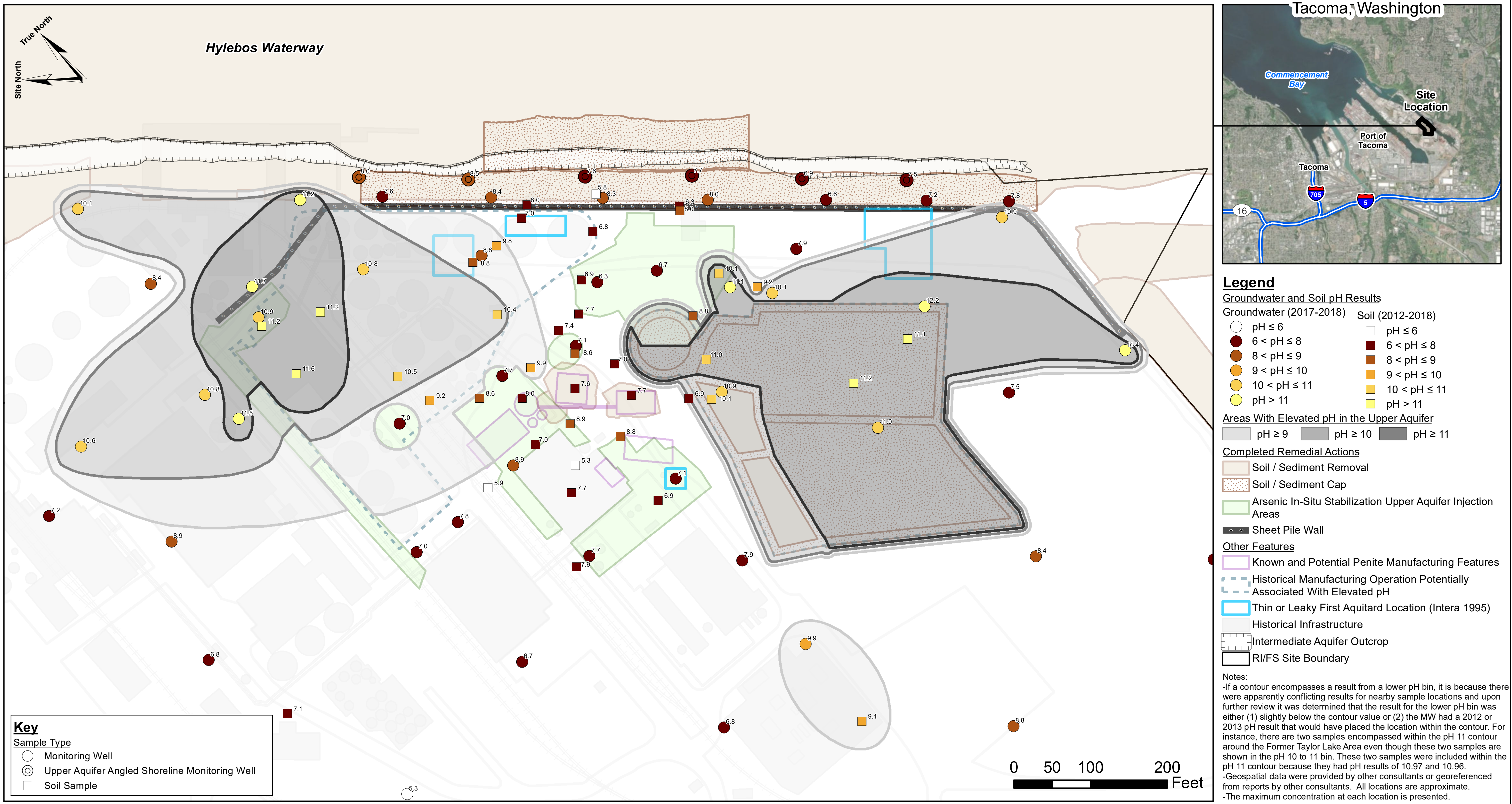
2005 - 2018 Arsenic Time-Series Plots for the Intermediate Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-12

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-12_IA_As_Time-Series_Plots_2005-2017.mxd; Author: VN; Date Saved: 5/30/2019



Notes:
-If a contour encompasses a result from a lower pH bin, it is because there were apparently conflicting results for nearby sample locations and upon further review it was determined that the result for the lower pH bin was either (1) slightly below the contour value or (2) the MW had a 2012 or 2013 pH result that would have placed the location within the contour. For instance, there are two samples encompassed within the pH 11 contour around the Former Taylor Lake Area even though these two samples are shown in the pH 10 to 11 bin. These two samples were included within the pH 11 contour because they had pH results of 10.97 and 10.96.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-The maximum concentration at each location is presented.

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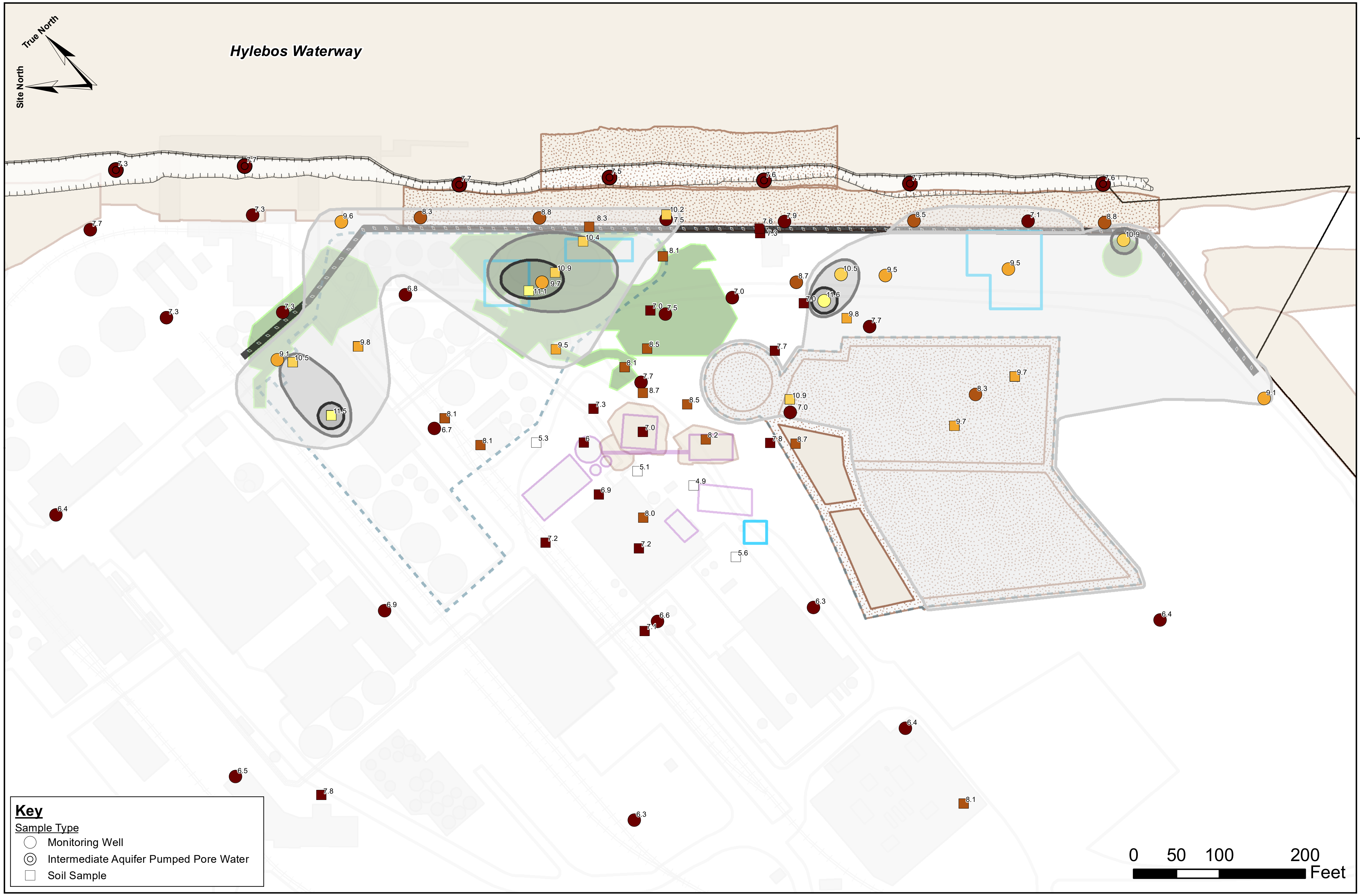
Current Areas with Elevated pH in the Upper Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-13

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-13_Current_UA_pH_SO_GW_2017-2018.mxd; Author: VN; Date Saved: 6/19/2019



Legend

Groundwater and Soil pH Results

Groundwater (2017-2018)		Soil (2012-2018)	
○	pH ≤ 6	☐	pH ≤ 6
●	6 < pH ≤ 8	■	6 < pH ≤ 8
●	8 < pH ≤ 9	■	8 < pH ≤ 9
●	9 < pH ≤ 10	■	9 < pH ≤ 10
●	10 < pH ≤ 11	■	10 < pH ≤ 11
●	pH > 11	■	pH > 11

Areas With Elevated pH in the First Aquitard and/or the Intermediate Aquifer

▨ pH ≥ 9 ▨ pH ≥ 10 ▨ pH ≥ 11

Completed Remedial Actions

- Soil / Sediment Removal
- Soil / Sediment Cap
- Arsenic In-Situ Stabilization Intermediate Aquifer Injection Areas
- Sheet Pile Wall

Other Features

- Known and Potential Penite Manufacturing Features
- Historical Manufacturing Operation Potentially Associated With Elevated pH
- Thin or Leaky First Aquitard Location (Intera 1995)
- Historical Infrastructure
- Intermediate Aquifer Outcrop
- RI/FS Site Boundary

Notes:

-If a contour encompasses a result from a lower pH bin, it is because there were apparently conflicting results for nearby sample locations and upon further review it was determined that the result for the lower pH bin was either (1) slightly below the contour value or (2) the MW had a 2012 or 2013 pH result that would have placed the location within the contour. For instance, there are two sample locations encompassed within the pH 11 contour near the thin/leaky First Aquitard location due east of the former Penite Manufacturing Building even though these two samples are not shown in the pH > 11 bin. The soil location was included within the pH 11 contour because it had a pH result of 10.94 while the MW location was included within the pH 11 contour because it had a pH of 11.3 during the 2013 sampling event.

-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

-The maximum concentration at each location is presented.

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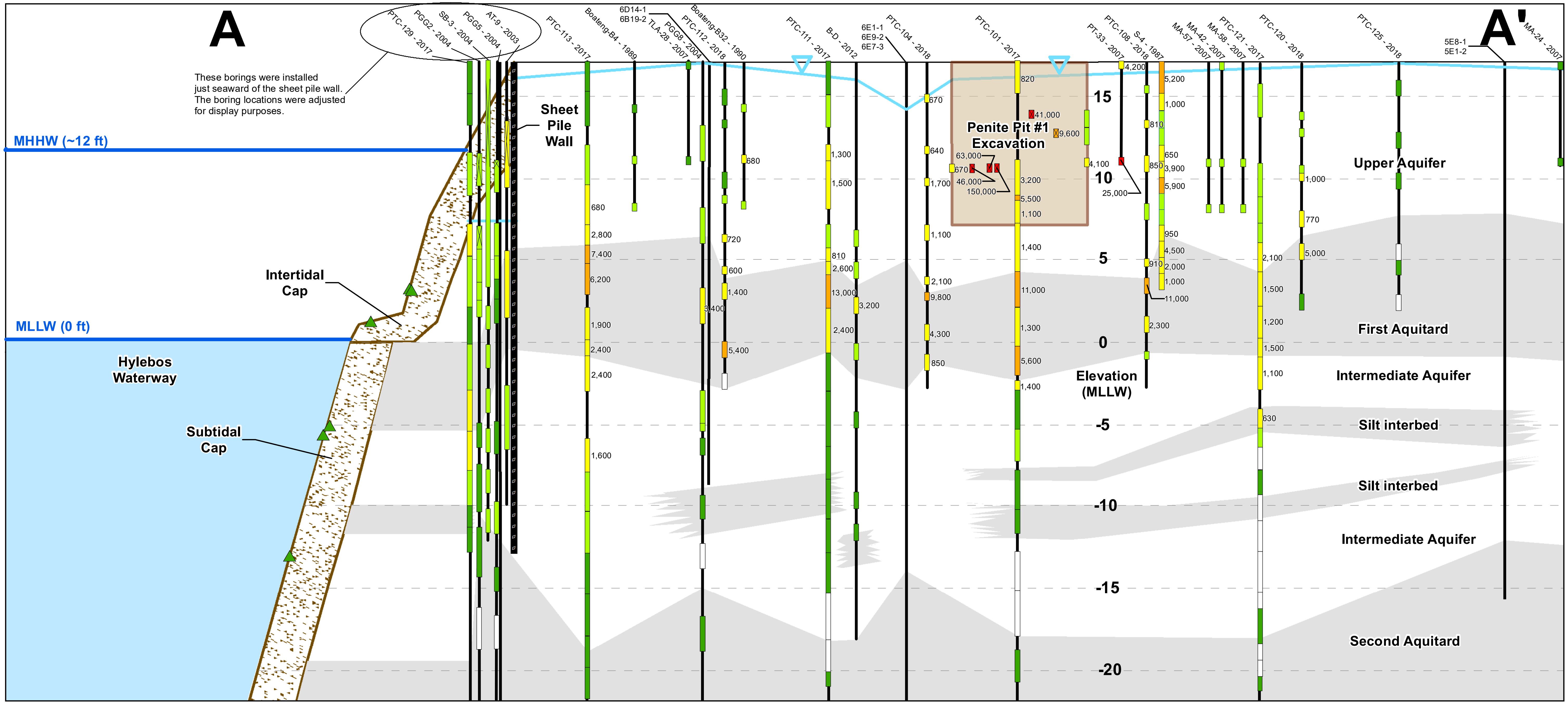
Current Areas with Elevated pH in the First Aquitard and/or the Intermediate Aquifer
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-14

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-14_Current_IA_pH_SO_GW_2017-2018_Litho.mxd; Author: VN; Date Saved: 6/19/2019



Arsenic Soil/Sediment Concentration[1]

☐	Nondetect
🟩	Nondetect < Arsenic ≤ 88 mg/kg
🟩	88 mg/kg < Arsenic ≤ 590 mg/kg
🟨	590 mg/kg < Arsenic ≤ 5,000 mg/kg
🟧	5,000 mg/kg < Arsenic ≤ 20,000 mg/kg
🟥	Arsenic > 20,000 mg/kg
☒	No Longer In Place

Other Features

—	March 2012 Low Tide Groundwater Elevation
▨	First / Second Aquitard or Silt Interbed
▨	Intertidal / Subtidal Caps
▨	Penite Pits Excavation

Boring ID and year

Soil Sample Interval

Concentration in mg/kg

Sediment Sample △

Notes:

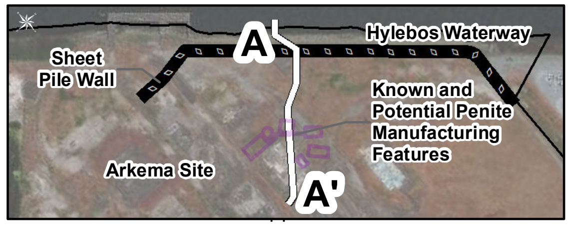
[1] Both laboratory and field XRF concentrations are shown on this figure. If both types of data were collected from a boring interval, the maximum concentration is displayed.

-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

-For simplicity, a flat ground surface was assumed for the upland portion of this cross section since the upland ground surface is essentially flat along the cross section and spot elevations are not available for most boring locations.

-Concentrations greater than 590 mg/kg in borings landward of the SPW are labeled. Results are shown to two significant figures.

Scale (ft)
Horizontal 0 30 60 120
Vertical exaggeration is ~7x
Vertical 0 5 10 20



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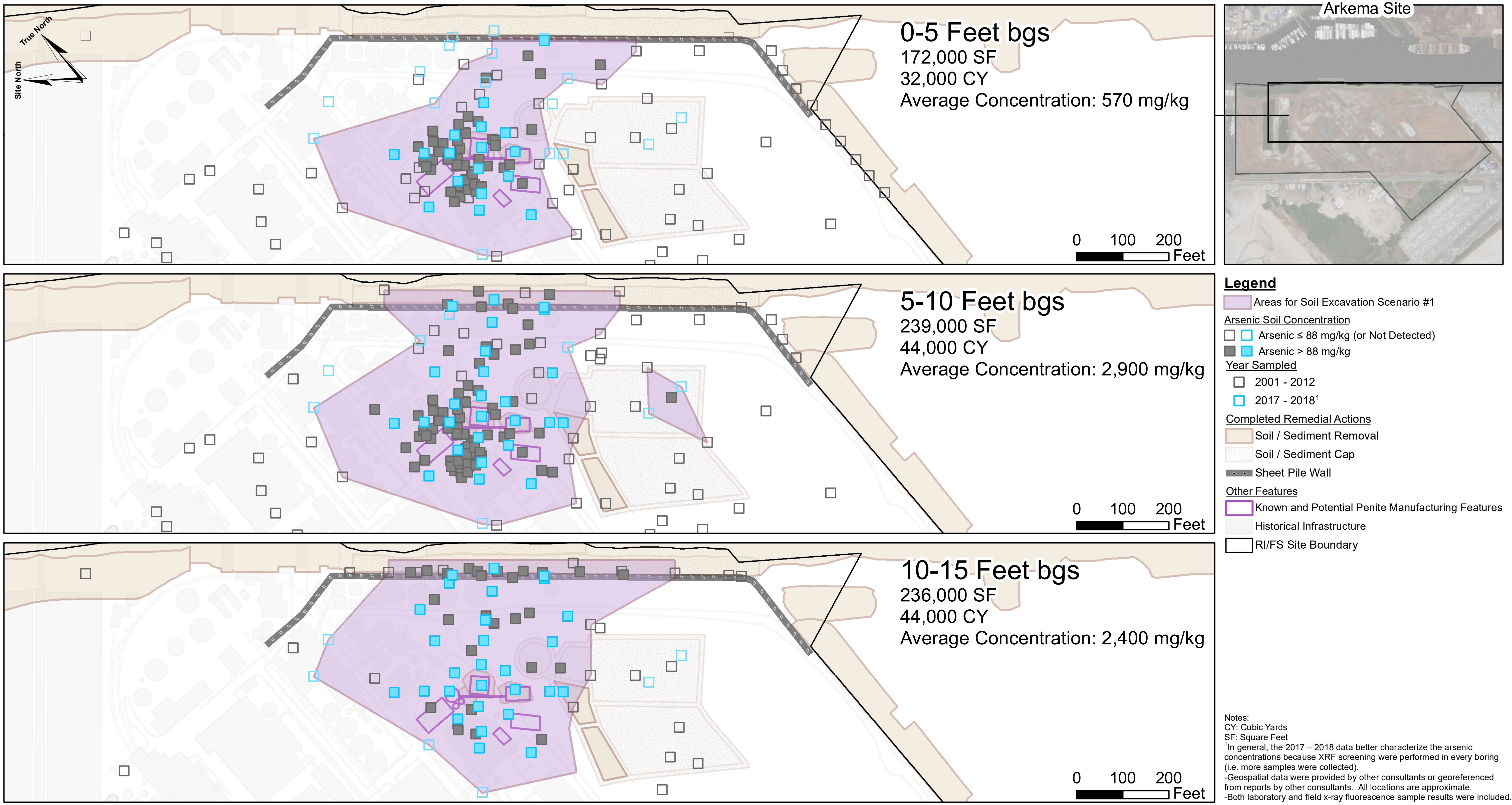
Conceptual Cross Section of Arsenic Soil and Sediment Concentrations
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-15

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-15_X_Section_As_SO_SED.mxd; Author: VN; Date Saved: 6/27/2019



0-5 Feet bgs
172,000 SF
32,000 CY
Average Concentration: 570 mg/kg

5-10 Feet bgs
239,000 SF
44,000 CY
Average Concentration: 2,900 mg/kg

10-15 Feet bgs
236,000 SF
44,000 CY
Average Concentration: 2,400 mg/kg

Notes:
CY: Cubic Yards
SF: Square Feet
[1] In general, the 2017 – 2018 data better characterize the arsenic concentrations because XRF screening were performed in every boring (i.e. more samples were collected).
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Both laboratory and field x-ray fluorescence sample results were included.

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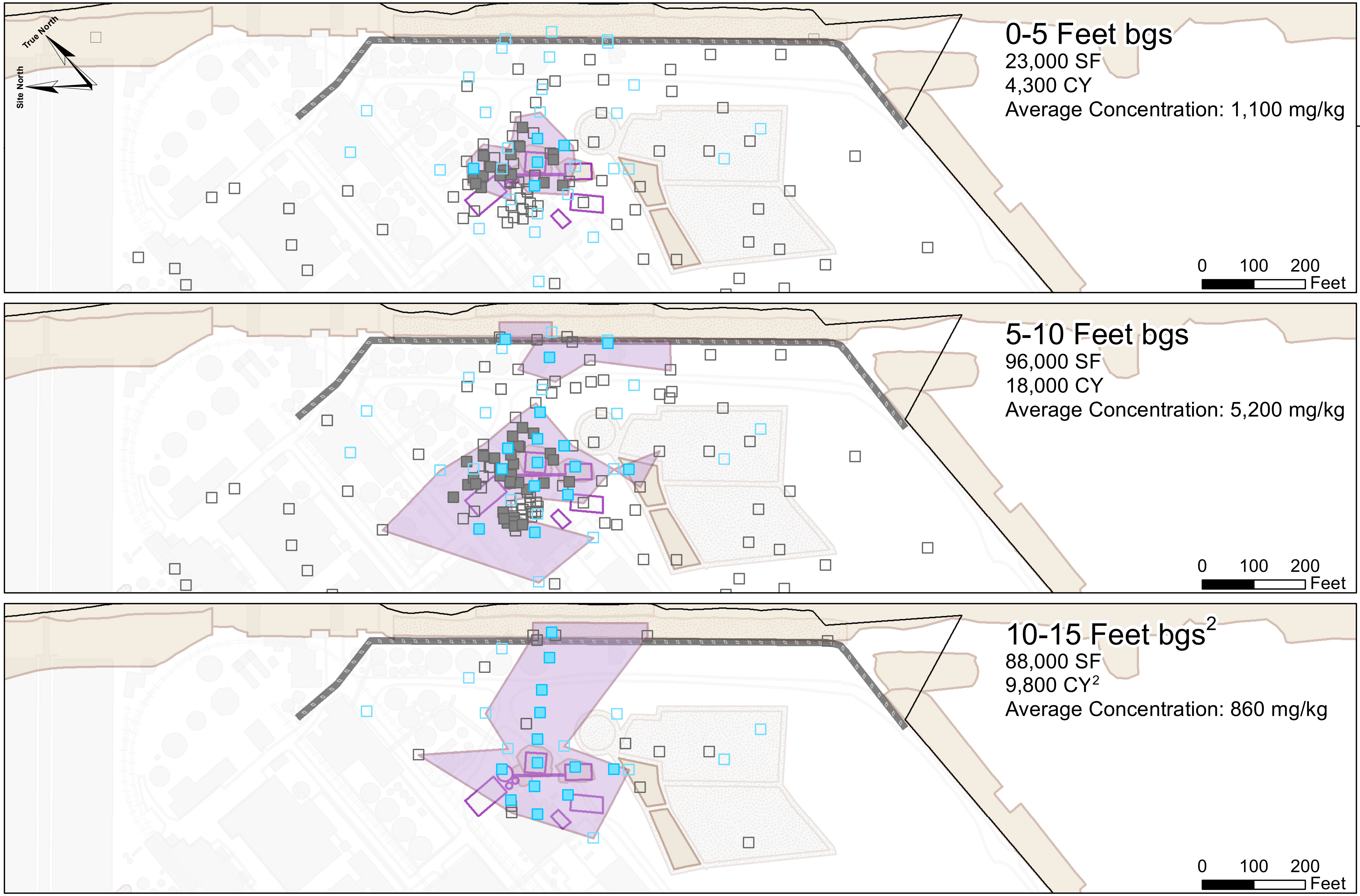
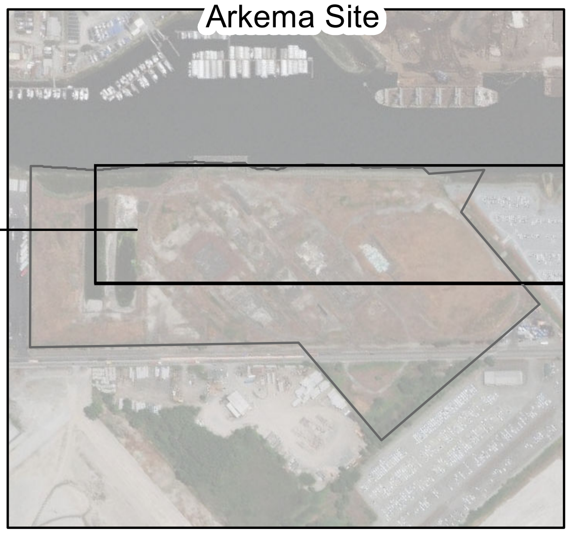
Areas for Soil Excavation Scenario #1
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-16

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-16_Excavation_Senario1.mxd; Author: VN; Date Saved: 6/19/2019





Legend

▨ Areas for Soil Excavation Scenario #2

Arsenic Soil Concentration

☐ ☐ Arsenic ≤ 590 mg/kg (or Not Detected)

■ ■ Arsenic > 590 mg/kg

Year Sampled

☐ 2001 - 2012

☐ 2017 - 2018[1]

Completed Remedial Actions

▨ Soil / Sediment Removal

▨ Soil / Sediment Cap

▬ Sheet Pile Wall

Other Features

☐ Known and Potential Penite Manufacturing Features

▨ Historical Infrastructure

☐ RI/FS Site Boundary

Notes:
CY: Cubic Yards
SF: Square Feet
[1]In general, the 2017 – 2018 data better characterize the arsenic concentrations because XRF screening were performed in every boring (i.e. more samples were collected).
[2]For this excavation scenario, the point of compliance depth is 15 feet or the top of the 1st Aquitard, whichever occurs first. The average depth to the top of the 1st Aquitard was assumed to be 13 feet based on borings advanced within the excavation footprint.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Both laboratory and field x-ray fluorescence sample results were included.

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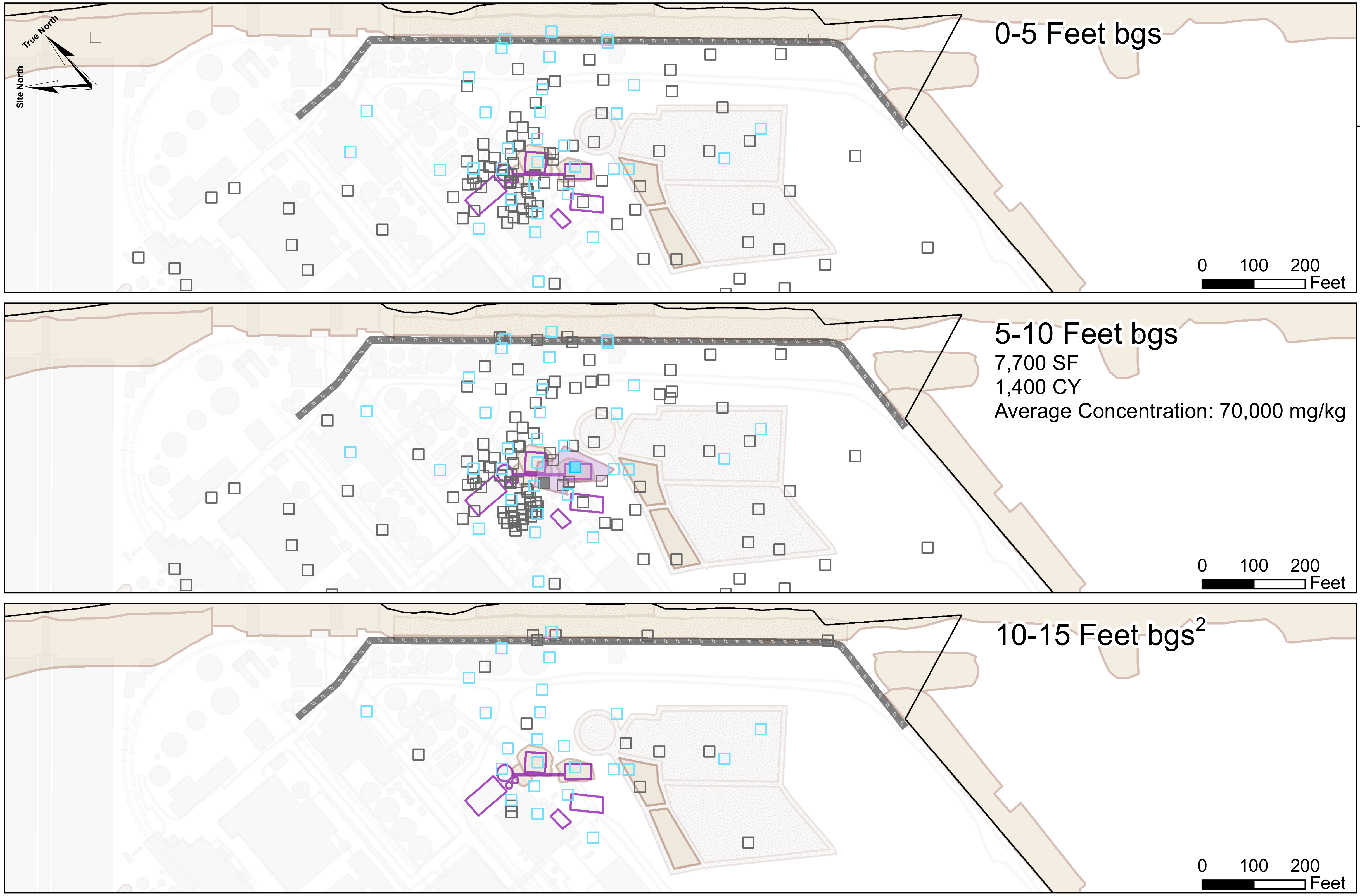
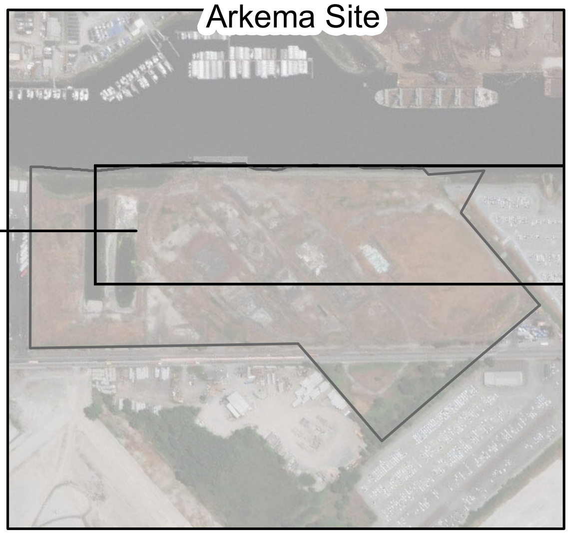
Areas for Soil Excavation Scenario #2
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-17





Legend

🟪 Areas for Soil Excavation Scenario #3

Arsenic Soil Concentration

☐ ☐ Arsenic ≤ 10,000 mg/kg (or Not Detected)

■ ■ Arsenic > 10,000 mg/kg

Year Sampled

☐ 2001 - 2012

☐ 2017 - 2018[1]

Completed Remedial Actions

▨ Soil / Sediment Removal

▨ Soil / Sediment Cap

▬ Sheet Pile Wall

Other Features

☐ Known and Potential Penite Manufacturing Features

▨ Historical Infrastructure

☐ RI/FS Site Boundary

Notes:
CY: Cubic Yards
SF: Square Feet

[1] In general, the 2017 – 2018 data better characterize the arsenic concentrations because XRF screening were performed in every boring (i.e. more samples were collected).

[2] For this excavation scenario, the point of compliance depth is 15 feet or the top of the 1st Aquitard, whichever occurs first. The average depth to the top of the 1st Aquitard was assumed to be 13 feet based on borings advanced within the excavation footprint.

-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

-Both laboratory and field x-ray fluorescence sample results were included.

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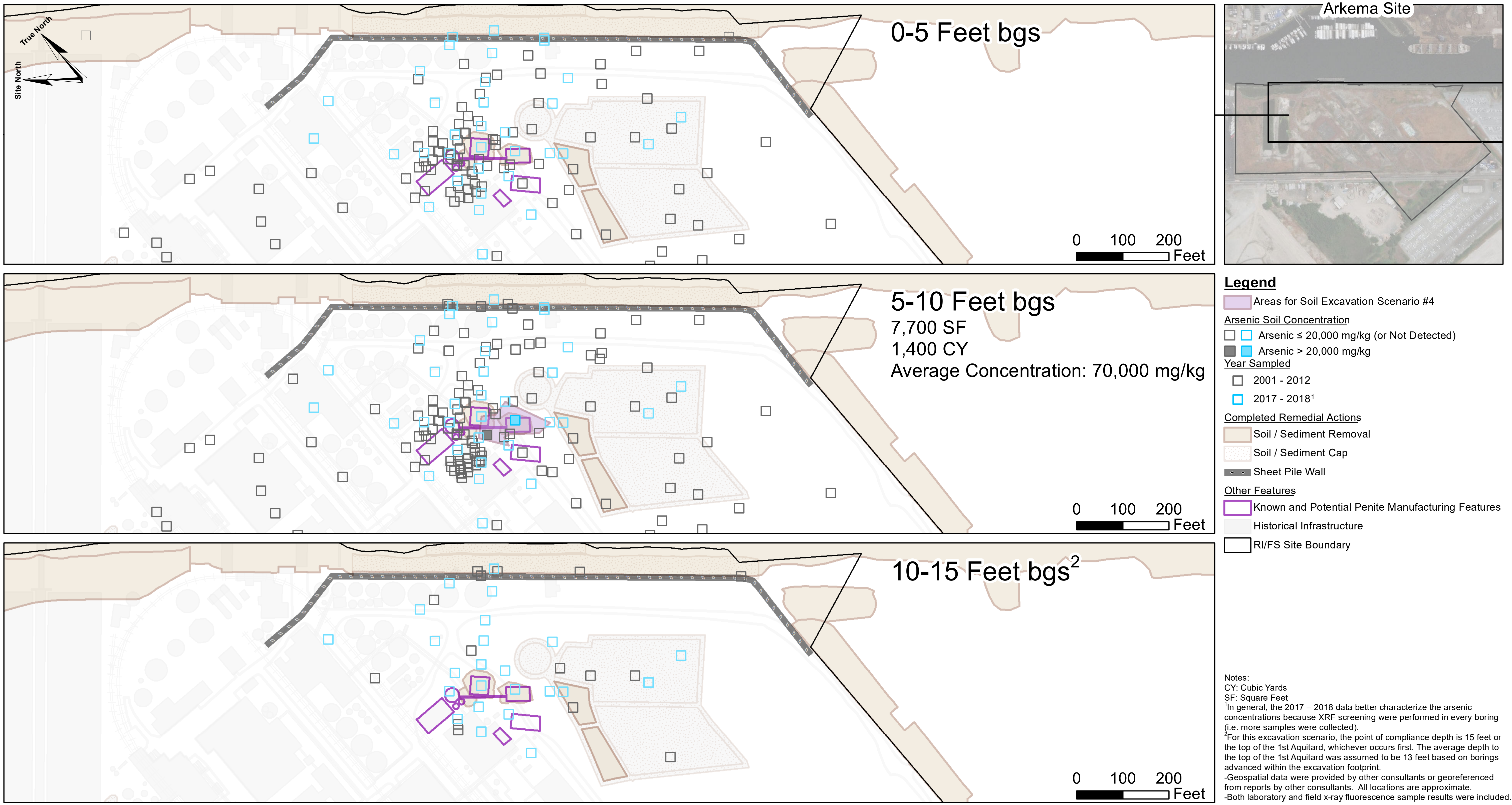
Areas for Soil Excavation Scenario #3
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-18

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-18_Excavation_Senario3.mxd; Author: VN; Date Saved: 6/19/2019



Notes:
CY: Cubic Yards
SF: Square Feet
[1] In general, the 2017 – 2018 data better characterize the arsenic concentrations because XRF screening were performed in every boring (i.e. more samples were collected).
[2] For this excavation scenario, the point of compliance depth is 15 feet or the top of the 1st Aquitard, whichever occurs first. The average depth to the top of the 1st Aquitard was assumed to be 13 feet based on borings advanced within the excavation footprint.
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.
-Both laboratory and field x-ray fluorescence sample results were included.

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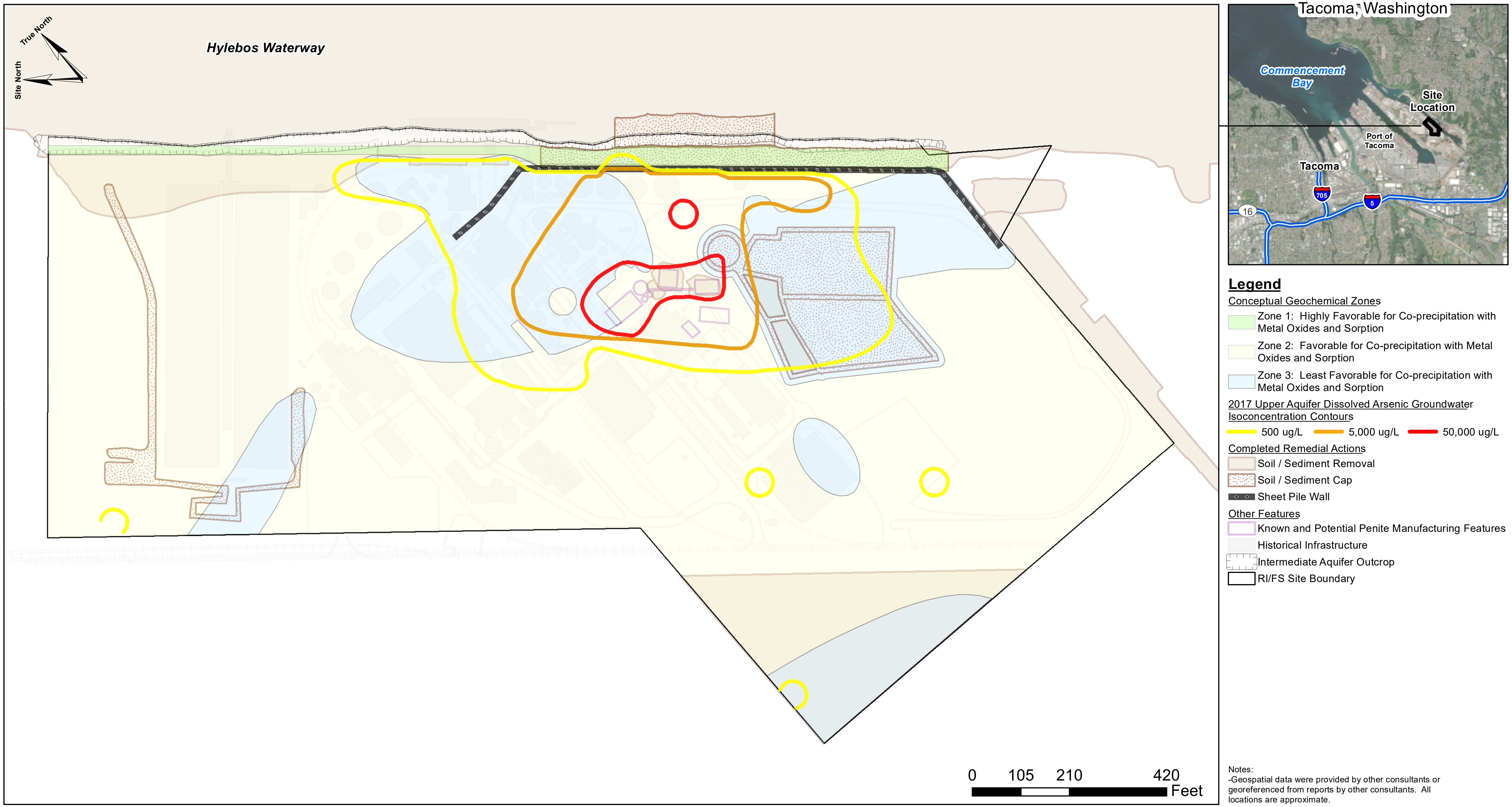
Areas for Soil Excavation Scenario #4
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 6-19

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\6-19_Excavation_Senario3.mxd; Author: VN; Date Saved: 6/19/2019



Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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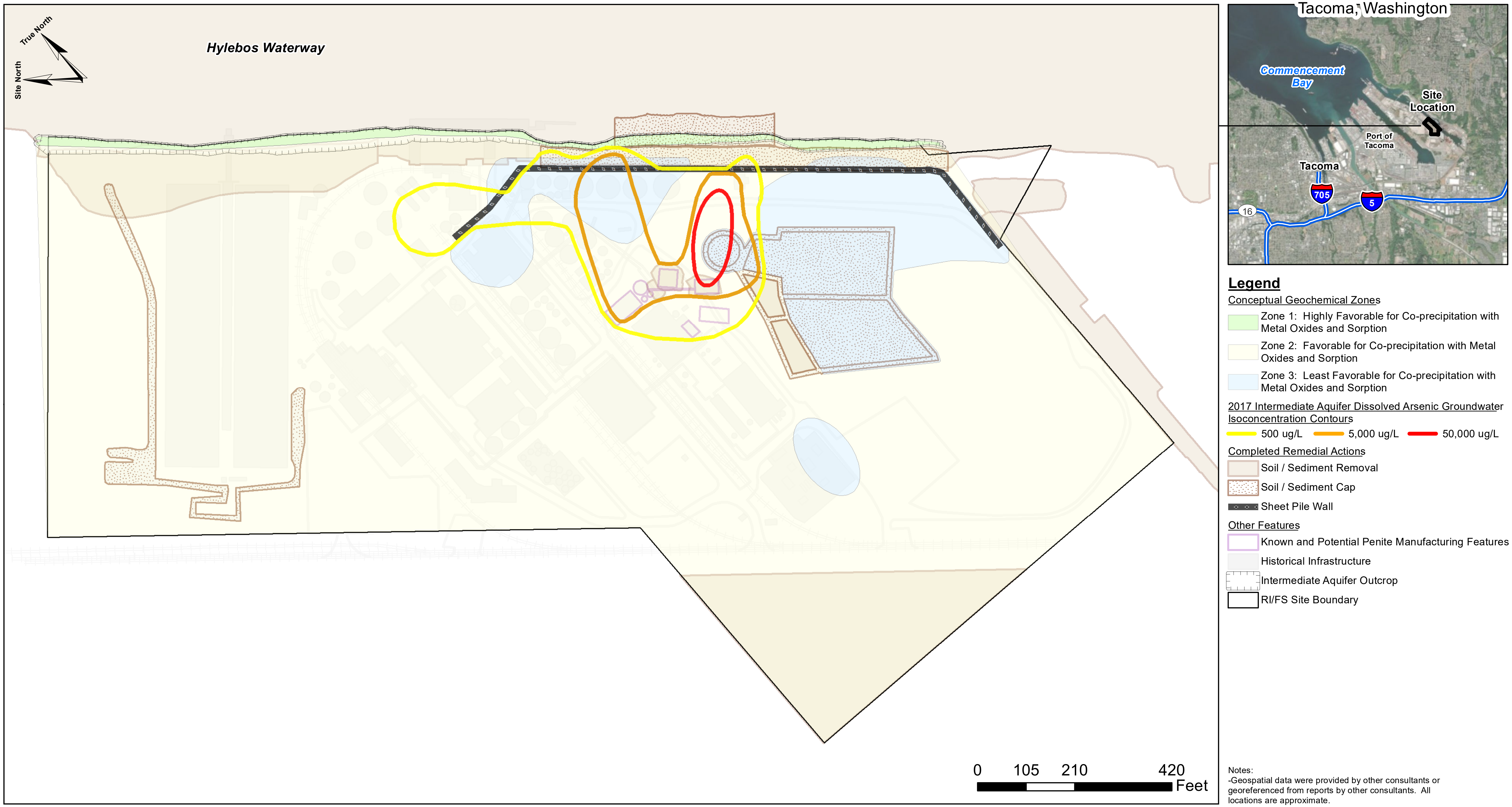
Conceptual Upper Aquifer Geochemical Zones for Co-precipitation with Metal Oxides and Sorption
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 7-1

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\7-1_UA_Conceptual_Geochemical.mxd; Author: SM; Date Saved: 6/27/2019



Notes:
-Geospatial data were provided by other consultants or georeferenced from reports by other consultants. All locations are approximate.

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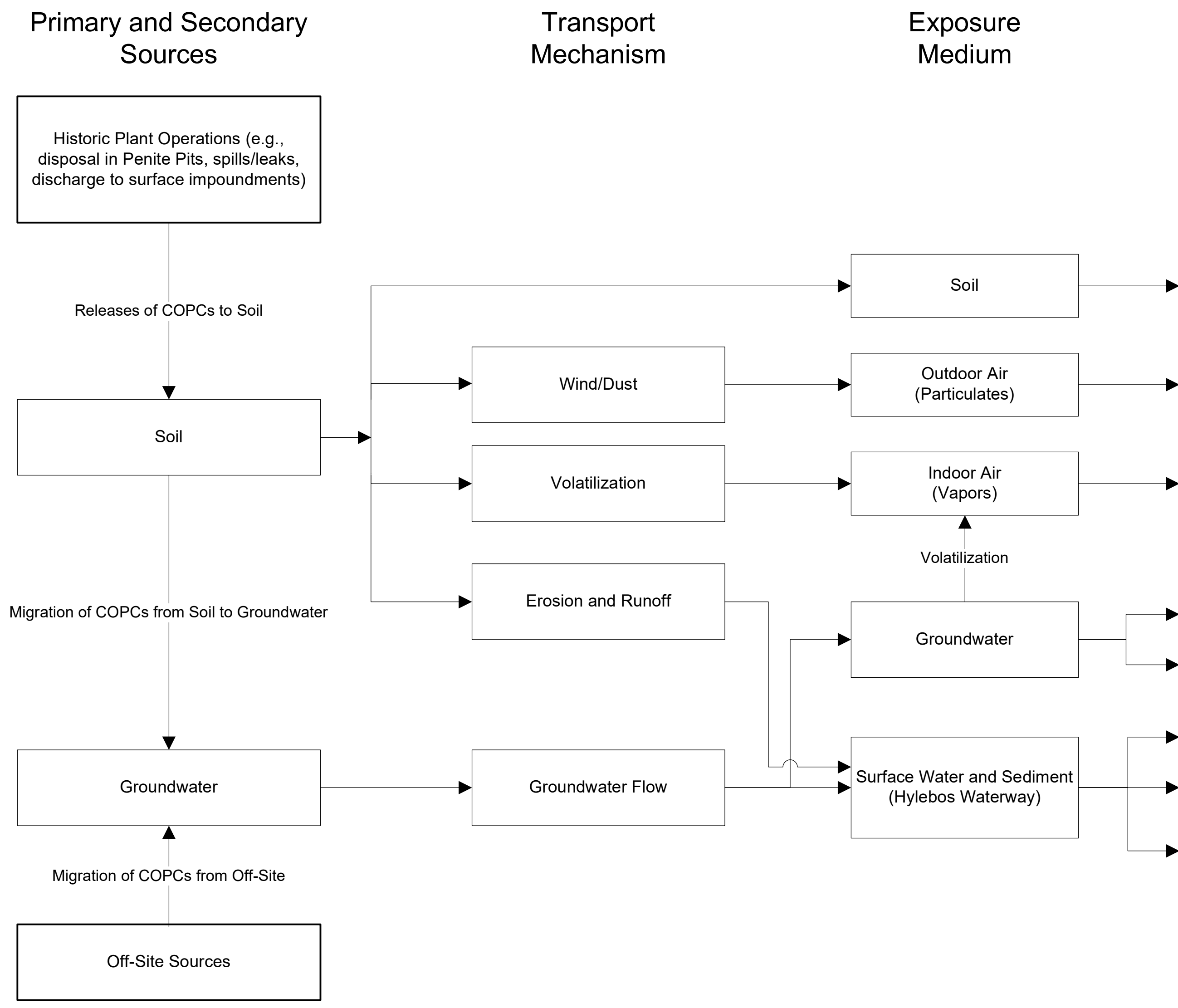
Conceptual Intermediate Aquifer Geochemical Zones for Co-precipitation with Metal Oxides and Sorption
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 7-2

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\7-2_IA_Conceptual_Geochemical.mxd; Author: SM; Date Saved: 6/27/2019



Receptor

Exposure Medium	Exposure Route	Baseline Case (Assuming No Further Action)[1]				Post-Remediation and Post-Redevelopment[4]				Off-Site (Hylebos Waterway)	
		Commercial/ Industrial Workers	Utility Workers	Trespassers	Terrestrial Organisms	Commercial/ Industrial Workers	Utility Workers	Trespassers	Terrestrial Organisms	Aquatic Organisms	Recreators/ Fishers
Soil	Ingestion	●	●	●	○	◐	◐	◐	○	▨	▨
	Dermal Contact	●	●	●	○	◐	◐	◐	○	▨	▨
Outdoor Air (Particulates)	Inhalation	●	●	●	○	◐	◐	◐	○	▨	▨
Indoor Air (Vapors)	Inhalation	◐[2]	○	○	○	◐	○	○	○	▨	▨
Groundwater	Ingestion	○	○	○	○	○	○	○	○	▨	▨
	Dermal Contact	○	◐[3]	○	○	○	◐	○	○	▨	▨
Surface Water and Sediment (Hylebos Waterway)	Ingestion	▨	▨	▨	▨	▨	▨	▨	▨	●	●
	Dermal Contact	▨	▨	▨	▨	▨	▨	▨	▨	●	●
	Consumption of Seafood from Hylebos Waterway	▨	▨	▨	▨	▨	▨	▨	▨	●	●

Key

● = Complete Pathway

◐ = Potentially Complete Pathway

○ = Incomplete Pathway

Notes:

These exposure scenarios are reasonable maximum exposures and are considered protective of other similar exposure scenarios (e.g., the off-site recreator scenarios are more protective than other off-site human exposure scenarios). All potential receptors are on-site unless otherwise noted. The shaded boxes represent exposure pathways that are not applicable.

Potential exposures for remediation construction workers and redevelopment construction workers will be addressed as necessary during remedy implementation and redevelopment activities, respectively. Specifically, it is expected that these potential exposures will be controlled with institutional and engineering controls designed to prevent unacceptable exposures. For instance, it is expected that all applicable workers will be contractually required to comply with Occupational Safety & Health Administration regulations as appropriate (e.g., Hazardous Waste Operations and Emergency Response training, health and safety plan, dust control measures, personnel monitoring, personal protective equipment).

The terrestrial ecological pathway is not a complete and significant pathway at the Site per WAC 173-340-7491(1) since the Site does not have any meaningful terrestrial habitat because it was previously developed for industrial use and it will be redeveloped in the future for Port maritime industrial use (e.g., grading activities and installation of a cap/cover, construction of buildings and operational areas for a container yard).

1. This baseline scenario was used to determine the pathways of potential concern. It was assumed that the Site will be redeveloped without any controls or further remedial action, even though this is not a realistic scenario. The baseline scenario is not representative of current exposures (e.g., there are no current commercial/industrial worker exposures since there are no commercial/industrial workers currently at the site and there are no current trespasser exposures since an existing perimeter fence and signs prevent access to the site).
2. This pathway is considered potentially complete; however, it could be complete if new buildings are constructed without vapor intrusion mitigation systems at locations with applicable groundwater VOC exceedances. Since the VOC exceedance footprints in the Upper Aquifer are relatively small, the pathway would be incomplete if buildings are not constructed over these relatively small areas.
3. Although this pathway could hypothetically be complete in the baseline case, it is more likely that this pathway would be incomplete since (1) utilities are ideally installed in the unsaturated zone, and (2) any saturated zone work would involve dewatering the utility excavation prior to anyone entering the utility excavation.
4. The potentially complete pathways may be complete or incomplete depending on the final site remedy. For example, if the final remedy includes installing a cap/cover over applicable soil exceedances, then soil ingestion, soil dermal contact, and particulate inhalation exposures for post-remediation and post-redevelopment commercial/industrial workers and trespassers will be incomplete. Likewise, if vapor intrusion mitigation systems are installed in new buildings constructed in locations with applicable groundwater VOC exceedances, then indoor air inhalation exposures for post-remediation and post-redevelopment commercial/industrial workers will be incomplete. Similarly, if the final remedy includes institutional and engineering controls designed to prevent unacceptable exposures (as outlined above for remediation construction workers and redevelopment construction workers), then soil ingestion, soil dermal contact, particulate inhalation, and groundwater dermal contact exposures for post-remediation and post-redevelopment utility workers will be controlled.

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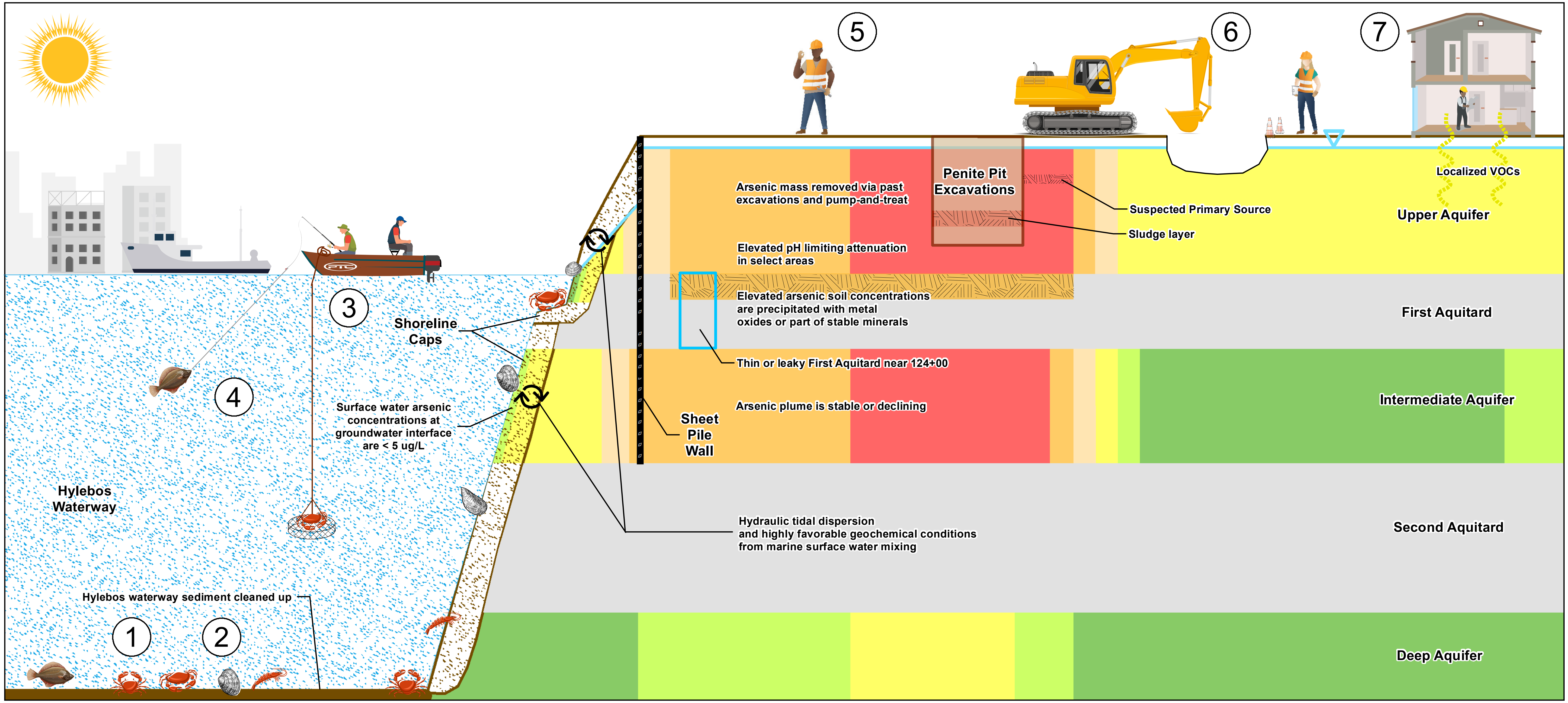
Conceptual Site Exposure Model
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

Figure 7-3

Document Path: G:\Projects\Arkema\Maps\FS Data Gap Investigation Report\7-4_X_Section_CSM.mxd; Author: VN; Date Saved: 7/22/2019



① Ingestion and dermal contact with surface water and sediment by aquatic organisms.

② Consumption of seafood by aquatic organisms.

③ Incidental ingestion and dermal contact with surface water and sediment by recreators/ fishers.

④ Consumption of seafood by recreators/ fishers.

⑤ Incidental ingestion, dermal contact, and inhalation of particulates from surface soil by on-site workers and trespassers.

⑥ Incidental ingestion, dermal contact, and inhalation of particulates from subsurface soil by utility workers.

⑦ Inhalation of indoor air vapors by on-site workers if occupied building is constructed without vapor instrusion mitigation systems in the few isolated areas that have VOCs.

Note:
Not to Scale

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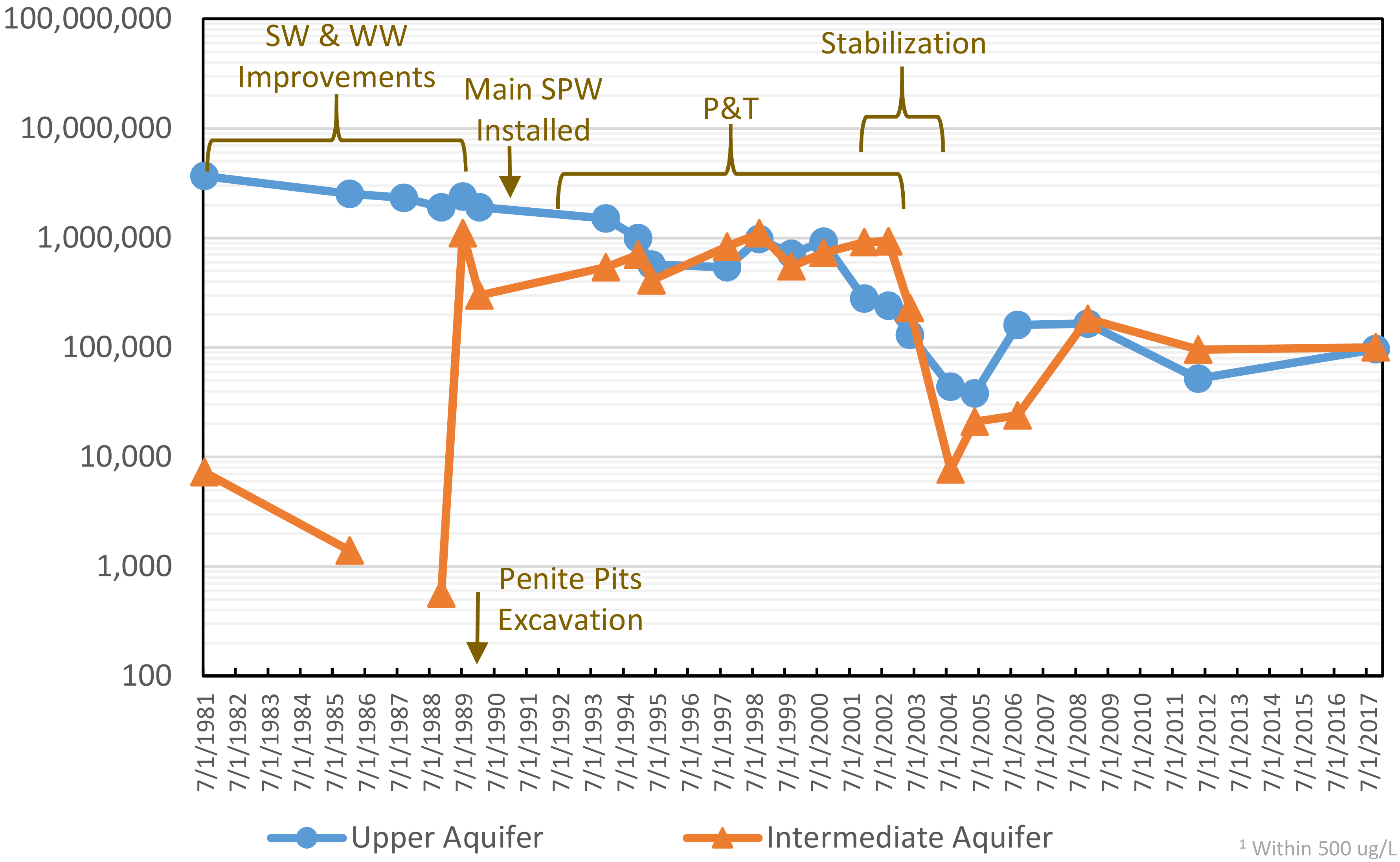
Overview of the Conceptual Site Model
FS Data Gap Investigation Report
Former Arkema Manufacturing Site

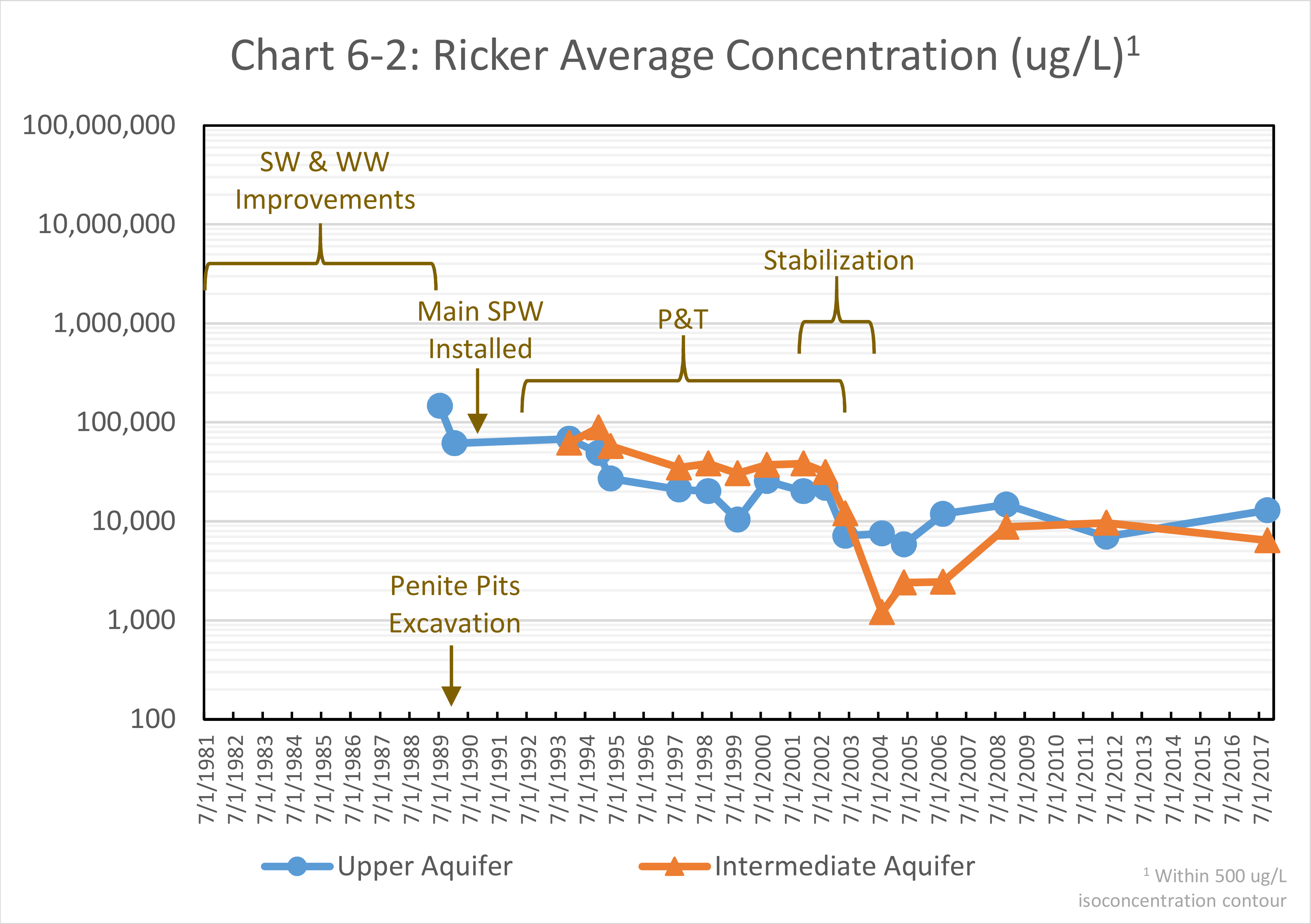
Figure 7-4

Charts

Chart 6-1: Ricker Maximum Concentration (ug/L)[1]



[1] Within 500 ug/L isoconcentration contour

Chart 6-2: Ricker Average Concentration (ug/L)¹
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
SW & WW Improvements
Main SPW Installed
P&T
Stabilization
Penite Pits Excavation
7/1/1981
7/1/1982
7/1/1983
7/1/1984
7/1/1985
7/1/1986
7/1/1987
7/1/1988
7/1/1989
7/1/1990
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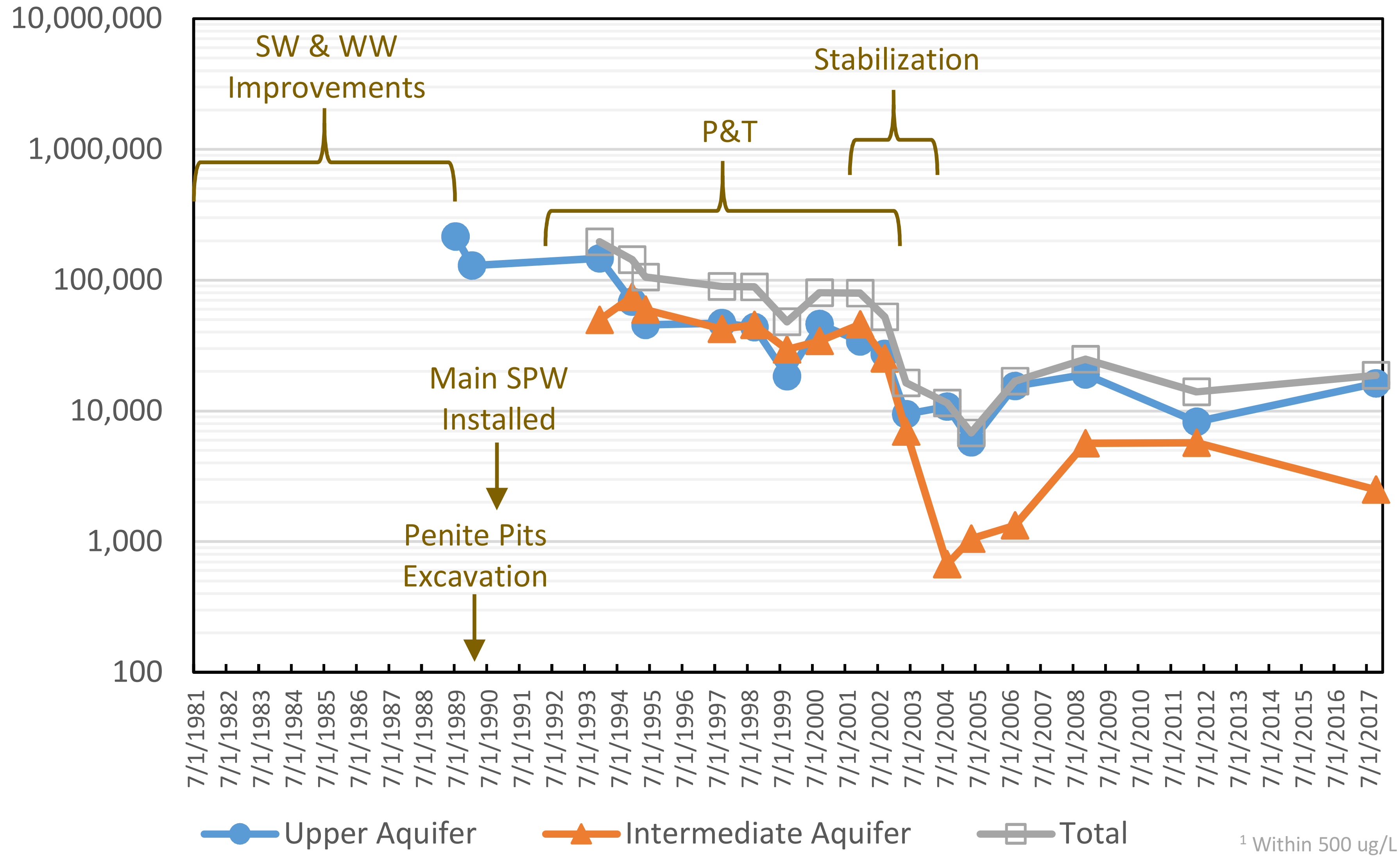
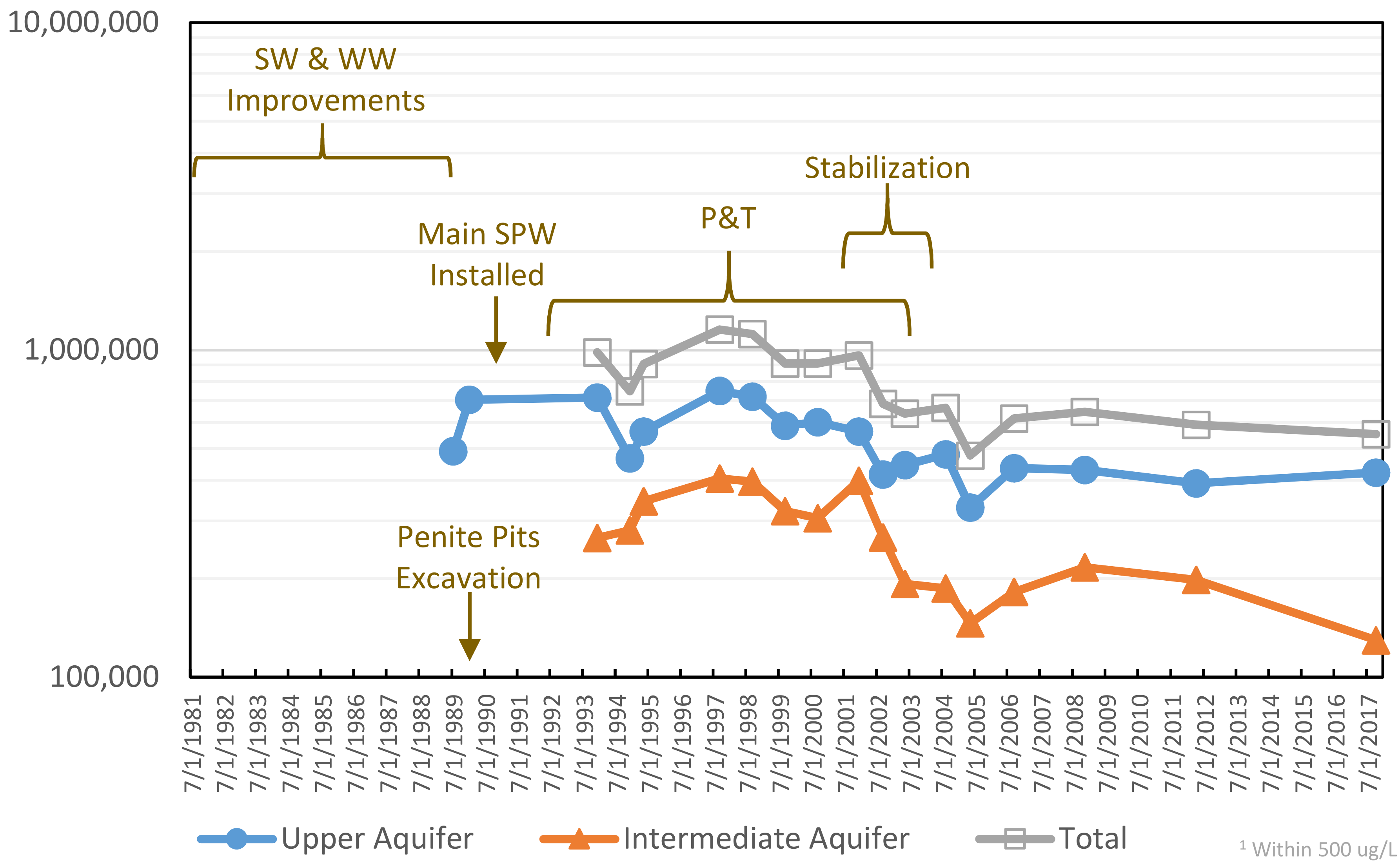
7/1/2008
7/1/2009
7/1/2010
7/1/2011
7/1/2012
7/1/2013
7/1/2014
7/1/2015
7/1/2016
7/1/2017
Upper Aquifer
Intermediate Aquifer
¹ Within 500 ug/L isoconcentration contour

Chart 6-3: Ricker Plume Mass (kg)[1]

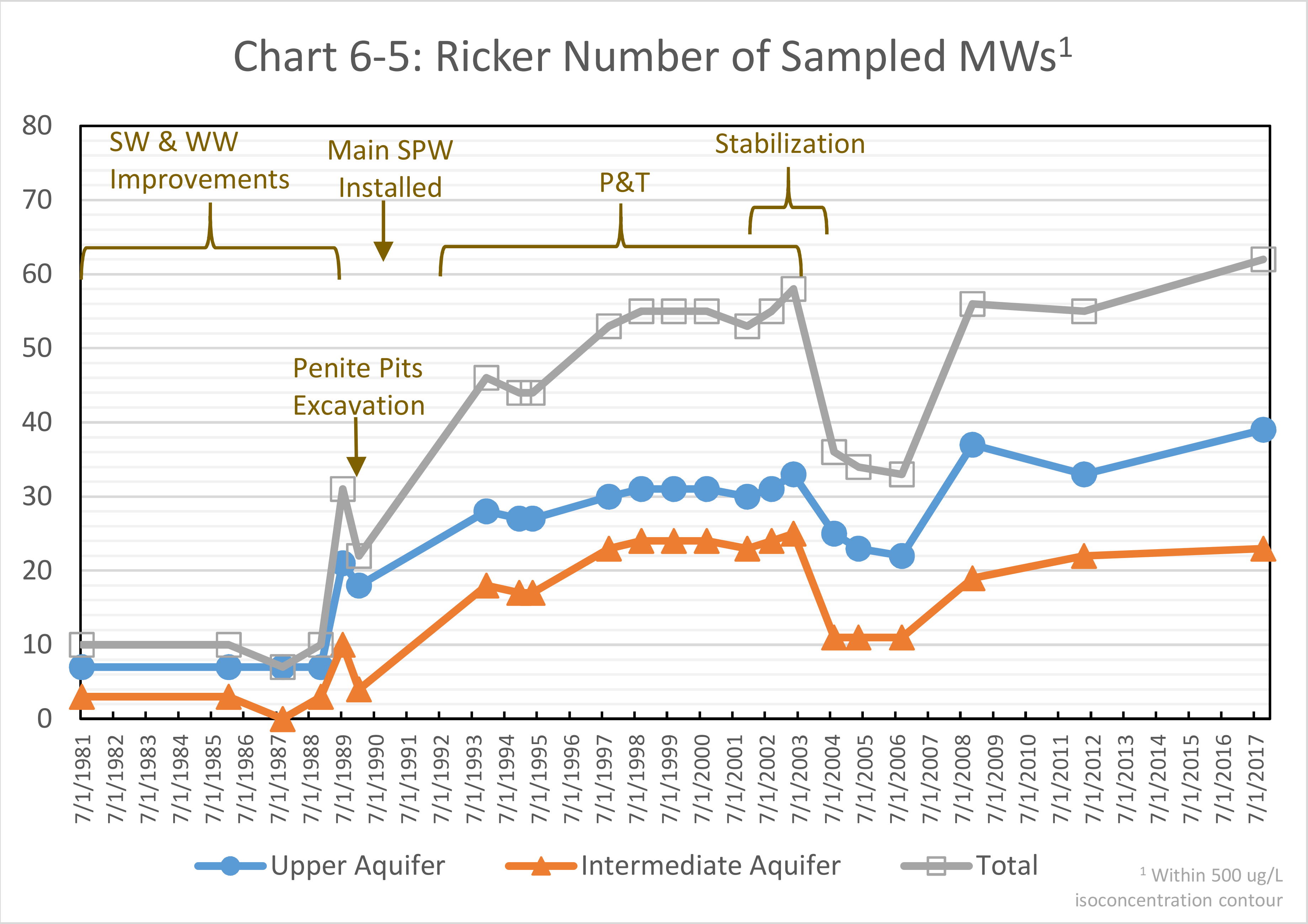


[1] Within 500 ug/L isoconcentration contour

Chart 6-4: Ricker Plume Area (ft^2)[1]

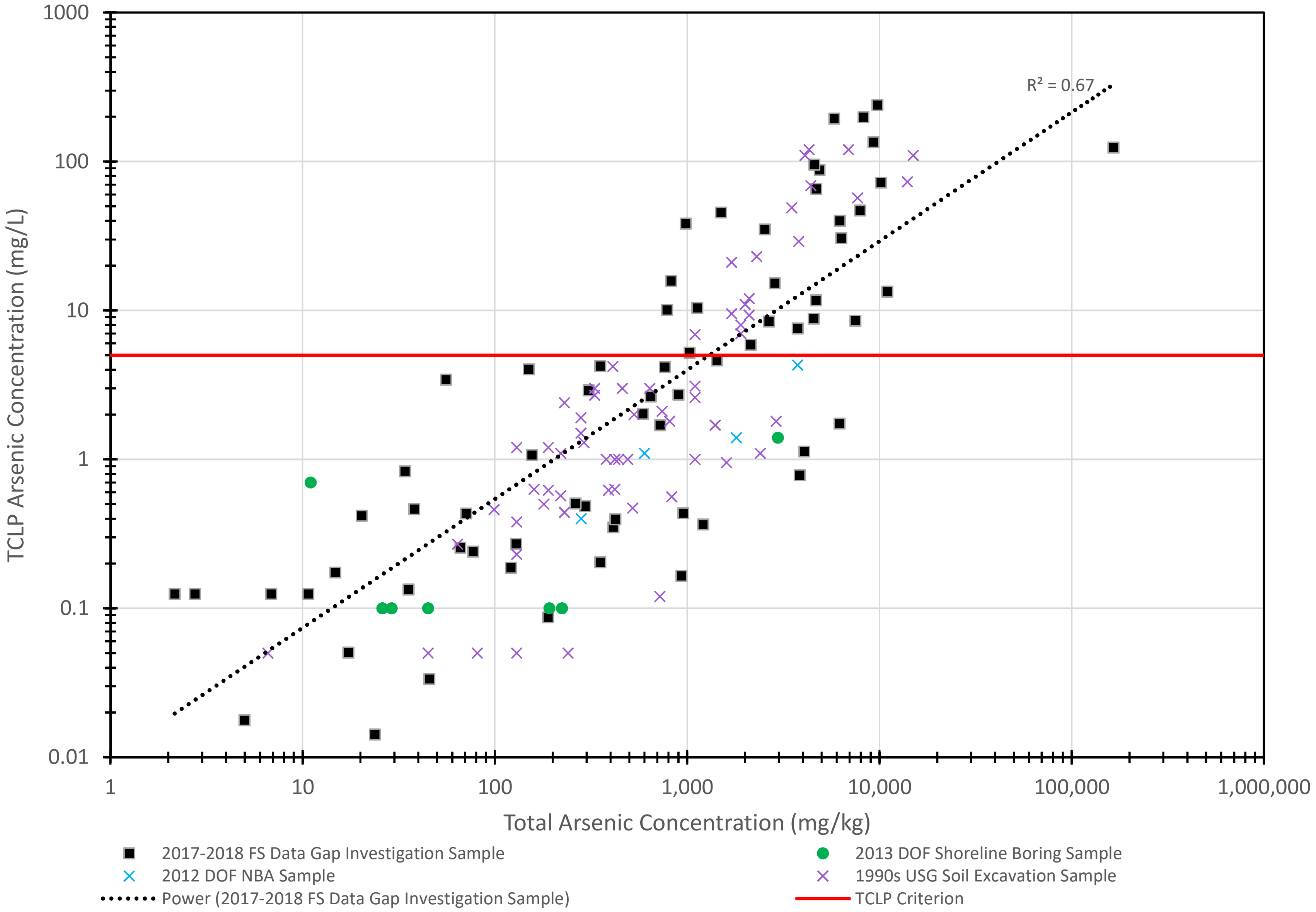


[1] Within 500 ug/L isoconcentration contour



[1] Within 500 ug/L isoconcentration contour

Chart 6-6: Comparison of Total Arsenic and TCLP Arsenic Concentrations



Tables

Table 2-1: Summary of Completed Remedial Actions

Remediation Category	Figure	Date(s)	Completed Remedial Action
Historical Stormwater and Wastewater Improvements	N/A	November 1981 and August 1986	Improvements were made to the stormwater collection and treatment system, which decreased the arsenic mass discharging from the Site to the Hylebos Waterway. Three stormwater catch basins near the former Penite Pits were sealed in 1981 and the system was modified in 1981 and 1986 to improve collection and treatment (AWARE Corporation 1981; Hart Crowser 1986). No stormwater infrastructure remains at the Site.
		1980s	Wastewater discharges to the Taylor Lake Area surface impoundments ceased by 1990. Discontinuing this practice reduced recharge to the Upper Aquifer in this area and decreased the transport of elevated pH to groundwater.
Soil/Sediment Removal	Figure 2-1A	January 1990	Approximately 3,000 CY of soil within and surrounding the former Penite Pits was excavated due to elevated arsenic soil concentrations and disposed of off-site (MPS Incorporated 1990; ICF 1990b).
		1990	Approximately 1,200 CY of sludge (containing asbestos and elevated pH) from the former Asbestos Ponds (two of the former Taylor Lake Area surface impoundments) was excavated and disposed of off-site (ICF 1990b).
		2003	Approximately 185 CY of soil northwest of former Penite Pit #1 was excavated due to elevated arsenic soil concentrations and disposed of off-site (ERM 2003b).
		2003	Soil and sediment were excavated from the North Boundary Area shoreline and disposed of off-site as part of the reconfiguration of the shoreline in this area (DOF 2011).
		2003 to 2005	Hylebos Waterway sediment was dredged adjacent to the Site (including the areas where sediment caps were subsequently placed) and disposed of off-site (DOF 2011).
		2004	Approximately 13,100 tons of soil, sediment, and debris were excavated from the intertidal zone of the Site shoreline due to elevated arsenic concentrations and disposed of off-site (DOF 2011).
		2013 to 2014	Approximately 25,000 tons of soil was excavated from the Arkema Mound site due to elevated arsenic soil concentrations and disposed of off-site. This action is included as a soil removal IA since a small portion of the soil was from within the Site boundary (DOF 2015a).
		2014	Approximately 2,200 tons of soil was excavated from Wypenn due to elevated arsenic soil concentrations and disposed of off-site during an IA to achieve compliance with the MTCA Standard Method C industrial soil cleanup level of 88 mg/kg for the soil direct contact pathway (DOF 2015b).
Soil/Sediment Cap	Figure 2-1A	1990	All of the former Taylor Lake Area surface impoundments and the former Waggoner's Wallow surface impoundment in the North Boundary Area were backfilled with soil (DOF 2013). The thickness of the soil cap is likely one to four feet based on the depth of the former surface impoundments (AWARE Corporation 1981).
		2004 to 2005	A three-foot-thick sediment cap was installed in the intertidal zone of the Site shoreline (seaward of the SPW) as part of the backfill for the 2004 intertidal soil removal (DOF 2011).
		2006	A four-foot-thick sediment cap was installed in the subtidal zone of the Site shoreline (seaward of the sheet pile wall) to cap elevated arsenic concentrations in sediment that could not feasibly be dredged (DOF 2011).
SPW	Figure 2-1A	October 1990	A SPW was installed west of the Site shoreline to reduce arsenic mass discharge from the Site to the Hylebos Waterway (ICF 1990a, 1990b). The SPW was constructed of interlocking steel sheet piles that were 21.6 inches wide, 0.315 inches thick, and 30 feet long. The SPW was seated into the Second Aquifer. Every second joint was welded, and joints that were not welded were sealed with an asphalt material. Two gaps in the top part of the SPW were discovered and filled in 2004 (see Appendix A). The source of these two gaps is unknown but may have been due to the SPW construction or earth movement during the 2001 Nisqually earthquake.
		February 1991 to April 1992	The SPW was extended to the south to improve containment of arsenic in groundwater near the southern end of the original wall (ICF 1991, 1992). This extension is referred to as the southern SPW wing.
		August 1995	The SPW was extended to the north to improve containment of arsenic in groundwater near the northern end of the original SPW (Elf Atochem 1995). The 1995 and 1997 extensions are referred to as the northern SPW wing.
		June 1997	The northern portion of the SPW was further extended to improve containment of arsenic in groundwater near the northern end of the SPW (DOF 2013). The 1995 and 1997 extensions are referred to as the northern SPW wing.
Arsenic P&T System	Figure 2-1B	1992 to 2003	A groundwater P&T system that included four Upper Aquifer extraction trenches, 15 Upper Aquifer extraction wells, and five Intermediate Aquifer extraction wells was installed and operated within the main arsenic plume (ICF 1990c, 1995; DOF 2013). The P&T system removed more than 22,000 pounds of arsenic (Boateng 2003). Once the arsenic concentrations in the extracted groundwater reached an asymptote, the P&T system was shut down as part of a planned transition from P&T to polishing with in-situ stabilization (ICF 1990c).
In-Situ Stabilization	Figure 2-1B	November 2001 to June 2004	In situ stabilization was performed within portions of the main arsenic plume as a planned post-P&T polishing activity (ICF 1990c; ERM 2003a, 2005). In-situ stabilization consisted of injecting hydrogen peroxide and ferric chloride into the Upper and Intermediate Aquifers to reduce pH, oxidize arsenite to arsenate, and provide ferric iron, which combined to facilitate sorption and co-precipitation of arsenic in groundwater onto soil. Approximately 139 tons of iron was injected (ERM 2005).
VOC Remediation	Figure 2-1B	1996 to 2000	A soil vapor extraction system and a groundwater P&T system were installed and operated in order to remove VOCs in a few areas along the southern border of the North Boundary Area where localized VOCs in groundwater was identified (Boateng 2002).
		2003	In-situ chemical oxidation was performed in 2003 (using hydrogen peroxide) to treat VOCs in an area east of the former Taylor Lake Area surface impoundments where localized VOCs in groundwater where identified (ERM 2003c).
Remediation of Miscellaneous Releases	Figure 2-1B	Various	Historical process-related spills were remediated (e.g., sodium chlorate, No. 2 fuel, hydrochloric acid) as necessary (DOF 2013).

Notes:

CY: cubic yards

ERM: Environmental Resources Management

N/A: Not applicable

ICF: ICF Technology Incorporated

Table 2-2: Comparison of Arsenic Concentrations (mg/kg Wet Weight) in Puget Sound and Site Mussels

Dataset	Number of Samples	Minimum	Mean	Median	90th Percentile	Maximum
All Transplanted Mussels in WDFW PSEMP Study (1)	90	0.65	0.87	0.86	0.98	1.2
Transplanted Mussels in Hylebos Waterway Downgradient of Site	9	0.84	0.95	0.93	1.0	1.1
All Native Mussels in WDFW PSEMP Study (1)	6	0.58	0.79	0.81	0.91	0.95
Native Mussels in Hylebos Waterway Downgradient of Site	1	0.82				

Notes:

(1) Includes sampling locations in Puget Sound (north, central, and south), the Whidbey Basin, the Bellingham Basin, Admiralty Inlet, the San Juan Archipelago, and Hood Canal. A specific subset of sample locations that constitutes a "background" cannot be readily determined since the study objective was to achieve "the most extensive geographic coverage possible." However, many of the sample locations are likely representative of background concentrations within Puget Sound and surrounding marine waters. Examples of several sample locations expected to be representative of background concentrations are shown below.

Table 4-1: Identified Work Plan Deviations

FS Data Gap	Deviation	Explanation
1 (Shoreline Concentrations)	A smaller nylon screen mesh size was used to construct the NSDSs.	A 22 micron mesh was used to construct the NSDSs (rather than the 120 to 250 micron mesh size indicated in the Work Plan) based on lessons learned on another project in order to minimize the potential for turbidity in the samples.
	Five additional pore water NSDSs were installed for use during the 2018 water sampling event.	NSDSs were installed at 119+25-0-DS, 120+75-0-DS, 119+25-ST1-DS, 123+25-ST1-DS, and 126+80-ST1-DS for the 2018 water sampling event in order to facilitate determining arsenic concentrations in representative pore water samples at additional shoreline locations.
2 (Arsenic Plume Stability)	Groundwater samples were not collected form MW-A2-2 on the Arkema Mound site.	A groundwater sample could not be collected because the MW was decommissioned pursuant to work on the Arkema Mound site and a replacement MW was not installed.
	Synoptic static water level measurements were only obtained for a 2017 high-tide event.	Synoptic static water level measurements were not obtained for a 2017 low-tide event or during 2018 because these data were not needed for the CSM or groundwater modeling efforts. This Work Plan simplification was made because existing static water level data were deemed sufficient for understanding low-tide and high-tide groundwater elevations at the Site.
	Eleven additional water samples were collected and analyzed during the 2018 water sampling event.	The 11 additional samples were collected in 2018 to support the evaluation of shoreline concentrations, the evaluation of plume stability, the CSM, and/or groundwater modeling efforts. The 11 additional sample locations consisted of five NSDSs (119+25-0-DS, 120+75-0-DS, 119+25-ST1-DS, 123+25-ST1-DS, and 126+80-ST1-DS), three high-tide samples (124+00-0, 125+50-0, and 126+90-0), three Upper Aquifer MWs (5E1-1, 5E2-1, 5E8-1), and two Deep Aquifer MWs (5D1-3 and 6E7-3).
	Fifteen planned water samples were not collected during the 2018 water sampling event.	Samples were not collected from 2A1-1, 3A3-1R, 3A7-1R, 4B4-1, 3A2-2R, 3A6-2R, 4B4-2, 5C10-2, 5C14-2, 5D8-2, 6B19-2, 7E13-2R, 7F1-2, 8F2-2R, and 8G3-2 during the 2018 water sampling event because existing results from 2017 and previous investigations were deemed sufficient for characterizing arsenic concentrations in these MWs (e.g., many of these MWs are located in the far northern or far southern portions of the Site).
	Field measurements of total iron and sulfate were not obtained during the water sampling events, and field measurements of ferrous iron and sulfide were only obtained during the 2017 water sampling event.	Field measurements were not obtained for total iron and sulfate during the water sampling events because total iron and sulfate data were already being obtained via laboratory analyses. Field measurements of ferrous iron and sulfide were not obtained during the 2018 water sampling event because the 2017 field ferrous iron and sulfide results were deemed sufficient for the purposes of the investigation.
	Select samples during the 2017 water sampling event were not analyzed for ortho-phosphorus or alkalinity.	Select water samples near the shoreline were not analyzed for ortho-phosphorus due to matrix interference issues experienced by the laboratory. Select groundwater samples with elevated pH (e.g., pH greater than 11) were not analyzed for alkalinity (a measure of buffering capacity) because the analytical method is not appropriate for such samples.
	Samples collected upgradient of the SPW during the 2018 water sampling event were not analyzed for dissolved coper, lead, nickel, and mercury.	Samples collected downgradient of the SPW during the 2018 water sampling event were analyzed for dissolved copper, lead, nickel, and mercury as planned. However, samples collected upgradient of the SPW during the 2018 water sampling event were not analyzed for dissolved copper, lead, nickel, and mercury as originally planned because the 2017 results from these locations were deemed sufficient for the purposes of the investigation.
	Brooks Applied Labs (BAL) utilized a different USEPA Method for analyses of copper, nickel, and lead analyses in most water samples.	In order to improve detection limits, BAL utilized USEPA Method 1638 Mod (rather than USEPA Method 1640 Mod) for copper, nickel, and lead analyses in most water samples due to interferences encountered with USEPA Method 1640 Mod.
	A few 2017 water samples were submitted in sample containers that did not match Work Plan expectations.	The sample container expectation for BAL analysis of mercury in a water sample was one 125 mL fluorinated polyethylene container. The sample container expectation for BAL analysis of arsenic, copper, lead, and nickel in a water sample was one 125 mL high density polyethylene container. A few samples for mercury analysis were inadvertently submitted in high density polyethylene containers and a few samples for arsenic, copper, lead, and nickel analysis were inadvertently submitted in fluorinated polyethylene containers. BAL was notified of this oversight in a timely manner and BAL made any necessary sample container adjustments for these samples.
	Soil and sediment samples collected pursuant to Data Gap #2D were not analyzed for arsenic species.	Analysis of select soil and sediment samples for arsenic species was deemed unnecessary for the purposes of this investigation since water samples were analyzed for arsenic species.
	Fewer soil samples collected pursuant to Data Gap #2D were analyzed for conventionals.	All Data Gap #2D samples were analyzed for pH, and all samples collected from the Upper Aquifer and Intermediate Aquifer in 2017 were analyzed for the other conventionals (i.e., iron, aluminum, manganese, sulfate, ortho-phosphorus, total organic carbon, total inorganic carbon, and sulfide) as planned. However, analysis of First Aquitard and Second Aquitard samples for the other conventionals was deemed unnecessary for the purposes of this investigation since aquifer samples were analyzed for conventionals. In addition, soil samples collected from PTC-117, PTC-118, PTC-127, and PTC-128 were not analyzed for the other conventionals as originally planned because these conventionals were deemed to be sufficiently characterized based on soil sampling results from 2017 and previous investigations.
	The list of Data Gap #2D soil and sediment samples selected for sequential extraction and follow-on analyses was modified.	The initial Work Plan list of soil and sediment samples for sequential extraction and follow-on analyses was optimized to focus on the 14 most important sample locations: Upper Aquifer and Intermediate Aquifer soil samples from PTC-101, PTC-111, PTC-113, PTC-121, PTC-129, PTC-204, and PTC-208. Eleven additional samples were subsequently selected for sequential extraction and follow-on analyses in order to support groundwater modeling efforts: eight First Aquitard soil samples (PTC-001, PTC-104, PTC-108, PTC-112, PTC-120, PTC-122, PTC-127, and PTC-129) and three sediment samples (125+50-0-SED, 125+00-ST1-SED, and 128+50-ST1-SED).
	Total arsenic analyses by BAL were added for all samples selected for sequential extraction.	All soil and sediment samples were analyzed by ARI for total arsenic as planned. In addition, soil and sediment samples selected for sequential extraction were also analyzed by BAL for total arsenic in order to enable sequential extraction arsenic results provided by BAL to be compared to total arsenic results provided by BAL.
	Modifications were made to the batch adsorption test (BAT) sampling design.	The BATs were included in the Work Plan for the purpose of developing Site-specific sorption isotherms that could hopefully be used for the groundwater modeling efforts. Modifications to the BAT sampling design included (1) using a laboratory prepared aqueous solution (rather than Site groundwater) to eliminate interferences from co-precipitation of arsenic, (2) analyzing for arsenic species rather than total arsenic, (3) revising laboratory procedures to ensure anoxic test conditions were maintained, and (4) revising the list of samples to be analyzed by BAT. See the analytical laboratory reports for details on how the BATs were performed.
	Data quality validation was not performed on the analyses related to sequential extraction and BATs.	Data quality validation was not performed on the analyses related to sequential extraction and BATs due to the nature and purpose of these analyses.
4 (Feasibility of Focused Soil Excavation)	The size of the area investigated pursuant to Data Gap #4A was expanded, and two additional Data Gap #4A soil borings were advanced and sampled.	Based on an evaluation of results from the five Data Gap #4A borings advanced and sampled in 2017, the size of the Data Gap #4A investigation area was expanded to better assess the extent of arsenic in Upper Aquifer and First Aquitard soil surrounding and downgradient of the former Penite Pits, and the number of Data Gap #4A soil borings was increased from 28 to 30.
	The 2018 Data Gap #4A soil borings were only advanced into the First Aquitard.	The five soil borings advanced in 2017 did extend into the Second Aquitard as planned. However, the 25 soil borings advanced in 2018 did not extend into the Second Aquitard as originally planned since arsenic soil concentrations within the Intermediate Aquifer and Second Aquitard were deemed to be sufficiently characterized based on soil sampling results from 2017 and previous investigations.
	Four planned soil borings associated with Data Gap #4B were not advanced.	Soil borings PTC-201, PTC-202, PTC-203, and PTC-206 were not advanced since the four Data Gap #4B soil borings that were advanced and sampled (PTC-204, PTC-205, PTC-207, and PTC-208) provided sufficient data to fill Data Gap #4B. In other words, the results obtained from PTC-204, PTC-205, PTC-207, and PTC-208 adequately demonstrated that elevated pH is widely distributed in soil throughout the Upper Aquifer and First Aquitard (rather than being concentrated in a discrete soil layer).

Notes:
Sampling design components that were included in the Work Plan as contingent actions (e.g., contingent borings, contingent analyses for the 2018 water sampling event) and actions associated with field decisions (e.g., Data Gap #3 test pit locations) were not considered deviations. Likewise, changes to the preliminary and conceptual fieldwork schedule included in the Work Pan were not considered deviations.

Table 5-1: 2018 Field Eh, pH, and Conductivity Results in the Upper and Intermediate Aquifers

Sample Type	Sample Location	Eh (Volts)	pH (Standard Units)	Conductivity (uS/cm)
Upper Aquifer Pore Water NSDS	119+25-0-DS	0.38	6.51	42,000
	120+75-0-DS	0.30	7.31	38,000
	122+60-0-DS	0.29	7.45	40,000
	124+00-0-DS	0.28	7.72	42,000
	125+50-0-DS	0.29	7.78	45,000
	126+90-0-DS	0.29	7.71	43,000
	128+30-0-DS	0.29	7.64	42,000
Upper Aquifer Angled Shoreline MW	122+60-0	0.21	8.03	27,000
	124+00-0	0.31	8.46	39,000
	124+00-0 (High Tide)	0.36	8.22	32,000
	125+50-0	0.29	7.60	30,000
	125+50-0 (High Tide)	0.33	7.16	39,000
	126+90-0	0.34	7.71	37,000
	126+90-0 (High Tide)	0.37	7.74	28,000
	128+30-0	0.26	6.81	39,000
	129+65-0	0.28	7.48	29,000
Upper Aquifer Vertical Shoreline MW	5B1-1R	0.18	10.05	2,700
	121+80-1	0.010	11.15	6,100
	122+60-1	0.24	7.56	30,000
	124+00-1	0.30	8.42	37,000
	125+50-1	0.31	8.33	38,000
	126+90-1	0.31	8.04	41,000
	128+30-1	0.25	6.59	38,000
	129+65-1	0.31	7.19	33,000
	131+00-1	0.29	7.41	34,000

Table 5-1: 2018 Field Eh, pH, and Conductivity Results in the Upper and Intermediate Aquifers

Sample Type	Sample Location	Eh (Volts)	pH (Standard Units)	Conductivity (uS/cm)
Upper Aquifer MW	4C1-1	0.12	10.81	4,500
	4D1-1	-0.11	11.47	12,000
	5C12-1	-0.080	11.59	6,900
	5C13-1	-0.092	10.30	8,800
	5C16-1R	0.011	8.45	1,900
	5D2-1R	-0.024	10.81	4,900
	5D5-1	0.35	7.01	8,500
	5D7-1R	0.048	7.49	1,100
	5E1-1	0.15	6.40	560
	5E2-1	0.10	7.21	2,200
	5E4-1	-0.018	8.83	6,500
	5E8-1	0.11	7.50	530
	6D14-1	0.067	6.01	18,000
	6D25-1	-0.017	8.70	2,100
	6E1-1	0.088	6.88	1,100
	6E2-1	0.17	6.68	5,900
	6E5-1	0.10	7.08	4,400
	6E6-1	-0.15	10.86	14,000
	7E10-1	-0.13	10.05	11,000
	7E3-1	0.055	7.89	6,000
	7E8-1	-0.23	11.07	24,000
	7F2-1	0.10	7.06	11,000
	7F3-1	-0.054	10.54	14,000
	7F4-1	-0.17	12.06	54,000
	8F1-1R	0.054	10.92	13,000
	8G2-1	-0.13	11.38	29,000
Surface Water Sample	120+75-SW	0.30	7.71	44,000
	125+00-SW	0.29	7.71	44,000
	128+50-SW	0.28	7.68	40,000
Intermediate Aquifer Pore Water NSDS	119+25-ST1-DS	0.30	7.35	44,000
	120+75-ST1-DS	0.29	7.38	42,000
	123+25-ST1-DS	0.29	7.62	44,000
	125+00-ST1-DS	0.29	7.71	42,000
	126+80-ST1-DS	0.29	7.65	44,000
	128+50-ST1-DS	0.29	7.63	43,000
Intermediate Aquifer PPS	119+25-ST1	0.19	7.30	47,000
	120+75-ST1	0.12	7.36	47,000
	123+25-ST1	0.22	7.65	46,000
	125+00-ST1	0.24	7.55	45,000
	126+80-ST1	0.24	7.39	47,000
	128+50-ST1	-0.040	7.66	47,000
	130+75-ST1	0.089	7.41	48,000

Table 5-1: 2018 Field Eh, pH, and Conductivity Results in the Upper and Intermediate Aquifers

Sample Type	Sample Location	Eh (Volts)	pH (Standard Units)	Conductivity (uS/cm)
Intermediate Aquifer Vertical Shoreline MW	5B1-2R	0.11	7.01	42,000
	120+75-2	0.19	7.30	37,000
	121+80-2	-0.011	9.59	11,000
	122+60-2	0.25	8.10	30,000
	124+00-2	0.19	8.85	32,000
	125+50-2	0.14	7.49	29,000
	126+90-2	0.12	7.92	29,000
	128+30-2	-0.036	8.54	18,000
	129+65-2	-0.010	7.05	27,000
	131+00-2	0.0013	8.85	13,000
Intermediate Aquifer MW	5C16-2R	0.067	7.14	22,000
	5C21-2	0.053	6.50	22,000
	6D25-2	-0.021	9.52	4,800
	6E12-2	0.0066	6.66	48,000
	6E3-2	0.15	6.96	32,000
	6E9-2	-0.011	7.66	15,000
	7E16-2	0.074	7.20	3,100
	7E4-2	-0.095	9.98	11,000
	7E6-2	-0.17	10.30	7,900
	7E7-2	-0.016	9.54	1,700
	7E9-2	0.036	7.38	8,600

Notes:

Eh results were conservatively estimated by adding 0.2 volts to the field ORP measurements based on the type of electrode and solution used for the ORP measurements (see Appendices B and C).

Eh and conductivity results shown to two significant figures. pH results shown to two decimal places.

Table 5-2: Total Arsenic Soil Concentrations in Data Gap #4A Soil Borings

Soil Boring	Sample Depth Top (feet bgs)	Sample Depth Bottom (feet bgs)	Lithologic Unit	Arsenic Concentration (mg/kg)	Qualifier	Field XRF or Lab?
PTC-101	0.0	2.0	Upper Aquifer	816		Field XRF
	6.0	8.2	Upper Aquifer	3,160		Field XRF
	8.2	8.5	Upper Aquifer	5,479		Field XRF
	8.2	10.2	Upper Aquifer	786		Lab
	8.5	10.0	Upper Aquifer	1,057		Field XRF
	10.0	13.0	Upper Aquifer	1,407		Field XRF
	13.0	15.0	First Aquitard	10,746		Field XRF
	13.0	15.0	First Aquitard	4,880		Lab
	15.0	17.5	First Aquitard	1,287		Field XRF
	17.5	19.3	First Aquitard	5,599		Field XRF
	19.3	20.3	Intermediate Aquifer	301		Lab
	19.5	20.0	Intermediate Aquifer	1,369		Field XRF
	20.0	22.5	Intermediate Aquifer	84		Field XRF
	22.5	24.5	Intermediate Aquifer	160		Field XRF
	25.0	27.5	Intermediate Aquifer	8		Field XRF
	27.5	29.0	Intermediate Aquifer	57		Field XRF
	30.0	32.5	Intermediate Aquifer	7	U	Field XRF
	32.5	35.0	Intermediate Aquifer	7	U	Field XRF
	36.0	38.0	Second Aquitard	5	J	Lab
	36.0	38.5	Second Aquitard	7	U	Field XRF
	38.5	40.0	Second Aquitard	7	U	Field XRF
	40.0	41.6	Deep Aquifer	7	U	Field XRF
	41.6	44.0	Deep Aquifer	7	U	Field XRF
	44.0	45.0	Deep Aquifer	7	U	Field XRF
PTC-102	2.0	3.0	Upper Aquifer	195		Field XRF
	6.0	7.0	Upper Aquifer	10,556		Field XRF
	7.5	8.0	Upper Aquifer	100,000	>	Field XRF
	7.5	8.5	Upper Aquifer	165,000		Lab
	8.0	8.5	Upper Aquifer	100,000	>	Field XRF
	9.0	10.0	Upper Aquifer	20,687		Field XRF
	11.0	12.0	Upper Aquifer	1,584		Field XRF
	12.5	13.5	First Aquitard	5,313		Field XRF
	14.5	15.0	First Aquitard	9,770		Lab
	14.5	15.0	First Aquitard	12,874		Field XRF
	16.0	17.0	First Aquitard	11,394		Field XRF
	18.5	19.0	Intermediate Aquifer	1,954		Field XRF
PTC-103	1.5	2.5	Upper Aquifer	2,938		Field XRF
	4.0	5.0	Upper Aquifer	753		Field XRF
	6.0	7.0	Upper Aquifer	2,097		Field XRF
	7.5	8.5	Upper Aquifer	1,500		Lab
	7.5	8.5	Upper Aquifer	5,229		Field XRF
	11.0	12.0	Upper Aquifer	304		Field XRF
	12.8	13.8	First Aquitard	5,820		Lab
	12.8	13.8	First Aquitard	9,935		Field XRF
	15.0	16.0	First Aquitard	5,504		Field XRF
	17.0	18.0	First Aquitard	1,434		Field XRF
	19.5	20.0	Intermediate Aquifer	215		Field XRF

Table 5-2: Total Arsenic Soil Concentrations in Data Gap #4A Soil Borings

Soil Boring	Sample Depth Top (feet bgs)	Sample Depth Bottom (feet bgs)	Lithologic Unit	Arsenic Concentration (mg/kg)	Qualifier	Field XRF or Lab?
PTC-104	2.0	2.5	Upper Aquifer	669		Field XRF
	5.0	5.5	Upper Aquifer	640		Field XRF
	7.0	7.5	Upper Aquifer	1,715		Field XRF
	10.0	11.0	Upper Aquifer	1,148		Field XRF
	13.4	13.9	Upper Aquifer	902		Lab
	13.4	13.9	Upper Aquifer	2,067		Field XRF
	14.2	14.7	First Aquitard	8,260		Lab
	14.2	14.7	First Aquitard	9,763		Field XRF
	16.0	17.0	First Aquitard	4,274		Field XRF
	18.0	19.0	First Aquitard	849		Field XRF
PTC-105	1.0	2.0	Upper Aquifer	35		Field XRF
	3.0	4.0	Upper Aquifer	233		Field XRF
	6.0	7.0	Upper Aquifer	925		Field XRF
	8.0	9.0	Upper Aquifer	1,130		Lab
	8.0	9.0	Upper Aquifer	996		Field XRF
	11.0	12.0	Upper Aquifer	459		Field XRF
	13.0	14.0	First Aquitard	11,367		Field XRF
	13.0	14.0	First Aquitard	7,940		Lab
	16.0	17.0	First Aquitard	958		Field XRF
	18.0	19.0	First Aquitard	19		Field XRF
PTC-106	2.0	2.5	Upper Aquifer	511		Field XRF
	5.0	6.0	Upper Aquifer	1,386		Field XRF
	7.0	8.0	Upper Aquifer	1,430		Lab
	7.0	8.0	Upper Aquifer	1,752		Field XRF
	11.0	12.0	Upper Aquifer	713		Field XRF
	12.6	12.9	First Aquitard	2,661		Field XRF
	13.0	14.0	First Aquitard	4,690		Lab
	13.0	14.0	First Aquitard	6,034		Field XRF
PTC-107	1.5	2.0	Upper Aquifer	123		Field XRF
	6.0	7.0	Upper Aquifer	150		Lab
	6.0	7.0	Upper Aquifer	253		Field XRF
	10.0	11.0	Upper Aquifer	962		Field XRF
	11.0	12.0	First Aquitard	20		Lab
	11.0	12.0	First Aquitard	68		Field XRF
	14.0	15.0	First Aquitard	8		Field XRF
PTC-108	1.5	2.0	Upper Aquifer	317		Field XRF
	3.5	4.0	Upper Aquifer	805		Field XRF
	5.5	6.5	Upper Aquifer	850		Field XRF
	8.5	9.5	Upper Aquifer	368		Field XRF
	12.0	12.5	Upper Aquifer	825		Lab
	12.0	12.5	Upper Aquifer	909		Field XRF
	13.2	14.2	First Aquitard	11,000		Lab
	13.2	14.2	First Aquitard	8,944		Field XRF
	15.5	16.5	First Aquitard	2,302		Field XRF
	18.0	18.5	Intermediate Aquifer	368		Field XRF

Table 5-2: Total Arsenic Soil Concentrations in Data Gap #4A Soil Borings

Soil Boring	Sample Depth Top (feet bgs)	Sample Depth Bottom (feet bgs)	Lithologic Unit	Arsenic Concentration (mg/kg)	Qualifier	Field XRF or Lab?
PTC-109	2.0	3.0	Upper Aquifer	275		Field XRF
	5.0	6.0	Upper Aquifer	4,700		Lab
	5.0	6.0	Upper Aquifer	982		Field XRF
	8.0	9.0	Upper Aquifer	114		Field XRF
	11.0	12.0	Upper Aquifer	840		Field XRF
	13.0	14.0	First Aquitard	6,340		Lab
	13.0	14.0	First Aquitard	8,372		Field XRF
	16.0	17.0	First Aquitard	1,252		Field XRF
	18.0	19.0	First Aquitard	98		Field XRF
PTC-110	2.0	2.5	Upper Aquifer	62		Field XRF
	5.0	5.5	Upper Aquifer	273		Field XRF
	7.5	8.0	Upper Aquifer	150		Field XRF
	11.0	12.0	Upper Aquifer	295		Lab
	11.0	12.0	Upper Aquifer	202		Field XRF
	14.5	15.0	Upper Aquifer	2,015		Field XRF
	16.0	17.0	First Aquitard	9,300		Lab
	16.0	17.0	First Aquitard	8,701		Field XRF
	19.0	20.0	First Aquitard	3,240		Field XRF
PTC-111	0.0	2.0	Upper Aquifer	64		Field XRF
	2.0	4.0	Upper Aquifer	126		Field XRF
	5.0	6.0	Upper Aquifer	1,307		Field XRF
	6.0	8.0	Upper Aquifer	955		Lab
	6.0	9.0	Upper Aquifer	1,492		Field XRF
	10.0	11.6	Upper Aquifer	423		Field XRF
	11.6	12.4	Upper Aquifer	812		Field XRF
	12.4	13.1	First Aquitard	2,621		Field XRF
	13.1	15.0	First Aquitard	10,200		Lab
	13.1	15.0	First Aquitard	13,248		Field XRF
	15.0	17.9	First Aquitard	2,379		Field XRF
	17.9	20.0	Intermediate Aquifer	55		Field XRF
	20.0	22.0	Intermediate Aquifer	39		Lab
	20.0	23.3	Intermediate Aquifer	62		Field XRF
	23.3	25.5	Intermediate Aquifer	19		Field XRF
	25.5	28.0	Intermediate Aquifer	22		Field XRF
	28.0	30.0	Intermediate Aquifer	12		Field XRF
	30.0	32.5	Intermediate Aquifer	9		Field XRF
	32.5	35.0	Intermediate Aquifer	7	U	Field XRF
	35.0	37.3	Intermediate Aquifer	7	U	Field XRF
	37.3	39.5	Second Aquitard	4	J	Lab
	37.3	40.0	Second Aquitard	7	U	Field XRF
PTC-112	1.5	2.5	Upper Aquifer	71		Field XRF
	3.5	4.0	Upper Aquifer	81		Field XRF
	6.5	7.5	Upper Aquifer	76		Field XRF
	8.0	8.5	Upper Aquifer	244		Field XRF
	10.5	11.0	Upper Aquifer	723		Lab
	10.5	11.0	Upper Aquifer	1,347		Field XRF
	12.5	13.0	Upper Aquifer	602		Field XRF
	13.5	14.5	First Aquitard	1,367		Field XRF
	17.0	18.0	First Aquitard	2,530		Lab
	17.0	18.0	First Aquitard	5,435		Field XRF
	19.0	20.0	First Aquitard	6	U	Field XRF

Table 5-2: Total Arsenic Soil Concentrations in Data Gap #4A Soil Borings

Soil Boring	Sample Depth Top (feet bgs)	Sample Depth Bottom (feet bgs)	Lithologic Unit	Arsenic Concentration (mg/kg)	Qualifier	Field XRF or Lab?
PTC-113	0.0	1.8	Upper Aquifer	57		Field XRF
	1.8	4.0	Upper Aquifer	19		Field XRF
	5.0	7.5	Upper Aquifer	99		Field XRF
	7.5	10.0	Upper Aquifer	685		Field XRF
	7.5	10.0	Upper Aquifer	414		Lab
	10.0	11.3	Upper Aquifer	2,834		Field XRF
	11.3	12.5	First Aquitard	7,415		Field XRF
	12.3	14.3	First Aquitard	6,210		Lab
	12.5	15.0	First Aquitard	4,369		Field XRF
	15.0	17.0	First Aquitard	1,863		Field XRF
	17.0	18.0	First Aquitard	2,369		Field XRF
	18.0	20.0	Intermediate Aquifer	2,395		Field XRF
	18.0	20.0	Intermediate Aquifer	1,430		Lab
	23.0	25.0	Intermediate Aquifer	1,596		Field XRF
	25.0	27.5	Intermediate Aquifer	242		Field XRF
	27.5	30.0	Intermediate Aquifer	152		Field XRF
	30.0	32.5	Intermediate Aquifer	9		Field XRF
	32.5	35.0	Intermediate Aquifer	11		Field XRF
	35.0	37.0	Intermediate Aquifer	22		Field XRF
	37.0	39.0	Second Aquitard	7	J	Lab
	37.0	40.0	Second Aquitard	7	U	Field XRF
PTC-114	1.5	2.0	Upper Aquifer	75		Field XRF
	3.5	4.0	Upper Aquifer	56		Field XRF
	7.0	7.5	Upper Aquifer	121		Lab
	7.0	7.5	Upper Aquifer	136		Field XRF
	10.0	10.5	Upper Aquifer	53		Field XRF
	13.3	13.8	First Aquitard	2,670		Lab
	13.3	13.8	First Aquitard	6,113		Field XRF
	15.0	15.5	First Aquitard	131		Field XRF
	18.0	18.5	First Aquitard	6	U	Field XRF
PTC-115	2.0	2.5	Upper Aquifer	18		Field XRF
	5.0	5.5	Upper Aquifer	48		Field XRF
	7.5	8.0	Upper Aquifer	36		Lab
	7.5	8.0	Upper Aquifer	24		Field XRF
	10.5	11.0	Upper Aquifer	19		Field XRF
	12.5	13.0	First Aquitard	42		Field XRF
	14.5	15.0	First Aquitard	156		Lab
	14.5	15.0	First Aquitard	101		Field XRF
PTC-116	1.0	1.5	Upper Aquifer	11		Field XRF
	5.5	6.0	Upper Aquifer	24		Field XRF
	8.5	9.0	Upper Aquifer	77		Lab
	8.5	9.0	Upper Aquifer	40		Field XRF
	11.0	11.5	Upper Aquifer	122		Field XRF
	13.1	13.6	First Aquitard	7,490		Lab
	13.1	13.6	First Aquitard	3,543		Field XRF
	16.0	16.5	First Aquitard	1,315		Field XRF
	18.0	18.5	First Aquitard	1,498		Field XRF

Table 5-2: Total Arsenic Soil Concentrations in Data Gap #4A Soil Borings

Soil Boring	Sample Depth Top (feet bgs)	Sample Depth Bottom (feet bgs)	Lithologic Unit	Arsenic Concentration (mg/kg)	Qualifier	Field XRF or Lab?
PTC-117	0.9	1.5	Upper Aquifer	11		Field XRF
	6.4	6.9	Upper Aquifer	298		Lab
	6.4	6.9	Upper Aquifer	288		Field XRF
	9.0	9.5	Upper Aquifer	68		Field XRF
	10.5	11.5	Upper Aquifer	166		Field XRF
	12.0	13.0	First Aquitard	1,899		Field XRF
	14.5	15.0	First Aquitard	4,580		Lab
	14.5	15.0	First Aquitard	6,769		Field XRF
PTC-118	2.0	2.5	Upper Aquifer	7		Field XRF
	5.0	5.5	Upper Aquifer	44		Field XRF
	8.0	8.5	Upper Aquifer	71		Lab
	8.0	8.5	Upper Aquifer	47		Field XRF
	10.5	11.0	First Aquitard	6,200		Lab
	10.5	11.0	First Aquitard	4,493		Field XRF
	12.0	12.5	First Aquitard	490		Field XRF
	14.5	15.0	First Aquitard	43		Field XRF
PTC-119	1.0	1.5	Upper Aquifer	60		Field XRF
	3.5	4.0	Upper Aquifer	324		Field XRF
	6.0	6.5	Upper Aquifer	590		Lab
	6.0	6.5	Upper Aquifer	819		Field XRF
	8.5	9.0	Upper Aquifer	391		Field XRF
	11.5	12.0	First Aquitard	2,860		Lab
	11.5	12.0	First Aquitard	2,271		Field XRF
	14.5	15.0	First Aquitard	760		Field XRF
PTC-120	3.0	3.5	Upper Aquifer	212		Field XRF
	4.0	4.5	Upper Aquifer	301		Field XRF
	6.0	7.0	Upper Aquifer	90		Field XRF
	6.5	7.0	Upper Aquifer	1,000		Field XRF
	9.0	10.0	Upper Aquifer	765		Lab
	9.0	10.0	Upper Aquifer	661		Field XRF
	11.0	12.0	First Aquitard	3,850		Lab
	11.0	12.0	First Aquitard	4,995		Field XRF
	14.0	15.0	First Aquitard	86		Field XRF

Table 5-2: Total Arsenic Soil Concentrations in Data Gap #4A Soil Borings

Soil Boring	Sample Depth Top (feet bgs)	Sample Depth Bottom (feet bgs)	Lithologic Unit	Arsenic Concentration (mg/kg)	Qualifier	Field XRF or Lab?
PTC-121	1.5	3.5	Upper Aquifer	286		Field XRF
	6.3	8.3	Upper Aquifer	237		Field XRF
	8.3	10.0	Upper Aquifer	364		Field XRF
	10.0	11.2	Upper Aquifer	456		Field XRF
	11.0	13.0	Upper Aquifer	2,140		Lab
	11.2	13.1	Upper Aquifer	1,739		Field XRF
	13.1	15.0	First Aquitard	1,130		Lab
	13.1	15.0	First Aquitard	1,451		Field XRF
	15.0	17.0	First Aquitard	1,216		Field XRF
	17.0	18.2	First Aquitard	1,503		Field XRF
	18.2	20.0	Intermediate Aquifer	1,130		Field XRF
	21.3	22.4	Intermediate Aquifer	631		Field XRF
	22.0	24.0	Intermediate Aquifer	38		Lab
	22.4	23.7	Intermediate Aquifer	215		Field XRF
	23.7	25.0	Intermediate Aquifer	7	U	Field XRF
	25.0	26.7	Intermediate Aquifer	7		Field XRF
	26.7	28.2	Intermediate Aquifer	7	U	Field XRF
	28.2	30.0	Intermediate Aquifer	7	U	Field XRF
	30.0	32.6	Intermediate Aquifer	7	U	Field XRF
	32.6	33.7	Intermediate Aquifer	7	U	Field XRF
	33.7	35.0	Intermediate Aquifer	12		Field XRF
	35.0	36.0	Intermediate Aquifer	7	U	Field XRF
	36.0	38.0	Second Aquitard	4	J	Lab
	36.0	38.6	Second Aquitard	7	U	Field XRF
	38.6	40.0	Deep Aquifer	7	U	Field XRF
PTC-122	2.0	2.5	Upper Aquifer	424		Field XRF
	2.0	3.0	Upper Aquifer	353		Lab
	5.0	5.5	Upper Aquifer	177		Field XRF
	7.0	7.5	Upper Aquifer	191		Field XRF
	9.5	10.0	First Aquitard	4,172		Field XRF
	9.5	10.5	First Aquitard	3,760		Lab
	12.0	12.5	First Aquitard	155		Field XRF
	14.0	14.5	First Aquitard	9		Field XRF
PTC-123	2.0	2.6	Upper Aquifer	957		Field XRF
	3.5	4.0	Upper Aquifer	646		Lab
	3.5	4.0	Upper Aquifer	827		Field XRF
	6.5	7.5	Upper Aquifer	558		Field XRF
	9.0	10.0	Upper Aquifer	448		Field XRF
	11.0	12.0	First Aquitard	1,337		Field XRF
	13.0	14.0	First Aquitard	4,560		Lab
	13.0	14.0	First Aquitard	10,167		Field XRF
	14.0	15.0	Intermediate Aquifer	256		Field XRF
PTC-124	2.5	3.5	Upper Aquifer	493		Field XRF
	6.0	7.0	Upper Aquifer	284		Field XRF
	8.5	9.5	Upper Aquifer	1,210		Lab
	9.0	9.0	First Aquitard	651		Field XRF
	11.0	12.0	First Aquitard	35		Field XRF
	12.0	13.0	First Aquitard	24		Lab
	14.0	15.0	First Aquitard	7		Field XRF

Table 5-2: Total Arsenic Soil Concentrations in Data Gap #4A Soil Borings

Soil Boring	Sample Depth Top (feet bgs)	Sample Depth Bottom (feet bgs)	Lithologic Unit	Arsenic Concentration (mg/kg)	Qualifier	Field XRF or Lab?
PTC-125	1.0	2.0	Upper Aquifer	46		Lab
	1.0	2.0	Upper Aquifer	35		Field XRF
	4.0	5.0	Upper Aquifer	11		Field XRF
	6.5	7.5	Upper Aquifer	8		Field XRF
	11.0	12.0	First Aquitard	7	U	Field XRF
	12.0	13.0	First Aquitard	7	J	Lab
	14.0	15.0	First Aquitard	8	U	Field XRF
PTC-126	2.0	2.5	Upper Aquifer	413		Field XRF
	3.5	4.0	Upper Aquifer	132		Field XRF
	6.0	6.8	Upper Aquifer	230		Field XRF
	9.0	10.0	Upper Aquifer	307		Lab
	9.0	10.0	Upper Aquifer	472		Field XRF
	11.0	11.5	Upper Aquifer	328		Field XRF
	13.5	14.0	First Aquitard	423		Lab
	13.5	14.0	First Aquitard	410		Field XRF
	17.0	17.5	First Aquitard	281		Field XRF
	19.5	20.0	First Aquitard	182		Field XRF
PTC-127	2.0	2.5	Upper Aquifer	78		Field XRF
	4.5	5.0	Upper Aquifer	54		Field XRF
	7.0	7.5	Upper Aquifer	933		Lab
	7.0	7.5	Upper Aquifer	209		Field XRF
	10.0	10.5	Upper Aquifer	186		Field XRF
	12.0	12.5	Upper Aquifer	22		Field XRF
	14.5	15.0	Upper Aquifer	91		Field XRF
	17.0	17.5	First Aquitard	984		Lab
	17.0	17.5	First Aquitard	4,008		Field XRF
	19.5	20.0	First Aquitard	9		Field XRF
PTC-128	1.5	2.0	Upper Aquifer	20		Field XRF
	6.0	6.5	Upper Aquifer	56		Lab
	6.0	6.5	Upper Aquifer	1,688		Field XRF
	7.5	8.0	First Aquitard	4,060		Lab
	7.5	8.0	First Aquitard	1,214		Field XRF
	10.5	11.0	First Aquitard	36		Field XRF
	12.5	13.0	First Aquitard	203		Field XRF
PTC-129	0.0	2.0	Upper Aquifer	29		Field XRF
	2.0	4.0	Upper Aquifer	67		Field XRF
	5.5	8.2	Upper Aquifer	512		Field XRF
	10.0	12.0	Upper Aquifer	1,066		Field XRF
	10.0	12.0	Upper Aquifer	353		Lab
	12.0	15.0	Upper Aquifer	89		Field XRF
	15.0	17.3	Upper Aquifer	38		Field XRF
	17.3	20.0	First Aquitard	66		Lab
	17.3	20.0	First Aquitard	89		Field XRF
	20.0	22.5	First Aquitard	1,816		Field XRF
	22.5	25.0	Intermediate Aquifer	239		Lab
	22.5	25.0	Intermediate Aquifer	657		Field XRF
	25.0	27.2	Intermediate Aquifer	101		Field XRF
	27.2	28.6	Intermediate Aquifer	82		Field XRF
	28.6	30.0	Intermediate Aquifer	12		Field XRF
	33.0	35.0	Intermediate Aquifer	19		Field XRF
	35.0	35.8	Intermediate Aquifer	7	U	Field XRF
	35.8	36.5	Second Aquitard	7	J	Lab
	35.8	36.5	Second Aquitard	7	U	Field XRF
	36.5	40.0	Deep Aquifer	7	U	Field XRF

Table 5-2: Total Arsenic Soil Concentrations in Data Gap #4A Soil Borings

Soil Boring	Sample Depth Top (feet bgs)	Sample Depth Bottom (feet bgs)	Lithologic Unit	Arsenic Concentration (mg/kg)	Qualifier	Field XRF or Lab?
PTC-130	1.0	1.5	Upper Aquifer	13		Field XRF
	7.0	7.5	Upper Aquifer	99		Field XRF
	9.5	10.0	Upper Aquifer	129		Lab
	9.5	10.0	Upper Aquifer	100		Field XRF
	11.0	11.5	First Aquitard	263		Lab
	11.0	11.5	First Aquitard	267		Field XRF
	13.0	13.5	First Aquitard	101		Field XRF
	15.5	16.0	Intermediate Aquifer	84		Field XRF
	17.5	18.0	Intermediate Aquifer	230		Field XRF

Notes:

J: Estimated concentration

U: Constituent was not detected at the shown reporting limit

>: Concentration exceeded upper detection limit of XRF (100,000 mg/kg).

Arsenic concentrations are shown to the nearest whole number.

Table 5-3: TCLP Metals Concentrations in Data Gap #4A Soil Borings

Soil Boring	Sample Depth Top (feet bgs)	Sample Depth Bottom (feet bgs)	Lithologic Unit	TCLP Arsenic Concentration (mg/L)	Qualifier	TCLP Barium Concentration (mg/L)	Qualifier	TCLP Cadmium Concentration (mg/L)	Qualifier	TCLP Chromium Concentration (mg/L)	Qualifier	TCLP Lead Concentration (mg/L)	Qualifier	TCLP Mercury Concentration (mg/L)	Qualifier	TCLP Selenium Concentration (mg/L)	Qualifier	TCLP Silver Concentration (mg/L)	Qualifier
PTC-101	8.2	10.2	Upper Aquifer	10		0.028		0.064		0.0076	J	0.10	U	0.00010	U	0.25	U	0.015	U
	13.0	15.0	First Aquitard	88		0.017		0.10	U	0.014	J	0.10	U	0.00010	U	0.25	U	0.015	U
PTC-102	7.5	8.5	Upper Aquifer	120		0.18	U	0.40		0.0051	J	1.9		0.024		0.041		0.0022	U
	14.5	15.0	First Aquitard	240		0.29	U	0.22		0.019	J	0.013		0.00034		0.082		0.0044	U
PTC-103	7.5	8.5	Upper Aquifer	46		0.12	U	0.041		0.0024		0.016	J	0.000039	J	0.041		0.0022	U
	12.8	13.8	First Aquitard	190		0.14	U	0.19		0.0047		0.024	J	0.000043	J	0.082		0.0044	U
PTC-104	13.4	13.9	Upper Aquifer	2.7		0.045		0.0035	U	0.0031	J	0.015	J	0.000016	J	0.078	U	0.0022	U
	14.2	14.7	First Aquitard	200		0.026	J	0.095		0.030	J	0.013	U	0.000050	J	0.086	U	0.0044	U
PTC-105	8.0	9.0	Upper Aquifer	4.8		0.14	U	0.011	U	0.0081	J	0.0065	U	0.00021		0.041	U	0.0022	U
	13.0	14.0	First Aquitard	47		0.079	U	0.040		0.015	J	0.0065	U	0.000015	J	0.041	U	0.0022	U
PTC-106	7.0	8.0	Upper Aquifer	4.6		0.10	U	0.024		0.0024	U	0.0065	U	0.000010	J	0.041	U	0.0022	U
	13.0	14.0	First Aquitard	12		0.11	U	0.020		0.016	J	0.0065	U	0.0000070	U	0.041	U	0.0022	U
PTC-107	6.0	7.0	Upper Aquifer	4.0		0.10	U	0.0091	U	0.0039	J	0.0065	U	0.0000070	U	0.041	U	0.0022	U
	11.0	12.0	First Aquitard	0.42		0.18	U	0.0041	U	0.016	J	0.0065	U	0.0000070	J	0.041	U	0.0022	U
PTC-108	12.0	12.5	Upper Aquifer	16		0.12	U	0.017	U	0.0029	J	0.0065		0.0000080	J	0.041		0.0022	U
	13.2	14.2	First Aquitard	13		0.14	U	0.015	U	0.0079	J	0.0065		0.0000070		0.041		0.0022	U
PTC-109	5.0	6.0	Upper Aquifer	66		0.10	U	0.095		0.0066	J	0.0065	U	0.0000070	U	0.041	U	0.0022	U
	13.0	14.0	First Aquitard	31		0.11	U	0.051		0.0024	U	0.0065	U	0.0000070	U	0.041	U	0.0022	U
PTC-110	11.0	12.0	Upper Aquifer	0.48		0.023		0.0029	U	0.0024	U	0.0086	J	0.0000070	U	0.041	U	0.0022	U
	16.0	17.0	First Aquitard	140		0.029	J	0.0029	U	0.021	J	0.013	U	0.000020	J	0.082	U	0.0048	J
PTC-111	6.0	8.0	Upper Aquifer	0.44		0.021		0.010	U	0.0032	J	0.10	U	0.00010	U	0.25	U	0.015	U
	13.1	15.0	First Aquitard	72		0.060	U	0.024	J	0.024	J	0.40	U	0.00010	U	1.0	U	0.060	U
PTC-112	10.5	11.0	Upper Aquifer	1.7		0.009	J	0.0044	J	0.0024	U	0.0065	U	0.0000070	U	0.058	U	0.0022	U
	17.0	18.0	First Aquitard	35		0.028		0.028		0.0048	J	0.0065	U	0.0000070	U	0.086	U	0.0022	U
PTC-113	7.5	10.0	Upper Aquifer	0.35		0.015	U	0.00090	J	0.038		0.10	U	0.00010	U	0.25	U	0.015	U
	12.3	14.3	First Aquitard	40		0.012	J	0.024		0.025	U	0.0079	J	0.00010	U	0.25	U	0.015	U
PTC-114	7.0	7.5	Upper Aquifer	0.19	J	0.029	U	0.0027	U	0.0024	U	0.0065	U	0.0000070	U	0.090	J	0.0022	U
	13.3	13.8	First Aquitard	8.4		0.12	U	0.0072	U	0.060		0.0065	U	0.0000070	U	0.11	J	0.0022	U
PTC-115	7.5	8.0	Upper Aquifer	0.13	J	0.039	U	0.0015	U	0.0033	J	0.0065	U	0.0000070	U	0.041	U	0.0022	U
	14.5	15.0	First Aquitard	1.1		0.026	U	0.0030	U	0.0076	J	0.0065	U	0.000038	J	0.041	U	0.0022	U
PTC-116	8.5	9.0	Upper Aquifer	0.24	J	0.013	J	0.0029	U	0.0024	U	0.0065	U	0.0000070	U	0.041	U	0.0022	U
	13.1	13.6	First Aquitard	8.5		0.022		0.0033	U	0.0024	U	0.0065	U	0.0000070	U	0.041	U	0.0022	U
PTC-117	6.4	6.9	Upper Aquifer	0.16	J	0.012	J	0.00080	U	0.013	J	0.0065	U	0.0000070	U	0.065	U	0.0022	U
	14.5	15.0	First Aquitard	95		0.018		0.053		0.026		0.0065	U	0.0000070	U	0.085	U	0.0022	U
PTC-118	8.0	8.5	Upper Aquifer	0.43		0.030	U	0.0015	U	0.0024	U	0.0065	U	0.0000070	U	0.057	J	0.0022	U
	10.5	11.0	First Aquitard	1.7		0.013	J	0.0020	U	0.0058	J	0.0065	U	0.0000070	U	0.12	U	0.0022	U
PTC-119	6.0	6.5	Upper Aquifer	2.0		0.020		0.0030	U	0.040		0.0065	U	0.00011		0.041	U	0.0022	U
	11.5	12.0	First Aquitard	15		0.036		0.0065	U	0.0024	U	0.0065	U	0.0000070	U	0.041	U	0.0022	U
PTC-120	9.0	10.0	Upper Aquifer	4.2		0.10	U	0.0053	U	0.0024		0.0065		0.0000070	J	0.041		0.0022	U
	11.0	12.0	First Aquitard	0.78		0.10	U	0.0041	U	0.0044	J	0.0065		0.0000070		0.041		0.0022	U
PTC-121	11.0	13.0	Upper Aquifer	5.9		0.023		0.010	U	0.0079	J	0.10	U	0.00010	U	0.25	U	0.015	U
	13.1	15.0	First Aquitard	10		0.021		0.010	U	0.0055	J	0.10	U	0.00010	U	0.25	U	0.015	U
PTC-122	2.0	3.0	Upper Aquifer	4.2		0.017	U	0.0021	U	0.0065	U	0.0087	J	0.0000070	U	0.041	U	0.0022	U
	9.5	10.5	First Aquitard	7.6		0.027	U	0.0021	U	0.0054	U	0.0065	U	0.0000070	U	0.041	U	0.0022	U
PTC-123	3.5	4.0	Upper Aquifer	2.6		0.072	U	0.0021	U	0.0054	U	0.0065	U	0.000015	J	0.041	U	0.0022	U
	13.0	14.0	First Aquitard	8.8		0.036	U	0.0021	U	0.0054	U	0.0065	U	0.0000070	U	0.041	U	0.0022	U
PTC-124	8.5	9.5	Upper Aquifer	0.37		0.028	U	0.0021	U	0.0054	U	0.0065	U	0.0000070	U	0.041	U	0.0022	U
	12.0	13.0	First Aquitard	0.014	J	0.066	U	0.0021	U	0.0098	U	0.0079	J	0.0000070	U	0.041	U	0.0022	U
PTC-125	1.0	2.0	Upper Aquifer	0.034	J	0.043	U	0.0021	U	0.0054	U	0.011	J	0.0000070	U	0.041	U	0.0022	U
	12.0	13.0	First Aquitard	0.014	U	0.011	J	0.0029	U	0.0024	U	0.0065	U	0.0000070	U	0.041	U	0.0022	U
PTC-126	9.0	10.0	Upper Aquifer	2.9		0.014	J	0.0038	U	0.0024	U	0.0065	U	0.0000070	U	0.041	U	0.0022	U
	13.5	14.0	First Aquitard	0.40		0.035		0.0034	U	0.0024	U	0.0065	U	0.0000070	U	0.041	U	0.0022	U

Table 5-3: TCLP Metals Concentrations in Data Gap #4A Soil Borings

Soil Boring	Sample Depth Top (feet bgs)	Sample Depth Bottom (feet bgs)	Lithologic Unit	TCLP Arsenic Concentration (mg/L)	Qualifier	TCLP Barium Concentration (mg/L)	Qualifier	TCLP Cadmium Concentration (mg/L)	Qualifier	TCLP Chromium Concentration (mg/L)	Qualifier	TCLP Lead Concentration (mg/L)	Qualifier	TCLP Mercury Concentration (mg/L)	Qualifier	TCLP Selenium Concentration (mg/L)	Qualifier	TCLP Silver Concentration (mg/L)	Qualifier
PTC-127	7.0	7.5	Upper Aquifer	0.17	J	0.008	J	0.0037	U	0.0024	U	0.0065	U	0.00019		0.041	U	0.0022	U
	17.0	17.5	First Aquitard	38		0.047		0.0038	U	0.024	J	0.0065	U	0.0000070	U	0.041	U	0.0022	U
PTC-128	6.0	6.5	Upper Aquifer	3.4		0.029		0.0045	U	0.0024	U	0.0065	U	0.0000070	U	0.041	U	0.0022	U
	7.5	8.0	First Aquitard	1.1		0.032		0.0033	U	0.0024	U	0.0065	U	0.0000070	U	0.041	U	0.0022	U
PTC-129	10.0	12.0	Upper Aquifer	0.20	J	0.010	J	0.00080	J	0.025	U	0.10	U	0.00010	U	0.25	U	0.015	U
	17.3	20.0	First Aquitard	0.26		0.015	J	0.0016	J	0.025	U	0.10	U	0.00010	U	0.25	U	0.015	U
PTC-130	9.5	10.0	Upper Aquifer	0.27		0.023		0.0029	U	0.0024	U	0.0065	U	0.0000080	J	0.041	U	0.0022	U
	11.0	11.5	First Aquitard	0.51		0.033		0.0038	U	0.0024	U	0.0065	U	0.0000070	U	0.041	U	0.0022	U
Dangerous Waste Criteria Per WAC 173-303-090(8)				5.0		100.0		1.0		5.0		5.0		0.2		1.0		5.0	

Notes:

J: Estimated concentration

U: Constituent was not detected at the shown reporting limit

TCLP concentrations are shown to two significant figures.

🟨 A yellow highlighted cell means the constituent concentration is > the criterion, but ≤ 10 times the criterion.

🟧 A orange highlighted cell means the constituent concentration is > 10 times the criterion.

Table 5-4: Field Soil pH Results in Data Gap #4B Soil Borings

Sample Depth (feet bgs)	PTC-204	PTC-205	PTC-207	PTC-208
	pH Results (Standard Units)			
0.5	7.3	8.3	11.0	10.5
1	8.9	10.8	10.9	7.6
2	8.9	11.1	9.0	8.0
3	8.2	11.4	9.1	7.6
4	8.6	Not analyzed	9.6	Not analyzed
5	10.6	11.2	9.5	7.4
6	9.3	11.3	7.6	8.7
7	11.0	11.4	8.7	10.3
8	11.1	11.2	Not analyzed	10.7
9	11.0	11.4	Not analyzed	11.1
10	11.1	11.4	Not analyzed	7.6
11	11.2	11.5	8.7	7.2
12	11.1	11.4	9.1	10.6
13	9.1	11.0	10.8	10.8
14	8.5	10.3	11.2	10.8
15	7.8	9.5	10.5	10.8
16	6.9	9.2	9.7	7.1
17	6.9	9.8	8.8	7.1
18	7.0	10.4	8.4	Not analyzed
19	7.2	10.7	6.8	Not analyzed
20	7.3	10.7	7.7	7.2
21	Not analyzed	10.7	7.2	7.2
22	7.8	10.7	7.2	7.1
23	7.2	10.5	7.7	8.1
24	6.8	10.5	7.8	9.7
25	9.8	10.3	7.5	9.1
26	9.2	9.2	5.8	8.0
27	7.8	9.0	6.8	7.2
28	7.2	9.0	7.4	7.0
29	7.7	9.3	7.4	7.0
30	7.2	9.2	7.3	7.0
31	6.7	7.3	Not analyzed	7.0
32	6.7	7.2	6.2	7.1
33	6.7	6.7	6.9	7.0
34	6.5	6.6	6.8	6.9
35	6.5	6.6	7.9	6.8
36	6.8	7.1	7.3	7.0
37	6.6	6.4	7.5	7.1
38	6.4	6.4	7.4	7.2
39	6.6	6.4	7.1	7.1
40	6.9	6.3	7.3	7.2

Table 6-1: Discussion of Main Arsenic Plume MWs with Potential Post-2004 Rebound

Apparent Increasing Trend After Circa 2007 or 2008?	Plume Area	MW	Aquifer	2017 and 2018 Dissolved Arsenic Concentrations (ug/L)	Discussion
Yes	Surrounding Former Penite Manufacturing Building	5D7-1R	Upper	91,000 and 86,000	● Suspected Upper Aquifer source material near the former Penite Manufacturing Building is likely contributing to the apparent increasing trend in this MW since circa 2007 or 2008.
Yes		5E4-1	Upper	97,000 and 140,000	● Suspected Upper Aquifer source material near the former Penite Manufacturing Building is likely contributing to the apparent increasing trend in this MW since circa 2007 or 2008.
Yes		5D5-1	Upper	45,000 and 63,000	● Suspected Upper Aquifer source material near the former Penite Manufacturing Building is likely contributing to the apparent increasing trend in this MW since circa 2007 or 2008. ● Elevated pH and reducing conditions upgradient of this MW may limit co-precipitation with metal oxides and sorption near this MW.
Yes	Downgradient of Former Penite Manufacturing Building	124+00-2	Intermediate	39,000 and 76,000	● Transport of suspected Upper Aquifer source material near the former Penite Manufacturing Building is likely contributing to the apparent increasing trend in this MW since circa 2007 or 2008. ● The thin or leaky First Aquitard locations upgradient of this MW likely provide preferential pathways for Upper Aquifer mass to enter the Intermediate Aquifer upgradient of this MW. ● Elevated pH and reducing conditions in the thin or leaky First Aquitard locations and the Intermediate Aquifer upgradient of this MW likely limits co-precipitation with metal oxides and sorption near this MW.
Yes		124+00-1	Upper	3,100 and 1,100	● Transport of suspected Upper Aquifer source material near the former Penite Manufacturing Building is likely contributing to the apparent increasing trend in this MW since circa 2007 or 2008. ● Elevated pH and reducing conditions upgradient of this MW likely limits co-precipitation with metal oxides and sorption near this MW.
Yes	Downgradient of Former Penite Pit #2	6E3-2	Intermediate	100,000 and 63,000	● Transport of Upper Aquifer source material in former Penite Pits #2 is likely contributing to the apparent increasing trend in this MW since circa 2007 or 2008. ● Elevated pH and reducing conditions upgradient of this MW likely limits co-precipitation with metal oxides and sorption near this MW.
Yes		7E3-1	Upper	14,000 and 9,700	● Transport of Upper Aquifer source material in former Penite Pits #2 is likely contributing to the apparent increasing trend in this MW since circa 2007 or 2008. ● Elevated pH and reducing conditions upgradient of this MW likely limits co-precipitation with metal oxides and sorption near this MW.
Yes		7E16-2	Intermediate	2,900 and 3,600	● Transport of Upper Aquifer source material in former Penite Pits #2 is likely contributing to the apparent increasing trend in this MW since circa 2007 or 2008. ● Elevated pH and reducing conditions upgradient of this MW likely limits co-precipitation with metal oxides and sorption near this MW.
Yes	Near Northern SPW Wing	5C16-1R	Upper	480 and 1,200	● Elevated pH and reducing conditions upgradient of this MW may limit co-precipitation with metal oxides and sorption near this MW.
Yes	Upgradient of Source Area (But Within Main Arsenic Plume)	5E8-1	Upper	450 and 790	● Although there is an apparent increasing trend in this MW since circa 2007 or 2008, the potential increasing concentrations are not a significant concern because the MW is upgradient of the source area and dissolved arsenic concentrations are relatively low.
No	Downgradient of Former Penite Pits #1 and #2	6D14-1	Upper	50,000 and 44,000	● This MW was identified for potential post-2004 rebound based solely on the Mann-Kendall trend analysis of 2005 to 2017 data. The Mann-Kendall trend analysis indicated an apparent increasing trend because dissolved arsenic concentrations were temporarily depressed in 2005 and 2006 following in-situ stabilization. Dissolved arsenic concentrations in this MW were stable after circa 2007 or 2008.
No	Downgradient of Former Penite Pit #2	7E8-1	Upper	3,400 and 3,600	● This MW was identified for potential post-2004 rebound based solely on the Mann-Kendall trend analysis of 2005 to 2017 data. The Mann-Kendall trend analysis indicated an apparent increasing trend because dissolved arsenic concentrations were temporarily depressed in 2005 and 2006 following in-situ stabilization. Dissolved arsenic concentrations in this MW were stable after circa 2007 or 2008.
No	Upgradient of Source Area (But Within Main Arsenic Plume)	5E1-1	Upper	670 and 600	● This MW was identified for potential post-2004 rebound based solely on the Mann-Kendall trend analysis of 2005 to 2017 data. The Mann-Kendall trend analysis indicated an apparent increasing trend because dissolved arsenic concentrations were temporarily depressed in 2005 and 2006 following in-situ stabilization. Dissolved arsenic concentrations in this MW were stable after circa 2007 or 2008.

Table 6-2: Conceptual Estimates of Arsenic Mass in Soil Excavation Scenarios

Scenario Number	Scenario Description	Excavation Depth (1) (feet bgs)	Estimated Excavation Volume (1) (CY)	Associated Average Arsenic Concentration (1) (mg/kg)	Estimated Arsenic Mass (2) (kg)	Total Estimated Scenario Mass (kg)	Percentage of Mass Relative to Baseline Scenario (4)
1	Excavate soil with arsenic concentrations exceeding 88 mg/kg to a depth of 15 feet bgs.	0 - 5	32,000	570	25,000	343,000	37%
		5 -10	44,000	2,900	174,000		
		10 - 15	44,000	2,400	144,000		
2	Excavate soil with arsenic concentrations exceeding 590 mg/kg to a depth of 15 feet bgs or the top of the 1st Aquitard (whichever occurs first).	0 - 5	4,300	1,100	6,000	145,000	15%
		5 -10	18,000	5,200	128,000		
		10 - 15 (3)	9,800	860	11,000		
3	Excavate soil with arsenic concentrations exceeding 10,000 mg/kg to a depth of 15 feet bgs or the top of the 1st Aquitard (whichever occurs first).	0 - 5	N/A	N/A	N/A	134,000	14%
		5 -10	1,400	70,000	134,000		
		10 - 15 (3)	N/A	N/A	N/A		
4	Excavate soil with arsenic concentrations exceeding 20,000 mg/kg to a depth of 15 feet bgs or the top of the 1st Aquitard (whichever occurs first).	0 - 5	N/A	N/A	N/A	134,000	14%
		5 -10	1,400	70,000	134,000		
		10 - 15 (3)	N/A	N/A	N/A		

Notes:

CY: cubic yards, kg: kilograms, mg/kg: milligrams per kilogram, N/A: not applicable

(1) Values from Figures 6-16 through 6-19. Values rounded to two significant figures.

(2) Arsenic mass (kg) = excavation volume (CY) * assumed soil density of 1.5 tons/cy * 2000 pounds/ton * kg/2.2 pounds * arsenic concentration (mg/kg) * kg/1,000,000 mg. Values rounded to nearest 1,000.

(3) For this excavation scenario, the point of compliance depth is 15 feet or the top of the 1st Aquitard, whichever occurs first. The average depth to the top of the 1st Aquitard was assumed to be 13 feet based on borings advanced within the excavation footprint.

(4) The baseline scenario is excavating soil with arsenic concentrations exceeding 20 mg/kg to a depth of 15 feet bgs. The total mass for the baseline scenario was estimated to be 936,000 kg based on existing data and simplifying assumptions (see figure in Appendix H).