Feasibility Study Work Plan
Boeing Auburn Facility
Auburn, Washington

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Prepared for

The Boeing Company
Seattle, Washington

Landau Associates

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LIST OF ABBREVIATIONS AND ACRONYMS

AOC	area of concern
ARAR	applicable, relevant, and appropriate requirement
bgs	below ground surface
Boeing	The Boeing Company
BTEX	benzene, toluene, ethylbenzene, xylene
cDCE	cis-1,2-dichloroethene
CLARC	Cleanup Levels and Risk Calculations
CMT	continuous multichannel tubing
COLIWASA	composite liquid waste sampler
CRT	cleanup risk threshold
CUL	cleanup level
cVOC	chlorinated volatile organic compound
cy	cubic yards
DO	dissolved oxygen
DRO	diesel-range organic
Ecology	Washington State Department of Ecology
EPA	US Environmental Protection Agency
EPH	extractable petroleum hydrocarbon
FS	feasibility study
ft	foot/feet
GRO	gasoline-range organic
HI	hazard index
ID	identification
IHS	indicator hazardous substance
in. Hg	inches of mercury
LAI	Landau Associates, Inc.
LNAPL	light non-aqueous phase liquid
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
MNA	monitored natural attenuation
MTCA	Model Toxics Control Act
µg/m^3	micrograms per cubic meter
NA	natural attenuation
NTU	nephelometric turbidity unit
OM	Osceola Mudflow
ORO	oil-range organic
ORP	oxygen-reduction potential

PDB	passive diffusion bag
POC	point of compliance
RI	remedial investigation
SAP	sampling and analysis plan
SWMU	solid waste management unit
TCE	trichloroethene
TOC	total organic carbon
TPH	total petroleum hydrocarbon
UST	underground storage tank
VC	vinyl chloride
VOA	volatile organic analyte
VOC	volatile organic compound
WAC	Washington Administrative Code

1.0 INTRODUCTION

This document presents a feasibility study work plan (FSWP) for field investigation activities and procedures for performing the feasibility study (FS) at the Boeing Company's (Boeing's) Auburn Fabrication Division Facility (Facility). FS procedures discussed in this document include: a description of how preliminary cleanup standards will be developed, preliminary screening of cleanup technologies and identification of cleanup action alternatives to be evaluated in the FS, and an outline for the FS report. The Facility is located at 700 15th Street Southwest in Auburn, Washington. The location of the Facility is shown on Figure 1.

Boeing is currently conducting corrective action at the Facility. Corrective action requirements are documented in the First Amended Agreed Order (Ecology 2006) No. 01HWTRNR-3345. For the purposes of this document, "Facility" refers to property currently owned by parties to the Agreed Order (Boeing and Prologis) and "Site" refers to all contiguous property affected by releases of hazardous substances that originated at the Facility.

The purpose of the FS field investigation is to collect the needed information to evaluate cleanup remedies and complete a FS. The FSWP was prepared in accordance with the Agreed Order and the applicable sections of the Washington State Department of Ecology's (Ecology's) Model Toxics Control Act (MTCA), Washington Administrative Code (WAC) 173-340.

Boeing previously provided a summary of the FSWP Scope (LAI 2017a) and a groundwater sampling matrix (LAI 2017b) to Ecology. These documents were provided in order to solicit comments from Ecology on the scope of the FSWP prior to submitting a formal work plan. The scope of the investigation was discussed during a meeting with Ecology on April 19, 2017. Ecology provided several comments during the meeting, which were incorporated into the FSWP.

1.1 Background

Boeing completed remedial investigation (RI) activities to characterize the nature and extent of contamination above Site-specific screening levels; data collection for the RI was completed in 2015 and the RI report was submitted for public comment in 2017 (LAI 2017c). The focus of the RI was to identify and characterize potential releases from solid waste management units (SWMUs) and areas of concern (AOCs) and determine the nature and extent of these impacts. As part of the RI, Boeing investigated two groundwater plumes emanating from the Facility and extending off Boeing property to the north and northwest. In addition to groundwater, the plumes impact drainage and stormwater collection surface water features northwest of the Facility. The Site-wide groundwater plumes are identified as the Area 1 plume (originating from former Area 1 Building 17-05) and the western plume (originating from the west side of the Facility in or near Building 17-07). The plumes primarily comprise trichloroethene (TCE) and its breakdown products cis-1,2-dichloroethene (cDCE) and vinyl chloride (VC). TCE and VC are the primary constituents of concern in Site-wide groundwater due to their prevalence and relative toxicity. The RI also identified localized areas with heavy metals, cyanide, and petroleum hydrocarbons in soil and groundwater at the Facility.

The RI report documented investigation activities at SWMUs and AOCs both at the Facility and in downgradient areas of the Site. Data collected as part of the RI was sufficient to determine the nature and extent of contamination and provide recommendations for which SWMUs and AOCs should be carried forward to the FS for evaluation of remedial alternatives. No SWMUs were carried forward to the FS[1]; however, five AOCs were carried forward to the FS:

- AOC A-01: Building 17-06 Former Underground Storage Tanks (USTs) TAU-01 and TAU-02
- AOC A-09: Building 17-07 Acid Scrubber Drain Line Leak
- AOC A-13: Building 17-06 Petroleum Hydrocarbon Contamination
- AOC A-14: Site-wide TCE and VC Groundwater Contamination
- AOC A-15: Site-wide TCE and VC Surface Water Contamination.

The list of AOCs carried forward to the FS are summarized in Table 1. The Facility AOCs are shown on Figure 2. The Site-wide groundwater AOC (A-14) is presented on Figure 3. The Site-wide surface water AOC (A-15) is shown on Figure 4.

1.2 Objectives

The objectives of this FSWP are:

- Summarize current soil and groundwater conditions and identify data gaps for evaluation of cleanup alternatives at the AOCs being carried forward to the FS.
- Present a scope of work necessary to fill data gaps to evaluate cleanup alternatives.
- Describe field procedures to complete the additional data collection required.
- Provide Boeing's approach to developing preliminary cleanup standards.
- Present screening of cleanup technologies and identify those technologies that will be further evaluated in the FS.
- Present an outline and methods to be used for cleanup alternative analysis in the FS.
- Present a schedule for investigation activities, including fieldwork and reporting.

1.3 Scope of Work

The scope of work for additional field activities and data collection at the five AOCs being carried forward to the FS is summarized below:

- AOC A-01 – Collection and analysis of additional groundwater samples at existing monitoring wells and completion of additional subsurface investigation to further refine the extent of

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[1] Investigation of SWMU S-15a/16 is carried forward as part of AOC A-13.

total petroleum hydrocarbon (TPH) contamination resulting from the presence of historical USTs (Section 3.1)

- AOC A-09 – Collection and analysis of additional groundwater samples for dissolved copper and cyanide for comparison to current screening levels (Section 3.2)
- AOC A-13 – Additional subsurface investigation of soil and groundwater to refine the current extent of TPH contamination (Section 3.3)
- AOC A-14 –Additional western plume and Area 1 plume source area investigations including installation and sampling of sub-slab soil gas monitoring points and groundwater wells in Building 17-07 and soil gas sampling near former Building 17-03; additional geochemical data collection and analysis to further evaluate monitored natural attenuation (MNA) as a part of the cleanup remedy for Site-wide TCE and VC contamination in groundwater (Section 3.4)
- AOC A-15 – Collection of one additional surface water sample to confirm the downgradient extent of VC impacts in Mill Creek; installation and sampling additional pore water monitoring points in Mill Creek (Section 3.5).

1.4 Report Organization

This report contains nine sections as described below:

- Section 1.0 introduces the purpose of the FSWP, provides background information about the Facility, defines the objectives of the FSWP, and lays out the organization of the FSWP.
- Section 2.0 provides information regarding the geology and hydrogeology of the Site.
- Section 3.0 presents a summary description of each AOC being carried forward to the FS, data related to the current understanding of soil and groundwater impacts at each AOC, and a description of the additional investigation work and data collection proposed at each AOC.
- Section 4.0 provides information regarding the field methods and procedures to be used for data collection during implementation of the FS investigation.
- Section 5.0 describes the approach used to determine preliminary cleanup standards.
- Section 6.0 presents a description of methods and processes that will be used to complete the FS report.
- Section 7.0 presents the schedule for completion of the fieldwork scope.
- Section 8.0 describes the appropriate use of this report.
- Section 9.0 provides a list of report references.

2.0 GEOLOGY AND HYDROGEOLOGY

The uppermost aquifer in the Auburn Valley consists of saturated portions of modern alluvium and recent alluvium deposited by the Green and White rivers. The Osceola Mudflow (OM) serves as a regional aquitard between the uppermost aquifer and deeper aquifers. Locally, beneath the Boeing property and off Boeing property to the north, the uppermost aquifer is up to 105 feet (ft) thick. For the purpose of the RI and FS, the uppermost aquifer has been subdivided into three groundwater zones based on depth below ground surface (bgs):

- A shallow zone, from the water table (approximately 5 ft) to 35 ft bgs. The shallowest wells within this zone are screened at or near the water table; water table data is considered a subset of the shallow zone data
- An intermediate zone, from approximately 35 to 75 ft bgs
- A deep zone, from approximately 75 to 105 ft bgs; the bottom of the deep zone is defined by the contact with the OM, the depth of which may vary based on location.

The current Phase VII groundwater monitoring well network includes 216 wells and 259 active sampling points[2] to monitor the groundwater plumes in all three upper aquifer zones[3]. For the FS investigation, an additional four wells[4] will be sampled only once (LAI 2017b). FS investigation groundwater monitoring is scheduled to coincide with the annual sampling event taking place June 2017 (LAI 2017b).

Surface water monitoring is completed semiannually to monitor the discharge of groundwater to surface water bodies, including stormwater collection and control features and Mill Creek (LAI 2015). The dry season surface water sampling event is scheduled to coincide with the quarterly groundwater sampling event in September 2017.

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[2] Several monitoring wells consist of multi-level wells that have multiple screens installed in different groundwater zones. Each sampled screen is considered a separate sampling point.

[3] Updated table submitted via email from Jennifer Wynkoop, Landau Associates, Inc., to Robin Harrover and Neal Hines, Washington State Department of Ecology on August 21, 2016.

[4] Wells scheduled for one-time sampling during the annual 2017 groundwater monitoring event include AGW011, AGW014, AGW016 (AOC A-01), and AGW 047 (AOC A-09).

3.0 FEASIBILITY STUDY INVESTIGATION ACTIVITIES

This section provides a description of each of AOC proposed for evaluation in the FS including results of pre-RI and RI investigations, the understanding of the current conditions, and proposed FS investigation activities. Field procedures are presented in Section 4.0.

3.1 AOC A-01: Building 17-06 Former Underground Storage Tanks TAU -01 and TAU-02

AOC A-01 consists of two former 10,000-gallon fuel USTs near the northwest corner of Building 17-06; UST TAU-01 was a diesel tank and TAU-02 was a gasoline tank. Both tanks were removed by Boeing personnel in July 1990 along with approximately 500 cubic yards (cy) of soil contaminated with petroleum hydrocarbons (GeoEngineers 1991). Documentation of the results from samples collected at the time of the excavation could not be located. Additional investigations to define the extent of the contamination in soil and groundwater were completed in 1990 and 1991 (GeoEngineers 1991, 1992). The August 1990 investigation included installation of four monitoring wells (AGW009 through AGW012) along with collection of soil and groundwater samples (GeoEngineers 1991). The August 1991 investigation included advancing five borings for collection of soil samples (B-1 through B-5) and installing five additional monitoring wells (AGW013 through AGW017) along with collection of soil and groundwater samples (GeoEngineers 1992). In 2004, an additional soil excavation was completed near the former USTs when petroleum-contaminated soil was discovered during underground utility work; approximately 10 cy of soil was removed (LAI 2004a). Confirmation samples around the excavation limits verified that soil left in place was below screening levels. The locations of the former USTs, the 1990 and 2004 excavation areas, and monitoring locations are shown on Figure 5. A cross section of the area including the historical UST locations is shown on Figure 6. Localized groundwater elevation contours are presented on Figure 7. Soil concentrations are shown on Figure 8 and maximum and most recent groundwater concentrations are shown on Figure 9.

3.1.1 Extent of Soil Contamination

Soil samples collected from several borings and monitoring wells in and near the former tank excavation had detections of gasoline-range, diesel-range and motor oil-range petroleum hydrocarbons (GRO, DRO, and ORO, respectively) and benzene, toluene, ethylbenzene, and xylene (BTEX). However, all results were below current screening levels with the exception of those from boring B-4, which had concentrations of ethylbenzene, xylene, and GRO above their respective screening levels. The samples from boring B-4 were collected from a depth of 13 ft bgs, which is within the smear zone of the groundwater table below the high water table[5]. However, the B-4 boring log indicated evidence of slight to moderate sheen along the entire depth of the soil boring. Concentrations of petroleum hydrocarbons and BTEX detected in soil are shown on Figure 8.

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[5] The high water table is approximately 10 to 12 ft bgs.

Although the excavation during the tank removal was extensive, it is unclear whether all soil contamination in the vadose zone has been removed. There was no documentation of soil conditions at the limits of the excavation. The only soil sample (from boring B-4) with exceedances of screening criteria was collected from the smear zone; however, observations of contamination were noted in the vadose zone soil but no samples were collected.

3.1.2 Extent of Groundwater Contamination

Releases from the former USTs resulted in groundwater contamination near the USTs to the north and northwest. Evidence of petroleum hydrocarbon contamination was historically detected at four of the monitored wells (AGW010, AGW011, AGW015, and AGW016). The constituents historically detected above screening levels at each of these wells were those listed below:

- AGW010: BTEX, DRO, GRO, ORO
- AGW011: Benzene, GRO, ORO
- AGW015: Benzene, DRO
- AGW016: Benzene, GRO, ORO.

The concentrations at all of these wells except AGW010 have decreased to below laboratory reporting limits. AGW011 was last sampled in 2004, at which time the benzene concentration in groundwater was below the screening level; however, the benzene screening level has decreased and the concentration from the 2004 sample exceeds the current screening level. Benzene concentrations have presumably declined in the intervening time period; however, confirmation sampling at this well is recommended to verify current benzene concentrations. Maximum and most recent groundwater petroleum hydrocarbon and BTEX concentrations are shown on Figure 9.

In December 2016, groundwater at AGW010 exceeded screening levels for DRO and GRO. The concentration of ethylbenzene in December 2016 in AGW010 was below the screening level; however, concentrations fluctuate and the ethylbenzene concentration exceeded screening levels as recently as December 2015. Free-phase petroleum product has not been observed in AGW010. Concentrations of petroleum hydrocarbons and ethylbenzene have shown a declining trends consistent with natural attenuation (NA) processes; however, the concentration trends appear to have leveled off in recent years. A time series plot of DRO, ORO, GRO and ethylbenzene concentrations for AGW010 is presented in Appendix A.

3.1.3 Proposed Scope of Work for AOC A-01

Additional groundwater sampling will be conducted to verify the current conditions in the vicinity of AGW010 and collect parameters for evaluation of aquifer redox conditions. Additionally, investigation activities are recommended to further refine the extent of contamination in vadose zone soil and in the groundwater. Refinement of the extent of contamination will support remedy selection in the FS. Potential FS remedies that will be screened or evaluated include soil excavation, MNA, bioventing, bioremediation injection, *in situ* chemical oxidation, and an air or ozone sparge with soil vapor extraction.

3.1.3.1 Additional Groundwater Sampling

Under the Phase VII groundwater sampling plan, only AGW010 is monitored for DRO and GRO. As part of the FS investigation, samples for GRO and DRO will also be collected at AGW009, AGW011, AGW014, and AGW016, which are not currently sampled; BTEX will also be analyzed in samples from AGW011, AGW014, and AGW016. The additional proposed groundwater analysis will help confirm that contamination remains localized in the vicinity of AGW010.

Wells AGW009, AGW010, AGW011, AGW014, and AGW016 will also be sampled for aquifer redox parameters to evaluate potential effectiveness of MNA or *in situ* treatment technologies. Geochemical parameters at AOC A-01 include nitrate/sulfate, total organic carbon (TOC), dissolved oxygen (DO), oxidation-reduction potential (ORP), and ferrous iron. Additional groundwater analyses are also presented in Table 2. The well locations identified for additional analysis are shown with the site plan on Figure 5 and with localized groundwater elevation contours on Figure 7.

3.1.3.2 Soil Borings

Following the completion of the additional groundwater monitoring, a subsurface investigation will be completed. The subsurface investigation will consist of advancing six soil borings to a maximum of 20 ft bgs and collecting soil and groundwater samples to further refine the extent of contamination contributing to persistent petroleum hydrocarbon and ethylbenzene concentrations at AGW010. Additional step-out borings may be completed, if required, based on field screening or laboratory results. Soil properties may also be measured at each boring in support of potential remedies. Soil borings will be advanced using direct-push probe drilling technology. Proposed soil boring locations are shown with the site plan on Figure 5.

Soil samples will be collected and field-screened at each location. The soil samples will also be visually classified for soil type. If field screening indicates no evidence of contamination, one sample will be collected from the vadose zone directly above the water table. If contamination is encountered in a boring, two to three samples will be collected; one sample will be collected from the area with the highest apparent contamination (based on field screening); one will be collected just below the observed contamination, if possible; and one sample may be collected higher up in vadose zone if the other two samples are within the groundwater smear zone. A groundwater sample will be collected from a temporary screen at each boring location. Soil boring locations are summarized in Table 3.

3.1.3.3 Potential Remediation Pilot Test

Based on the results of the additional sampling and investigation, Boeing may proceed with a pilot test for one of the technologies listed in Section 3.1.3. However, it is possible that additional sampling will clarify applicable remediation options and a pilot test will not be necessary. If additional work is proposed for completion of a remediation pilot test, an addendum to this FSWP will be prepared at that time.

3.2 AOC A-09: Building 17-07 Acid Scrubber Drain Line Leak

AOC A-09 is defined as a leak from the acid scrubber drain line located on the south side of Building 17-07 near column C11. The drain line connected the acid scrubber, located outside of Building 17-07, to the tank line inside the building. A leak in the drain line was discovered during an excavation for closure of two waste holding tanks that were located adjacent to the acid scrubber. Seventeen soil samples were collected in July 1996 as part of the tank closure. Screening level exceedances at three of the locations prompted additional soil removal in the northeast corner of the excavation (AGI 1996a). Contaminated soil was removed to the extent practicable; however, some soil was left in place around foundations due the risk of undermining and damaging infrastructure. Prior to backfilling the excavation, 20 additional soil samples were collected in the northeast corner of the excavation from the excavation sides and base, and from hand auger borings through the shored side walls of the excavation (AGI 1996b). Soil analytical results from 13 of the 20 samples indicated cadmium, copper, or cyanide concentrations exceeding soil screening levels.

Further assessment activities took place in September 1996. Five monitoring wells (AGW046 through AGW050) were subsequently installed and soil and groundwater samples were collected. Additionally, three hand-augured borings (HA1 to HA3) were advanced for collection of soil samples. Constituents of concern from the acid scrubber drain line leak are primarily metals. Cyanide was also detected in soil and groundwater. The previous excavation around AOC A-09, the 20 soil sample locations, the 3 hand-augured locations, and the current monitoring well locations are shown on Figure 10 through Figure 13.

3.2.1 Extent of Soil Contamination

Approximately 200 cy of soil were excavated to a depth of about 12 ft in July 1996. Twenty samples were collected to delineate the extent of soil contamination. Of the 20 boring locations, 13 locations had detections for cadmium, copper, lead, or cyanide above current screening levels. Impacted soil remains underneath the Building 17-07 floor, scrubber pad foundations, and adjacent pavement. Soil sampling results from the subsequently installed monitoring wells and hand-augured borings indicated concentrations of cadmium, copper, and cyanide exceeding screening levels at AGW049 and HA1 and copper and cyanide exceeded screening levels HA2. Screening levels were not exceeded for metals or cyanide at AGW046, AGW048, AGW050 or HA3. No soil samples were collected at AGW047. Concentrations of detected metals and cyanide in soil for all borings installed to define the extent of soil contamination associated with the acid scrubber drain line leak are presented on Figure 12.

3.2.2 Extent of Groundwater Contamination

Groundwater sampling following the excavation showed screening level exceedances of several dissolved metals (including cadmium, nickel, and copper) and cyanide at AGW047 through AGW050.

Dissolved metals concentrations in groundwater may have been influenced by low pH levels caused by the leak; groundwater at AGW048, AGW049, and AGW050 currently have a pH of approximately 6. Concentrations of metals in groundwater have continued to decline over time. Of the wells that are currently monitored (AGW048 through AGW050), only cadmium exceeds the screening levels at AGW049 and AGW050, as of December 2016. Time series plots for cadmium and nickel concentrations for AGW048 through AGW050 are presented in Appendix A. Groundwater sampling for copper and cyanide was discontinued in 2004 and 2000, respectively, because concentrations were below screening levels. However, screening levels for both compounds have changed. Concentrations of copper at well AGW049 during the most recent sampling event for that constituent (December 2004) exceeded the current screening level. Concentrations of cyanide exceeded the current screening levels during the most recent sampling event for that constituent (March 2000) at AGW047 and AGW049. The maximum and most recent concentrations of detected metals and cyanide in groundwater are shown on Figure 13.

3.2.3 Proposed Scope of Work

Additional groundwater sampling is needed to verify current concentrations of copper and cyanide in groundwater at AOC A-09. The additional data collection is scheduled for completion during the annual 2017 event.

FS investigation groundwater sampling will consist of the collection of additional groundwater data at several wells near AOC A-09. Total cyanide will be collected at wells AGW047 and AGW049 and dissolved copper will be collected at AGW049. Total cyanide will also be collected at wells AGW048 and AGW050 per Ecology’s request. The well locations identified for additional analyses are shown on Figure 10. Additional groundwater analyses are summarized in Table 2. Field pH data for wells in the area will also be compiled and a reviewed for evidence of the historical acid leak.

3.3 AOC A-13: Building 17-06 Petroleum Hydrocarbon Contamination

AOC A-13 was designated to address petroleum hydrocarbon soil and groundwater contamination on the east side of Building 17-06. The contamination was identified during investigation of SMWU S-15a (Building 17-06 Sump SAU06-12) and SWMU S-16 (Aluminum Briquetter and Chip Conveyance System). Investigations indicate that the source of petroleum hydrocarbons in the subsurface may be unrelated to the chip collection system and briquetter structures; rather it may be related to releases from individual mills. AOC A-13 was defined to incorporate the area of contamination and includes SWMUs S-15a and S-16.

In 1996, an investigation was conducted to assess soil and groundwater near the east side chip collection system and briquetter (SECOR 1996). Fifteen soil borings were advanced (ASB0022 through ASB0031); 10 were immediately decommissioned and 5 were converted to monitoring wells (AGW041 through AGW045). In 2004, five soil borings were advanced (ASB0159, ASB0167, ASB0169, ASB0170, and ABS0171) and four groundwater wells were installed (AGW115 through AGW118) along the east side of the building near the chip collection system. In 2008, four additional wells (AGW127 through AGW130) were installed along the east side chip collection system and adjacent to the briquetter and crossover area. The extent of AOC A-13 and exploration locations are shown on Figures 14 through 17.

A treatability study of the subsurface petroleum hydrocarbon product was conducted in 2018. The treatability study used soil samples collected from AOC A-13 and evaluated the effect of chemical oxidation on soil concentrations in the samples. A description of the study methods and results is presented in Appendix B.

3.3.1 Extent of Soil Contamination

Petroleum hydrocarbons were detected in soil in isolated locations throughout the extent of AOC A-13. Unax oil (ORO) was detected above screening levels in soil at ASB0031. DRO and ORO were detected above screening levels at ASB0160R and ASB0170. ORO was detected in soil above screening levels at ASB0169 and AGW128. Detections of petroleum hydrocarbons in soil were all located at depths that are within the smear zone of the groundwater table (10 ft to 15 ft bgs). Review of the boring logs confirms that field screening did not indicated the presence of petroleum hydrocarbons in soil at depths above the water table. This suggests that the releases were likely localized in soil but some spreading occurred when the hydrocarbons reached the water table. Soil detection data is presented on Figure 16.

3.3.2 Extent of Groundwater Contamination

Petroleum hydrocarbons were detected in groundwater in a number of wells and borings in AOC A-13. As of December 2016, monitoring wells AGW128 and AGW044 are the only locations that have detections of petroleum hydrocarbons; concentrations of ORO and DRO at both locations are above screening levels. In addition, well AGW128 periodically has had measureable light non-aqueous phase liquid (LNAPL); however, well AGW044 has never had measurable LNAPL. AGW128 has consistently had detections of ORO and DRO, since installation in 2008. AGW044 sporadically had detections prior to 2012. After 2012, concentrations were detected consistently; however, concentrations appear to be decreasing. Monitoring wells upgradient (AGW129) and downgradient (AGW130) of AGW044 and AGW128, do not have detections of petroleum hydrocarbons. The maximum and most recent (as of December 2016) concentrations of petroleum hydrocarbons in groundwater are shown on Figure 17. Time series plots of DRO and ORO concentrations at AGW044 and AGW128 are presented in Appendix A.

Several findings contribute to the premise that releases at AOC A-13 originated from the mills and not from the chip conveyance or briquetter systems. AGW128 was installed through the foundation of a former mill in a location that may have been susceptible to releases of hydraulic oil from the mill gantry. Additionally, Boeing completed forensic analysis of samples from AGW128, the chip and briquetter sumps, and raw hydrocarbon products used in the mills. The samples from the wells were not a match to the chip conveyor and sump samples. The closest product match to the well samples was hydraulic and gear oil used in the mill gantries.

3.3.3 Proposed Scope of Work

Additional investigation activities are focused to refine the extent of hydrocarbon releases near AGW128 because this location appears to have the most extensive impacts to groundwater. Although petroleum hydrocarbons have been detected in other areas of AOC A-13, they appear to be localized and do not appear to be impacting groundwater. Based on the localized nature of the contamination and the presence of the building and significant infrastructure, remedies being considered for screening and evaluation in the FS are focused excavation, passive product removal, containment, *in situ* chemical oxidation, and MNA. In order to evaluate these remedies, a more detailed delineation of the extent of soil and groundwater contamination near well AGW128 is needed. In addition, evaluation of passive product removal will be evaluated using sorbent socks.

3.3.3.1 Soil Borings

Proposed FS investigation work includes a subsurface soil and groundwater investigation at AOC A-13 to determine the lateral extent of petroleum hydrocarbons near AGW128. Four borings will be advanced to 20 ft bgs. If field tests indicate the presence of petroleum contamination, two additional step-out borings may be completed. Up to two boring locations may be converted to permanent monitoring wells, with the intent of providing downgradient monitoring points closer to AGW128. Soil borings at AOC A-13 will be completed using rotosonic drilling technology. Proposed boring locations are shown on Figure 14.

Soil samples will be collected and field-screened at each location. The soil samples will also be visually classified for soil type. If field screening indicates no evidence of contamination, one sample will be collected from directly above the water table. If contamination is encountered in a boring, up to three samples may be collected, one from the area with the highest apparent contamination (based on field screening) and one just below the observed contamination to verify clean conditions, and if necessary one from the vadose zone above the elevation of the high water table (approximately 10 ft bgs). A groundwater sample will be collected from a temporary screen at each boring location except the permanent well locations. A sample will be collected from the permanent well location(s) after well installation and development.

The proposed boring locations are shown with the site plan on Figure 14 and with localized groundwater elevation contours on Figure 15. Table 3 describes the proposed boring locations and Table 4 presents well details for the potential permanent groundwater monitoring wells.

3.3.3.2 Sorbent Sock Product Removal

The limited thickness, high viscosity, and seasonality of LNAPL in AGW128 is not conducive to active product removal. However, evaluation of passive product removal with sorbent socks is ongoing. Passive product removal with sorbent-socks may be beneficial in removing petroleum mass over time.

During the summer and early fall 2016, sorbent socks were used in AGW128 to evaluate dye testing at a nearby mill[6]. The socks were evaluated for saturation and weighed after removal. Information collected from the sorbent socks will be evaluated to determine if they are a cost effective way to remove LNAPL over time.

3.4 AOC A-14: Site-Wide Trichloroethene and Vinyl Chloride Groundwater Contamination

AOC A-14 was designated to address Site-wide volatile organic compound (VOC) contamination in groundwater, specifically TCE and VC. AOC A-14 is defined as the extent of VOC screening level exceedances in groundwater. The two plumes originating from the Facility (the Area 1 Plume and the Western Plume) are large, extending approximately 1 mile northwest of the Facility. The approximate extents of the two groundwater plumes are shown on Figure 3.

Cleanup of the source area for the Area 1 plume was completed in 2005. However, there is still an area north of the Prologis building (monitoring wells AGW125 and AGW126), where VOC concentrations (up to 8.8 µg/L TCE) are slightly higher than surrounding wells. Concentrations at AGW125 and AGW126 have declined over time, but trends at AGW125 in particular have remained stable (between 7 µg/L and 10 µg/L TCE) in recent years. Time series plots for AGW125 and AGW126 are presented in Appendix A. Groundwater flow analysis using the numerical flow model suggests that the source of the concentrations at these wells may be in the southeast portion of Area 1 near former Building 17-03 (Figure 23). Building 17-03 housed a TCE degreaser in the south end of the building, which was converted to a 1,1,1-trichloroethane (TCA) degreaser in 1976. The degreaser was decommissioned and Building 17-03 was demolished in 1992. A soil and groundwater investigation was completed during decommissioning and three monitoring wells [AGW001 (SZ), AGW097 (IZ), and AGW099 (DZ)] were installed at the location of the former degreaser following building demolition. Further discussion of environmental sample results near Building 17-03 is provided in Section 3.4.2. FS investigation activities will include soil gas screening to determine if a TCE source is present near the south end of former Building 17-03.

No cleanup activities have been completed for the Western plume source area (Building 17-07). Concentrations of TCE in monitoring wells installed near the former TCE degreaser in Building 17-07 have been below 5 µg/L. Time series plots of VOC concentrations at these wells (AGW037, AGW164, and AGW165) are presented in Appendix A. As part of the FS investigation, potential source areas at Building 17-07 will be further investigated including sub-slab soil gas investigations and installation of monitoring wells based on the results of the sub-slab soil gas investigation.

The FS investigation at AOC A-14 will include sampling activities to refine the source areas and determine whether additional active cleanup in the source areas may be warranted and practicable. Additionally, sampling will be completed to evaluate the suitability of MNA throughout the

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[6] Dye from the mill was not detected in AGW128.

groundwater plumes. Information obtained from the FS investigation activities will be used in the FS to evaluate where active treatment may be most effective and where MNA is appropriate.

3.4.1 Proposed Scope of Work – Western Plume Source Areas

In 2011, sub-slab soil gas sampling in Building 17-07 identified two areas with elevated levels of VOCs (LAI 2012): the tank line area and the column E2 area. The observed concentrations at these locations were consistent with concentrations that may be found in source areas. Additional investigation activities will be conducted in these areas to better characterize these potential source areas. Recently discovered historical information indicates that an additional TCE degreaser was located in the building at column B4. The column B4 area will be investigated based on this information to determine if another source area may exist at this location. These source area investigations will consist of installation and sampling at soil gas monitoring locations, followed by installation of multi-level wells if the analytical results indicate the presence of a potential TCE source. An addendum to this work plan will be submitted to Ecology proposing locations of the multi-level wells based on the soil gas sampling results. The three areas to be investigated in Building 17-07 and their investigation approach are presented in the following sections.

3.4.1.1 Current Tank Line and Soil Gas Sample Location SSV-29

The tank line, located in the south portion of Building 17-07, is the location of a former TCE vapor degreaser at column B9, a former TCA vapor degreaser between columns D9 and E9, and a former chrome waste sump that reportedly captured condensate from the column B9 vapor degreaser. A second former TCE vapor degreaser, that was smaller in size, was also located in the tank line at column C10 (approximately 80 ft southeast of the column B9 degreaser)[7]. SSV-29, collected in the central portion of the tank line, had the highest concentration of TCE in soil gas at the Site observed to date (1,010 micrograms per cubic meter [$\mu g/m^3$]). Other samples collected from the tank line also had elevated concentrations of TCE in soil gas, suggesting that one or more structures in the tank line may have contributed to a release. The tank line is relatively large, and refinement and confirmation of the soil gas sampling results will likely be helpful in narrowing down the likely area of the release(s). Eleven sub-slab soil gas sample locations will be installed in and around the tank line. Sample locations on the main floor will be permanent; sample locations located in the secondary containment area in the pit area (below the main floor), will be temporary. Following receipt of the sub-slab soil gas analytical results, one multi-level well will be installed at or near the highest concentration in sub-slab soil gas, expected to be near 2012 sampling location SSV-29. During drilling, soil samples will be collected for VOC field screening and laboratory analysis. Field screening results will dictate screen placement in the permanent multi-level well; it is expected that screens will be located in all aquifer zones (shallow, intermediate, and deep). The depth profile data from the new multi-level well is expected to assist in evaluating the practicality and potential effectiveness of active cleanup,

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[7] The previously undocumented column C10 vapor degreaser was discovered in 2017 on Mylar building plans from 1973. The operational history and length of service of the degreaser is unknown.

evaluation of potential cleanup remedies, and refinement of the target depth for *in situ* remediation technologies. The tank line area is shown on Figure 18 and local groundwater elevation contours are shown on Figure 19. Groundwater monitoring well details are presented in Table 4 and sub-slab soil gas sample location details are presented in Table 5.

3.4.1.2 Column E2 and Soil Gas Sample Location SSV-17

The second highest soil gas concentration observed at the Site to date was located near column E2 (500 µg/m^3). No known or apparent sources of TCE have been identified near column E2, so the specific source of contaminant release in this area is unknown. Additional sub-slab soil gas samples will be collected to confirm results from the 2011 sampling event and provide additional data to refine the area of impact. Five permanent sub-slab soil gas sample locations will be installed near column E2. If results indicate the presence of a TCE source area, a multi-level well will be installed using the process presented above. This area is shown on Figure 20. Proposed groundwater monitoring well and sub-slab soil gas sample location details are presented in Tables 4 and 5, respectively.

3.4.1.3 Column B4 Historical Trichloroethene Degreaser Location

In 2017, a former vapor degreaser located at column B4 was identified on historical Facility drawings. The operating history of the degreaser is unknown but the age of the degreaser (installed during the original construction) suggests TCE may have been used. Four additional permanent sub-slab soil gas wells will be installed in the vicinity of the former vapor degreaser at column B4. If laboratory analytical results indicate the presence of a TCE source area, a multi-level well will be installed near Column B4 as well. This area is shown on Figure 21. Groundwater monitoring well and sub-slab soil gas sample location details are presented in Tables 4 and 5, respectively.

3.4.2 Proposed Scope of Work – Area 1 Southeast

Investigation of soil and groundwater was completed around the former Building 17-03 degreaser during building demolition in 1992 (Kennedy/Jenks 1993). A shallow monitoring well (AGW001) was installed at the location of the former vapor degreaser after the building demolition. Additional soil and groundwater investigations of the former degreaser took place during the Area 1 property transfer in 2003 and 2004 (LAI 2004b), during which, intermediate and deep monitoring wells (AGW097 and AGW099, respectively) were installed near AGW001. An investigation of chromium waste piping that included soil gas sample collection near former Building 17-03 occurred in 1996 (Kennedy/Jenks 1997). The former Building 17-03 degreaser and the adjacent historical soil gas investigation sample locations are shown on Figure 22, and local groundwater elevation contours are shown on Figure 23.

During the Building 17-03 degreaser decommissioning in November and December 1992, four soil samples were collected directly beneath or adjacent to the degreaser pit (SS-26 through SS-29) at a depth of approximately 8.5 ft, and a groundwater grab sample (SS-33) was collected adjacent to the pit at a depth of 25 ft bgs (Kennedy/Jenks 1993). Monitoring well AGW001 was later constructed at the location of the former degreaser (Kennedy/Jenks 1997). A time series plot of VOC concentrations detected at AGW001 is presented in Appendix A. There were no detections of TCE, TCA, or their breakdown products in the soil samples. TCE was detected at 11 µg/L in groundwater at SS-33 and at a maximum concentration of 5.6 µg/L in groundwater from AGW001. In December 2003, intermediate and deep monitoring wells (AGW097 and AGW099, respectively) were installed near AGW001 (LAI 2004b). Shallow soil samples were collected from just above the water table (16 ft bgs) in the borings for each well. No VOCs were detected in soil samples at these two borings. No VOCs of concern were detected in groundwater from wells AGW097 and AGW099.

An investigation of the Building 17-03 and Building 17-05 chrome Waste Piping occurred in December 1996 (Kennedy/Jenks 1997). Soil and soil gas samples were collected from 106 locations and analyzed for selected VOCs and metals. Results from soil gas sampling near former Building 17-03 indicated TCE concentrations in soil gas ranging from 0.01 parts per million volume (ppmv) to 1.13 ppmv (approximately 50 µg/m^3 to 6,070 µg/m^3). The sample with the highest TCE concentration (sample B-19) was collected adjacent to the southeast corner of former Building 17-03. 1,1,1-TCA was also detected in soil gas in the same area at concentrations ranging from 0.02 ppmv to 0.44 ppmv (approximately 110 µg/m^3 to 2,400 µg/m^3). Soil gas sample results near former Building 17-03 are presented on Figure 22.

The limited VOC detections in groundwater and the lack of detections of constituents of concern in soil at the former Building 17-03 degreaser are not typical of an area where a significant release occurred. However, the TCE and 1,1,1-TCA concentrations detected in soil gas at the south end of the building are potentially indicative of a release. Additional soil gas sampling is proposed in order to determine if a potentially significant TCE release occurred near the south end of former Building 17-03.

Six temporary borehole soil gas sampling locations will be installed near former Building 17-03. During drilling, soil samples will be collected for VOC field screening. The proposed soil gas sampling locations are presented on Figure 22. If results indicate the presence of a TCE source area, additional discussion will occur with Ecology to determine the next steps.

3.4.3 Proposed Scope of Work - Monitored Natural Attenuation Evaluation

Given the magnitude and extent of the Site-wide groundwater VOC plume, MNA is likely to be part of the cleanup remedy for at least a portion of the plume. There are two lines of evidence necessary to evaluate the appropriateness of MNA as a site remedy (EPA 1998, 1999):

- Historical Trends in Contaminant Data showing Decreasing Concentration/Mass
- Chemical and Geochemical Data to demonstrate the NA processes occurring at the site, and the rate at which processes will reduce contaminant concentrations

These lines of evidence presented in the Site-wide NA assessment report (in progress) expand on the discussion in the RI report (LAI 2017c). Mann-Kendall statistical analysis was used to evaluate trends in

TCE and total chlorinated volatile organic compound (cVOC) concentrations. The Mann-Kendall analysis indicates TCE concentrations and total cVOC concentrations across the Site have stable or decreasing trends at a majority of the sampling locations. TCE concentrations are stable, decreasing or not detected at 210 of the 250 sampling locations analyzed (84 percent)[8]. Total cVOC concentrations are stable, decreasing or not detected at 195 of the 247 sampling locations (79 percent)[9].

Analysis of NA parameters in groundwater was completed at 78 sampling locations in the monitoring well network between 2014 and 2016. This evaluation has identified areas that are most conducive to reductive dechlorination. The areas conducive to reductive dechlorination are defined by evidence of total organic carbon (TOC) (detected concentrations), reducing aquifer redox conditions (typically sulfate-reducing to methanogenic), and predominance of daughter and end products from the breakdown of TCE (DCE, VC, and Ethene/Ethane).

3.4.3.1 Additional Groundwater Sampling

Boeing proposes to complete additional groundwater analysis of NA parameters in areas where historical trends show increasing concentrations of total cVOCs. The sampling locations with increasing trends are presented in Table 6; only locations where groundwater has not previously been analyzed for NA parameters are proposed for additional NA sampling. In some cases, analysis of NA parameters is also proposed at co-located wells even if the co-located well does not have an increasing total cVOC trend.

The additional groundwater sampling will be completed during the 2017 annual sampling event. A groundwater sampling matrix is presented in Table 2. Thirty-five sample points will be analyzed for NA parameters including ethene/ethane/methane, sulfate/nitrate, TOC, and ferrous iron, to supplement the current understanding of Site-wide conditions. Monitoring locations, which have been analyzed for NA parameters, as well as the additional locations where NA parameters will be collected, are shown on Figure 24.

3.5 AOC A-15: Site-Wide Trichloroethene and Vinyl Chloride Surface Water Contamination

AOC A-15 was designated to address VOC contamination in surface water, specifically TCE and VC. AOC A-15 is defined as the areas within the Cities of Auburn and Algona, where concentrations of TCE and VC are detected in surface water (Chicago Avenue ditch, Auburn 400 north and south ponds, and

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[8] The Mann-Kendall analysis was completed using all historical TCE data available for wells in the monitoring well network through June 2015 (LAI 2017c). The number of wells in the TCE and cVOC analysis differ because some wells did not have a sufficient number of data points for statistical analysis at the time of the TCE analysis and because of changes in the monitoring program between 2015 and 2016.

[9] The Mann-Kendall analysis was completed for cVOC data (TCE, DCE isomers, and VC) collected between the beginning of 2011 and the end of 2016 (Site-wide NA Assessment report, in progress).

Mill Creek). Boeing is currently monitoring surface water on a semiannual frequency. The extent of AOC A-15 is shown on Figure 4.

3.5.1 Proposed Scope of Work

FS fieldwork at AOC A-15 will include the addition of one surface water sample location and three permanent pore-water sampling locations in Mill Creek. Boeing will obtain approval from the City of Auburn for the addition of surface water sampling locations along Mill Creek.

3.5.1.1 Additional Surface Water Sampling Location

Boeing detected VC in Mill Creek at SW-18 for the first time in 2016. This area is downgradient of the Area 1 groundwater plume. A new annual surface water sampling location will be added downstream of SW-18. The new location, SW-27, will be located north of SW-18, on the other side of the West Main Street culvert. SW-27 will be sampled annually in the dry season. The complete surface water sampling matrix, including the changes listed above, is presented in Table 7.

3.5.1.2 Sediment Pore Water Sampling

In addition to surface water sample location SW-27, FS investigation work will include the installation and annual sampling of three permanent sediment pore water sampling locations along Mill Creek. Two locations, PW-18a and PW-18b, will be located along Mill Creek, near surface water sample location SW-18. PW-18a will be located adjacent to SW-18 and SW18b will be located approximately 50 meters south, upgradient in Mill Creek. The third permanent pore water sample location, PW-27, will be located north of West Main Street, adjacent to proposed surface water sampling location SW-27.

The permanent pore water sample locations will be installed using a hand auger or drive points and will be constructed of 2-inch diameter, schedule 40 PVC, or 1-inch stainless-steel casing with a 1-ft long, .020-inch slot size screen. Each location will include two sample depths. One sample will be collected from a screen located 1.5 to 2.5 ft bgs, and another sample will be collected from a screen located 4 to 5 ft bgs. The depth will located in the sample identification (ID). Samples, depths, and sampling frequency are presented in Table 7.

Each permanent pore water sample locations will be placed at final depth and firmly lodged in placed using rebar or a similarly rigid structure as a support. The screened interval will be placed in a location where the passive diffusion bag (PDB) will be fully submerged during the dry season. Samples will be collected using low-flow sampling techniques with a peristaltic pump or 12-inch PDBs hung within the screened interval. The PDBs will be allowed to equilibrate for a minimum of 2 weeks, and will be sampled annually, during the dry season. Proposed sample locations are shown on Figure 4; however, actual locations may vary based on access. Locations will be documented using a hand-held GPS.

4.0 FIELD PROCEDURES

This section presents descriptions of field procedures for FS investigation activities taking place at the Site. All field activities will be completed in accordance with the Site Health and Safety Plan, included in this work plan as Appendix C. Additional details can be found in the Sampling and Analysis Plan (SAP) and the Quality Assurance Project Plan, included as Appendix D and Appendix E, respectively.

4.1 Drilling Methods

This section describes the techniques used to advance soil borings for the installation of monitoring wells or collection of groundwater and/or soil samples for chemical analysis. The soil borings will be advanced using rotosonic or direct-push drilling techniques, based on expected conditions and boring depth. In general, the shallow zone is defined from 5 to 35 ft bgs, the intermediate zone is defined from 35 to 75 ft bgs, and the deep zone is defined from 75 to 105 ft bgs. Depths of wells may vary depending on the data objectives for the well, field screening results, depth of the geologic units, or varying geologic conditions within a unit. In particular, the final depth of deep zone wells will depend on the depth of the OM deposit.

During the drilling of deep wells, the borings will be advanced until the OM is identified, or to a depth of 110 ft bgs, whichever is shallower. A layer of silt (1 to 5 ft thick) is commonly identified overlying the OM. The well screens at the bottom of the deep zone will be installed 1 ft above the contact with the OM, or if the silt layer is present, 1 ft above the contact with the silt layer over the OM.

4.1.1 Direct-Push Drilling

Direct-push drilling will be used at AOC A-01 and the soil gas investigation for AOC A-14 in Area 1. Direct-push drilling will be accomplished using a truck-mounted rig. Depending on the manufacturer, make, and model, direct-push drill tooling is advanced by static push, pneumatic impact, or vibratory methods, or a combination thereof. Unlike rotosonic drilling, there is no rotation of the tooling. In its standard configuration, direct-push drilling collects a continuous soil core in a 2.25-inch diameter core barrel with a removable polyethylene liner. Once the desired depth is reached, the core is extracted from the ground and the liner and soil core are removed from the core barrel.

4.1.2 Rotosonic Drilling

Rotosonic drilling will be used at AOC A-13 and the source area investigation for AOC A-14 at Building 17-07. Rotosonic drilling will be accomplished with a limited-access, track-mounted drill rig. Rotosonic drilling uses high frequency mechanical oscillations, developed in a special drill head, to transmit resonant vibrations and rotary power through the drill tooling to the drill bit. Frequencies between 150 to 180 hertz are generated. These frequencies match the natural frequency of the drill tooling, causing no dampening of the vibratory wavelength to the bit and can be adjusted to optimize drilling in different formations. Rotosonic drilling has the ability to produce continuous core samples of both unconsolidated and consolidated formations.

Rotosonic drilling will be used inside Buildings 17-07 and 17-06; venting and fans will be deployed to capture and transmit all exhaust created by the rig to the outside of the building. An air monitor (MultiRae or equivalent) will be used to monitor air quality in the area.

4.2 Well Installation

All wells will be drilled and installed using a rotosonic drill rig. Conventional wells will be installed in accordance with the Minimum Standards for Construction and Maintenance of Wells WAC 173-160. Multi-level wells will be installed in accordance with WAC 173-160 as modified by a well variance from Ecology that provides exception to specific sections of WAC 173-160. Boeing will apply for and obtain the well variance prior to installation of the multi-level wells.

4.2.1 Conventional Well Installation

The conventional wells will be constructed of 2-inch diameter, flush-threaded, schedule 40 PVC well casing and screen. The well screen (0.020-inch slot size) will be 10 ft long and the sand pack (10/20 or equivalent) will extend 2 ft above the top of the screen. A well seal of bentonite chips, pellets, and/or bentonite grout will extend from the sand pack to the surface completion. If bentonite grout is used, a minimum of 3 ft of bentonite chips or pellets will be placed above the sand pack and allowed to hydrate prior to the placement of the grout. Conventional monitoring wells will be finished with standard traffic-rated flush-mount monuments set in concrete.

4.2.2 Multi-Level Well Installation

Multi-level wells will be constructed using the Solinst® Continuous Multichannel Tubing (CMT) Model 403 seven channel well (CMT well). This well tubing is pre-cut to the desired length of the well and is delivered on a roll. The well sample ports must be constructed on-site at the desired depth. CMT monitoring wells will be constructed in accordance with the Solinst CMT (7-channel) Multilevel System Assembly Manual (CMT Manual) provided in the SAP (Appendix D).

In addition to the specific procedures described in the CMT Manual, each of the CMT channels will be grouted immediately prior to installation from below the well screen (below the packer) to the bottom of the well. The purpose of pre-installation grouting of the void space below the screen in each channel is to facilitate appropriate decommissioning of the well once it has reached the end of its useful life. The pre-installation grout mixture will be a Nittetsu superfine cement with Mighty 150 superplasticizer or equivalent products. Pre-installation grouting will be completed in accordance with the procedures described in the CMT decommissioning paper provided in the SAP (Appendix D).

Each sampling port will be at least 6 inches in length and constructed according to the CMT Manual. The screens will proceed from shallowest at Port 1 to deepest at Port 7. At least one screened interval will be installed in each groundwater zone; however, the actual depths will be determined at the time of drilling based on field screening for VOCs and soil type.

During installation, a bottom anchor will be utilized and the depth of screen 7 is determined by the depth of the bottom anchor. A 3-ft thick sand pack (20/40 silica sand or equivalent) will be centered on each sampling port that is 1 ft long or less. If a longer screen interval is used (e.g., water table screens, if used, may be longer than 1 ft) the sand pack will extend at least 1 ft above and below the screened interval. Bentonite seals will be constructed between the sand pack intervals. Coated bentonite pellets will be used as annular seal material in order to delay hydration of the bentonite and allow additional time to frequently check the height of the pellets in relationship to the screens. A 5-ft length of 2-inch diameter PVC will be installed as a straightening sleeve at the top of each CMT well to minimize curvature of the tubing at the surface completion. Numbered channel identifiers will be installed at the top of the CMT to identify the channels corresponding to individual sampling ports.

4.3 Field Screening

Field screening techniques will be used to identify, to the extent practicable, vertical, and horizontal extents of contamination. Several methods will be used during FS investigation work and are described in detail below:

- **Petroleum Products in Soil:** Several tests will be used at AOC A-01 and AOC A-13 to identify TPH in soil. A sheen test is performed by placing a handful of soil in a container, saturating the soil with water, and observing the water surface for signs of petroleum sheen. Soil will also be field inspected for indications of contamination by olfactory and visual observation. The container for sheen testing may be disposable or will be decontaminated between uses and reused.
- **VOCs in Soil or Groundwater:** A multi-gas meter or ppbRAE will be used at AOC A-13 to identify areas of VOC contamination in the field for permanent placement of a CMT well screen. VOC headspace analysis is performed by placing a handful of soil into a quart-sized Ziploc® bag. The bag is then closed and the soil is broken up or agitated inside the bag and air in the bag is allowed to equilibrate for 2 to 5 minutes. After equilibration, the probe or tubing is carefully inserted into the bag while minimizing release of vapors, and the highest reading for each compound is recorded. The Ziploc bag will be disposed of after each use.
- **VOCs in Sub-slab Soil Gas:** A multi-gas meter or ppbRAE will be used at Building 17-07 to field screen sub-slab soil gas sample locations. A rotohammer will be used to core through the concrete slab, and the probe or tubing attached to the meter will be immediately placed down the hole to identify the presence of VOCs.

- **VOCs in Borehole Soil Gas:** A multi-gas meter or ppbRAE will be used at former Building 17-03 to field-screen borehole soil gas sample locations. A direct-push probe will be advanced to a depth of 5 to 10 ft bgs. Tubing attached to the meter will be immediately placed downhole to identify the presence of VOCs. In addition, VOC headspace analysis will be performed on the soil cores extracted during drilling of the borehole soil gas sampling points.

4.4 Well Development

After construction, groundwater monitoring wells will be developed to remove formation material and drilling water (if added) from the well boring and the filter pack prior to groundwater sampling.

Once a permanent groundwater monitoring well has been completed, it will be required to sit for at least 24 hours prior to well development. All downhole development tools will either be dedicated to a specific well or decontaminated prior to use in each well.

Conventional wells will be developed by purging up to 10 casing volumes of groundwater or until the groundwater becomes free of turbidity (less than 50 nephelometric turbidity units [NTU]), whichever is later. Where drilling water is added, the volume of water removed during development will be a minimum of 200 percent of the volume added. During development, wells will be surged using a surge block or stainless-steel bailer to assist in removal of fines from the sand pack. A whale pump or other appropriate pump will be used to remove water from the well.

CMT monitoring wells will be developed using a peristaltic pump or mini inertial pump to purge water from each individual sampling chamber. CMT wells will be purged until a minimum of five casing volumes are removed from each channel and the purge water has relatively low turbidity. The target turbidity is less than 50 NTU; however, higher turbidity may be acceptable if reaching 50 NTU is not practicable due to the limitations on development of CMT wells.

Chloroform, if present in groundwater samples, will be used as an indicator that drilling water is still present in the vicinity of the well and may have affected the sample result. Chloroform is a byproduct of chlorine in drinking water (i.e., drilling water) interacting with aquifer organics. If chloroform is present in initial samples, wells will be resampled after 1 month.

4.5 Soil Sampling

Soil samples for volatile constituents, including GRO and BTEX, will be collected using US Environmental Protection Agency (EPA) Method 5035A procedures. The procedures involve using a small coring device or open-ended syringe to collect an undisturbed soil sample of a specified weight, which is then placed in a pre-preserved volatile organic analyte (VOA) vial. This method minimizes loss of VOCs to volatilization during the sampling process. The contracted laboratory will provide specific sampling equipment and instructions on how to collect the samples (e.g., sample quantity to for each VOA vial).

Soil samples for non-volatile constituents including, diesel-range petroleum hydrocarbons, will be collected in laboratory-provided jars of an appropriate size for the number of analyses being conducted. Care will be taken to collect an appropriately representative sample. Larger samples may be mixed in stainless steel bowls to homogenize the sample before collecting into sample jars. Sampling spoons and bowls will be cleaned between samples using an Alconox® wash, tap water rinse, and final deionized water rinse.

4.6 Groundwater Sampling

Groundwater sampling will be conducted a minimum of 5 days after final well development for permanent wells, or 14 days after development at CMT wells were water was used during drilling.

Groundwater sampling will be conducted using a peristaltic pump and dedicated tubing using low-flow sampling techniques. Dedicated tubing for conventional wells will be standard 3/8-inch polyethylene tubing. Dedicated tubing for each channel of the CMT well will be 1/4-inch Teflon tubing. During purging, groundwater will be monitored for the following field parameters: pH, conductivity, DO, temperature, ORP, and turbidity. Permanent wells will be sampled utilizing low-flow procedures.

4.7 Soil Gas Sampling

This section describes the field activities, and provides sampling procedures and analytical procedures for sub-slab soil gas sampling using permanent soil vapor implants. Sub-slab soil gas sampling is accomplished by drilling or coring a hole through the slab, inserting a sample collection device, and sealing the hole around the sample collection device so that ambient air cannot enter the subsurface. Sub-slab soil gas samples will be collected for the FS investigation by placing a vapor implant and sealing the hole with hydrated bentonite and a concrete surface seal. A protective cover will be installed for permanent sampling point.

4.7.1 Vapor Implant Installation

Vapor implants will be used to collect samples from beneath the slab in buildings (sub-slab soil gas) and outside of buildings under asphalt or cement pavement (borehole soil gas).

4.7.1.1 Sub-Slab Soil Gas

Sub-slab soil gas samples will be collected from just beneath a slab. The building slab may vary in thickness depending on location. The rotary hammer coring will be completed by a concrete coring contractor[10]. Coring will be attempted without the use of water; however, in some circumstances, water may be required. If water is used for coring, sample collection must be delayed for 24 hours to allow water to drain from the filter pack and the coring contractor shall minimize the amount of water allowed to escape downhole. Immediately following coring, field staff will insert a MultiRae or ppbRAE (or equivalent) into the drilled hole to quickly check for VOCs, and will proceed with installing the sample point to minimize the introduction of soil gas into indoor air.

Vapor implants will be installed in a 1-inch-diameter vertical hole within the slab; larger holes may be used, but are not anticipated for this project. Vapor implants are constructed with a porous sampling tip connected to sample tubing placed in the core hole. Teflon or Nylaflow® tubing may be used as sample tubing. The porous sampling tip will extend 3 to 6 inches below the bottom of the slab. The void space around the sampling tip will be backfilled with drilling grade silica sand up to the bottom of the slab. Approximately 2 inches of dry granular bentonite will be placed above the sand and hydrated bentonite grout will be used to seal the annular space between the sample tubing and the slab within

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[10] Some coring debris will remain at the bottom of the boring; therefore, drilling should extend beneath the bottom of the slab by approximately 3 to 6 inches to expose the soil before installing the vapor implant. A broom and dustpan will be used to collect coring debris deposits on the ground surface; a vacuum will not be used once the coring/drilling device penetrates the slab.

the hole. Care will be taken to avoid getting water into the silica sand layer. For permanent implant locations, hydrated bentonite grout will be added until the bentonite is within 2 inches of the top of the slab and concrete cement will be placed on top of the bentonite grout to form a surface seal. For temporary implant locations, hydrated bentonite grout will be added until the bentonite is within ½ inch of the top of the slab and no concrete surface seal will be used. For permanent vapor implants, a small flush-mounted monument will be used to protect the sampling ports from foot and vehicle traffic. The tubing will be capped with a valve to prevent gas exchange between sampling events.

Most likely, coring and vapor implant installation will be completed at all planned locations and then followed by sampling up to a week later. In some cases, sampling may need to be completed within a shorter timeframe, in which case, the sample point will be left undisturbed for a minimum of 2 hours (EPA 2015) to allow the soil gas to equilibrate. If water was used during coring, the point will be left undisturbed for a minimum of 24 hours to allow water to fully drain below the level of the implant.

4.7.1.2 Borehole Soil Gas

Borehole soil gas vapor implants will be installed using a direct-push drilling rig. The hole will be drilled to a depth of 5 to 10 ft bgs. The following procedure will be used to install the soil gas vapor implant.

- Measure depth to bottom of borehole and cut probe tubing to appropriate length to reach to the surface and through the helium shroud at the surface.
- Add about 2 inches of sand to the bottom of the borehole (calculate required volume based upon borehole ID).
- Insert vapor implant and tubing down borehole. Cover vapor implant with sand pack, with at least 2 inches of sand above the implant. (Calculate required volume based upon borehole ID.)
- Place at least 6 inches of dry granular bentonite above the sand pack. Following the dry bentonite, fill the borehole to the surface with hydrated bentonite or bentonite grout. The bentonite should be hydrated in a container at the surface and then slowly poured into the borehole.
- Wait 30 minutes prior to sampling.

4.7.2 Soil Gas Sample Collection

Summa canisters will be used to collect soil gas samples. Each Summa canister will be evacuated to a vacuum pressure of 25 to 30 inches of mercury (in. Hg) by the laboratory and equipped with a pressure gauge and a calibrated critical orifice airflow controller to match the designated sample flow rate or collection time. Each soil gas sample will be collected in a 1-liter (L) Summa (vacuum) canister fitted with a flow controller. The flow controller will be calibrated by the laboratory to a flow rate not to exceed 200 milliliters per minute.

After the equilibration period is complete, a helium leak test and a shut-in test will be conducted, sample tubing will be purged, and a sample will be collected. Detailed procedures are provided in the SAP (Appendix D).

4.7.3 Sample Handling and Analysis

Summa canisters will be shipped using the original shipping packaging under chain-of-custody procedures to Boeing's contracted laboratory. The soil gas samples will be analyzed for the VOC constituents listed in Table 5 by using EPA Method TO-15 and for helium by ASTM International D-1946. Samples will be analyzed on a standard turnaround time.

4.8 Surface Water Sampling

Surface water sampling will occur only after a period of no measureable precipitation over a 48-hour period to minimize stormwater runoff contribution at sampling locations. Sampling is scheduled to occur coinciding with groundwater monitoring events when weather allows; therefore, sampling will be conducted in September 2017.

Surface water sampling will be conducted using a peristaltic pump and dedicated tubing or a composite liquid waste sampler (COLIWASA) as described in the SAP. Samples will be collected no more than 4 inches above the bed of the sediment and at least 2 inches below the water surface. If less than 4 inches of water is present, the sample will be collected from the approximate mid-point of the water column. When using the peristaltic pump, sample tubing will be attached to a rigid pole to allow control of the sampling location and depth. At the time of sampling, a multi-parameter probe (YSI 556 MPS) will be used to monitor the following field parameters: pH, conductivity, DO, temperature, and ORP. Field parameters will be measured either using a flow cell when using a peristaltic pump or by submerging the instrument probe directly into the surface water when using a COLIWASA.

4.9 Sediment Pore Water Sampling

Sediment pore water samples will be collected using a low-flow sampling techniques with a peristaltic pump or a PDB. The PDB will be removed from the well casing and water will be sampled from the PDB using the following procedures:

- A sampling straw will be used to puncture the side of the PDB (or a corner will be cut from the top)
- The contained water in the PDB will be carefully poured into laboratory-provided, clean sample containers. To facilitate pouring the sample, field personnel may suspend the bag by monofilament line attached at the top.
- After sample collection, any excess water contained in the PDB will be collected and disposed of as described in Section 4.11. The empty PDB will be disposed of as solid waste.

4.10 Sample Identification

The following sections below describe the creation of the sample ID number, which will be used for samples collected throughout the FS investigation. Additional sample labeling instructions can be found in the SAP (Appendix D). Permanent sampling locations are three or four-digit consecutive numbers, assigned by Boeing. The next number for each sample location type is listed below:

- Groundwater well – AGW277
- Soil boring – ASB0264
- Sub-slab soil gas monitoring location – SSV076
- Soil gas monitoring location – ASG001
- Surface water sample – SW-27.

4.10.1 Soil Samples

Soil samples will be collected from both well boreholes and temporary soil borings. The following sample identification schemes will be used for soil.

Well Borehole

Example: AGW277-20

A	GW	277	20
Boeing Auburn Plant	Location Type (groundwater monitoring well)	Well number	Depth (ft bgs)

Temporary Boring

Example ASB0264-20

A	SB	0264	20
Boeing Auburn Plant	Location Type (soil boring)	Boring number	Depth (ft bgs)

4.10.2 Groundwater Samples

Groundwater will be collected from conventional wells, multi-level wells, and borings (temporary wells). The following sample identification schemes will be used for groundwater samples.

Conventional Well

Example: AGW277-20170405

A	GW	277	20170405
Boeing Auburn Plant	Location Type (groundwater monitoring well)	Well number	Date: yyyymmdd

Multi-level Well

Example: AGW277-20170405

A	GW	277	2	30	20170405
Boeing Auburn Plant	Location type (groundwater monitoring well	Well number	Channel number	Depth of screen (ft bgs)	Date: yyyymmdd

Boring (Temporary Well)

Example: ASB0264-12-20170405

A	SB	0264	12	20170405
Boeing Auburn Plant	Location Type (boring)	Boring number	Depth (ft bgs)	Date: yyyymmdd

4.10.3 Sub-Slab Soil Gas Samples

Air samples will be collected from temporary and permanent sub-slab soil gas locations. The following sample identification schemes will be used for sub-slab soil gas samples:

Example: SSV076-20170405

SSV	076	20170405
Location Type (sub-slab soil vapor/gas)	Location number	Date: yyyymmdd

4.10.4 Soil Gas Samples

Air samples will be collected from soil gas locations (outside of buildings). The following sample identification schemes will be used for soil gas samples:

Example: ASG001-20170405

A	SG	001	20170405
Boeing Auburn Plant	Location Type (soil gas)	Location number	Date: yyyymmdd

4.10.5 Surface Water Samples

A surface sample will be collected from Mill Creek. The following sample identification scheme will be used for the surface water sample:

Example: SW-27-20170405

SW	27	20170405
Location type (surface water)	Location number	Date: yyyymmdd

4.10.6 Pore Water Samples

Pore water samples will be collected from Mill Creek. Each pore water sample is near a surface water sampling location. The pore water samples will have a number matching the nearest surface water sample location. If more than one pore water sample location is associated with a surface water sample location, the number will be followed by a letter starting with “a”. The following sample identification scheme will be used for the pore water sample:

Example: PW-18a-2.5-20170405

PW	18a	2.5	20170405
Location type (pore water)	Location number	Depth (ft bgs)	Date: yyyymmdd

4.11 Decontamination and Waste Management

All soil cuttings, decontamination water and purge water will be contained and placed into 55-gallon-steel drums or an equivalent receptacle provided by Boeing. Plastic sheeting will be used to protect the ground surface and contain drill cuttings at the well until they can be placed into the waste containers. All waste from off Boeing property will be transported back to the Facility the same day it is generated. Once at the Facility, waste will be placed into appropriate containers for storage. Boeing-provided labels will be attached to each container. If drums are used, they will be placed on Boeing pallets at the Facility. Boeing will be responsible for banding, transporting, and disposing of the containers.

4.12 Survey Information

After completion of the drilling and groundwater well installation activities, the horizontal location and vertical elevation of each new monitoring well and sub-slab soil gas and direct-push borings inside buildings will be surveyed by a professional land surveyor. Horizontal sampling locations will be surveyed in Washington State Plane Coordinate System North Zone 83. The elevation of the top of each well casing will also be surveyed to an accuracy of 0.01 ft National Geodetic Vertical Datum of 1929 (NGVD 29) in order to accurately determine groundwater elevations. Geographic coordinates of the direct-push borings and sub-slab soil gas locations will also be collected in the field using a hand-held GPS unit. The accuracy of the GPS unit is typically better than +/- 1 ft.

5.0 PRELIMINARY CLEANUP STANDARDS

This section discusses the approach to develop cleanup standards at the Site. Preliminary cleanup standards will be proposed in the FS and will be used in development and evaluation of cleanup alternatives for soil, groundwater, and surface water in the FS. Final cleanup standards will be approved by Ecology through incorporation into the final Cleanup Action Plan.

The development of cleanup standards requires identification of numeric and risk criteria to determine when a site is "clean"; determination of where the cleanup standards must be met (point of compliance [POC]); and consideration of other applicable, relevant, and appropriate requirements (ARARs). Discussion of ARARs that affect cleanup levels (CULs) is provided along with discussion of cleanup standard development for each media. Other ARARs that may affect the development and evaluation of remediation alternatives will be identified and discussed in the FS. A discussion of CUL development is provided in Section 5.1 and a discussion of POCs is provided in Section 5.2.

Pertinent to the development of CULs are indicator hazardous substances (IHSs). IHSs are constituents that make a significant contribution to the overall exposure risk at a Site. The RI presented screening levels for all media (soil, groundwater, surface water, and air) and presented a comparison of the Site data to the screening levels to identify IHSs (LAI 2017c). Constituents that exceeded screening levels in more than 5 percent of samples for a given media were included as IHSs for that media. No IHSs were selected for surface water in the RI report because there were no exceedances of screening criteria in surface water. For the purpose of CUL development, TCE and VC have been identified as IHSs for surface water in this document. IHSs are used in the evaluation of total Site risk and are presented in Table 8.

IHSs were not selected for air because there was only one exceedance of a screening level in indoor air and that exceedance was attributed to a background source and not to vapor intrusion. Empirical sampling data from multiple rounds of sampling at more than 24 commercial, industrial, and residential buildings indicate that groundwater screening levels presented in Ecology's Cleanup Levels and Risk Calculations (CLARC) database for vapor intrusion are overly conservative and that vapor intrusion is not resulting in unacceptable risk to human health within the site.

5.1 Cleanup Level Development

Eliminating all risk at a Site is not possible and MTCA identifies acceptable risk thresholds to be used in the development of cleanup standards. "Clean" means that a site is cleaned up to the point that contamination no longer poses an unacceptable risk to human health and the environment. This point may be defined in two ways, either by constituent concentrations (CULs) established based on acceptable risk for each constituent and each medium or by identifying cleanup risk thresholds (CRTs) for comparison to total risk calculations for each sampling point. The following subsections discuss the difference between CULs and CRTs and their use in development of cleanup standards for soil, groundwater, and surface water.

Total Site risk for IHSs in all applicable media will be evaluated as part of the CUL development process. Exceedances of screening levels in soil and surface water provide negligible contributions to total carcinogenic site risk[11] and the primary drivers of total site risk are TCE and VC in groundwater. For this reason, soil and surface water risk contributions will be calculated, but will not be included in the risk calculations for groundwater described in Section 5.1.3.

5.1.1 Cleanup Levels and Cleanup Risk Thresholds

This section explains the difference between CULs and CRTs and describes the methodologies for each approach. CRTs and CULs can be used in conjunction with one another. CRTs are a means by which to evaluate total risk from all applicable IHSs on a well by well basis.

To establish CULs, the acceptable risk thresholds identified in MTCA are used to calculate concentrations at which the constituent no longer poses unacceptable risk. CULs are expressed as a unit of mass per unit of volume [e.g., micrograms per liter (µg/L)] and individual constituent concentrations are compared to the CULs.

MTCA establishes three methods for calculating CULs for environmental media – Methods A, B, and C. Method A CULs are established in MTCA (WAC 173-340-900 Table 720-1 and Table 740-1) and are typically used for cleanups that involve only a few hazardous constituents, where cleanup is routine, and where all IHSs have an established Method A CUL. However, they may also be used for constituents when appropriate Method B values are not available. Method B is applicable to all sites and is the most common method for developing CULs. Method C may be used to set soil CULs at industrial sites, but typically requires land use restrictions to be placed on the property. Although it appears the Facility will meet the MTCA definition for an industrial property, Boeing has chosen to use MTCA Method B CULs.

CRTs are established based on acceptable thresholds for carcinogenic and non-carcinogenic risk identified in MTCA. CRTs are expressed as excess cancer risk (carcinogenic, e.g., 1 in 100,000 excess cancer risk, expressed as $1\text{x}10^{-5}$) and hazard index (HI; non-carcinogenic, e.g., HI of 1, expressed as HI = 1). The constituent concentrations at a given sampling point are used to calculate the excess cancer risk and HI for the combination of all IHSs at a given location. The excess cancer risk and HI at each location are then compared to the CRTs to determine compliance.

The acceptable risk thresholds used to develop CRTs are based on the risk criteria outlined in WAC 173-340-705. Total excess cancer risk may not exceed one in one hundred thousand and the HI[12] may not exceed one.

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[11] Based on an evaluation of the potential preliminary CULs, the contribution of soil and surface water to total carcinogenic site risk is three to four orders of magnitude lower than the risk threshold of $1\text{x}10^{-5}$.

[12] When two or more constituents have the same toxic effect, the HI is the sum of the hazardous quotients for each constituent with that toxic effect. A HI is calculated separately for each toxic effect.

The following Sections describe the CUL development approach for soil, groundwater, and surface water. Additional discussion is provided on the use of CULs and CRTs for various media.

5.1.2 Soil

Preliminary soil CULs will be developed for IHS constituents in soil established in the RI. The preliminary CULs will be developed for unrestricted land use in accordance with WAC 173-340-740 using MTCA Method B. Under MTCA Method B, soil CULs must be at least as stringent as all of the following:

- Concentrations established under applicable state and federal laws
- Concentrations determined using MTCA Equations 740-1 or 740-2, if sufficiently protective health-based criteria have not been established under applicable state and federal laws
- Concentrations protective of groundwater.

These criteria will be considered during development of preliminary soil CULs. As demonstrated in the RI, establishing a soil concentration protective of terrestrial ecosystems is unnecessary at this Site.

For constituents that exceed groundwater CULs, both human direct contact and protection of groundwater as drinking water (if available) will be evaluated. The preliminary soil CULs will be set at the lower of the two concentrations, and then, if appropriate, adjusted for natural background [WAC 173-340-740(5)(c)].

5.1.3 Groundwater

Both CRTs and CULs will be utilized to evaluate groundwater. Groundwater is the primary contributor to both carcinogenic and non-carcinogenic total Site risk. IHS compounds for groundwater include TCE, VC, cadmium, and petroleum hydrocarbons (DRO, ORO, and GRO). For drinking water, MTCA specifies a maximum non-carcinogenic risk equal to an HI of 1 and a maximum carcinogenic risk of 1×10^{-5} for constituents for which maximum contaminant levels (MCLs) have been established under applicable state or federal laws. These risk levels will be used to develop CULs under Method B and also as the CRTs for TCE, VC, and cadmium. Carcinogenic and non-carcinogenic risk cannot be calculated in the same way for petroleum hydrocarbons; therefore, MTCA Method A values will be used as preliminary CULs for petroleum hydrocarbons.

Of the groundwater IHS constituents, only TCE and VC are carcinogens and both compounds have established MCLs; therefore, the CRT for total carcinogenic risk will be set at 1×10^{-5}. TCE, VC, and cadmium all have associated non-carcinogenic risk; however, the toxicity endpoints are different for each constituent and, thus, do not result in additive effects from multiple constituents. The CRT for total non-carcinogenic risk will be set at an HI of 1.

CULs will be calculated as described above for each IHS, but will not account for total risk at a given location if more than one carcinogen is present. CRTs will be used to evaluate total risk at each sampling location based on the IHSs present. For a location to be considered “in compliance” with cleanup standards, the concentrations of IHSs must be less than or equal to the CULs and the total risk must be less than the CRTs. Use of CRTs requires calculation of the total carcinogenic and non-carcinogenic risk at each sampling location based on the analytical data. The total risk at each sampling location is then compared to the CRTs to determine if the cleanup standards are met. These calculations will be made on an ongoing basis to evaluate compliance with cleanup standards across the Site. In practice, these calculations are completed by entering sampling data for TCE, VC, and cadmium into a calculation spreadsheet. For carcinogens, the concentrations from the sample are divided by the concentrations equivalent to a carcinogenic risk of 1×10^{-5}, added together, and then multiplied by 1×10^{-5}. This calculation produces a total excess cancer risk for all carcinogens. For non-carcinogenic risk, the hazard index for each toxic effect is established by dividing the concentration of each constituent in the sample by the concentration equivalent to a hazard quotient of 1 and adding together the hazard quotients for the same toxicity endpoint. As previously discussed, none of the constituents have the same toxicity endpoints, so the HI for each toxicity endpoint is equal to the hazard quotient. If all calculated carcinogenic and non-carcinogenic risks at a given location meet the CRTs, then the location is considered to meet the cleanup standard. If one or more risk calculations exceed the CRT, then the location does not meet the cleanup standard.

5.1.4 Surface Water

Surface water at the Site consists of stormwater conveyance, treatment, and control structures; wetlands; and Mill Creek. Surface water screening levels in the RI were established based on highest beneficial use and reasonable maximum exposure for the various types of surface water. For example, State water quality criteria protective of drinking water and fish consumption were used for Mill Creek, but Site-specific health-risk based criteria were developed for stormwater conveyance, treatment, and control structures because these structures are not expected to be used for drinking water at any point in the future and individuals are not expected to consume fish from these structures at any time in the future. Health risk-based screening levels for stormwater conveyance, treatment, and control structures were developed based on reasonable maximum exposure scenarios that included direct contact, incidental ingestion, and inhalation. The reasonable maximum exposure scenarios were reviewed and approved by both Ecology and Washington State Department of Health. However, for the purposes of establishing preliminary surface water CULs; Ecology has requested that the Washington State surface water quality criteria under WAC 173-201A protective of drinking water and fish consumption be used for all surface water, including stormwater conveyance, treatment, and control structures[13]. Although no constituents in surface water exceeded the screening levels established in the RI, the Washington State surface water criteria based on drinking water and fish

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[13] Surface water criteria do not apply to stormwater conveyance in pipes.

consumption are considerably lower than the screening levels[14]. Boeing is continuing to discuss the applicability of Washington State surface water criteria with Ecology.

5.2 Points of Compliance

This section discusses the process used to establish POCs as part of the development of preliminary cleanup standards, and for use in the FS evaluation. Boeing understands that preliminary POCs used for the FS will not be final until approved by Ecology in the Cleanup Action Plan.

The preliminary POCs used in this FSWP and anticipated for use in the FS evaluation are the standard POCs for all media, as established under MTCA.

The preliminary POC for groundwater is: "*Throughout the site from the uppermost level of the saturated zone extending vertically to the lowest most depth which could potentially be affected by the site*" (WAC 173-340-720[8][b]).

For soil the standard POC is defined by MTCA based on the exposure pathway upon which the preliminary soil CUL is based (direct contact or protection of groundwater), as follows (WAC 173-340-740[6]):

- The POC is the point or points where the soil CULs shall be attained.
- For soil CULs based on the protection of ground water, the POC shall be established in the soils throughout the site.
- For soil CULs based on human exposure via direct contact or other exposure pathways where contact with the soil is required to complete the pathway, the POC shall be established in the soils throughout the site from the ground surface to 15 ft bgs. This represents a reasonable estimate of the depth soil could be excavated and distributed at the soil surface as a result of site development activities.

MTCA also recognizes that when cleanup actions involve containment of hazardous substances, the soil CULs will typically not be met at the POCs specified above. MTCA establishes conditions that must be met for the cleanup action to comply with the cleanup standards (WAC 173-340-740[6][f]). Boeing expects to include some cleanup alternatives that utilize containment technologies; therefore, this POC criterion may apply.

In this FSWP, Boeing is not proposing conditional POCs. However, at the time of the FS, Boeing may propose conditional POCs depending on the cleanup action alternatives developed and evaluated under the FS.

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[14] The only Site constituents detected in surface water are TCE, cDCE, and VC. No state or federal criteria are available for cDCE because insufficient toxicity information is available. Therefore, preliminary surface water CULs will only be identified for TCE and VC.

6.0 FEASIBILITY STUDY METHODS

The methods that will be used to complete the FS process include an initial cleanup technology screening completed as part of the FSWP and an outline for the FS report.

6.1 Technology Screening

This section identifies and screens potential cleanup action technologies that are available and may be appropriate for cleanup of the AOCs at the Boeing Auburn Facility. The intent of the screening procedure in the FSWP is to screen out cleanup technologies that are not appropriate or suitable to site conditions or constraints and to narrow down the potential candidate cleanup technologies to those that will be assembled into cleanup action alternatives in the FS report.

Technology screening was completed for each AOC carried forward to the FS. Technologies were evaluated based on their applicability and suitability in a given area, their presumed effectiveness based on site conditions, location constraints, and relative cost. Tables 9 through 15 present applicable technologies, screening, and decision criteria for each AOC. Table 16 presents a final list of technologies that will be carried forward to the FS.

6.2 Feasibility Study Outline

The methods that will be used to complete the FS process are presented in an annotated outline below. The section numbers below that begin with "FS" indicate the sections of the FS report. The italicized text within each FS report section describes the information that will be included in the section, and the methods and processes that will be used in that section. For example, a description of how prescreening for cleanup action alternatives will be completed is described under FS4.2.

FS1.0 Introduction

> *This section will present the requirements for the FS report as stated in the Agreed Order, Section VI (7), and WAC 173-340-350(8),(9), and -360 and will briefly summarize the Site location and description and overall site history.*

FS2.0 Current Conditions

> *This section will present the results of the current conditions investigation work conducted under the FSWP in accordance with the Agreed Order Section VI (6).*

FS3.0 Cleanup Standards

> *This section will propose preliminary CULs. The process for development of cleanup standards is discussed in Section 5.0 of this FSWP.*

FS4.0 Development of Cleanup Action Alternatives

FS4.1 Quantities and Location of Environmental Media Requiring Cleanup

This section will provide estimates of the quantities of contaminated media that require cleanup at each AOC and will describe the locations of the media requiring cleanup. This section will reply on the proposed cleanup standards developed in Section FS3.0

FS4.2 Description of Cleanup Action Alternatives

This section will describe a set of cleanup action alternatives to address these AOCs to be evaluated in the FS. The initial set of cleanup action alternatives will include options that meet the requirements of WAC 173-340-360 and -370. This includes the permanence and practicability of each option, characteristic of remediation wastes to be generated, compliance with appropriate regulations (ARARs), and limitations of the Site relative to each cleanup alternative. The section will also include discussion of laboratory or bench-scale tests necessary to evaluate the effectiveness of any cleanup action.

FS5.0 Analysis of Cleanup Action Alternatives

This section will evaluate each of the cleanup action alternatives developed for each AOC in Section 6.0 individually, using the criteria established by MTCA. WAC 173-340-360 (2) requires first that all alternatives evaluated meet the following four threshold requirements:

1. *Protect human health and the environment*
2. *Comply with cleanup standards (WAC 173-340-700 through 760)*
3. *Comply with applicable state and federal laws (WAC 173-340-710)*
4. *Provide for compliance monitoring (WAC 173-340-410 and 720 through 760).*

This section will document that cleanup action alternatives selected for evaluation meet these threshold criteria. The analysis in this section would satisfy Agreed Order Section VI(6)(B through D).

MTCA also requires that cleanup action alternatives that fulfill the threshold requirements be evaluated against the following "other requirements" (WAC 173-340-360[2][b]):

5. *Use permanent solutions to the maximum extent practicable by evaluating specific elements described in WAC 173-340-360(3).*
6. *Provide for a reasonable restoration time frame (WAC 173-340-360[4]) (see also Agreed Order Section VI(6)(F)*
7. *Consider public concerns (WAC 173-340-600).*

FS6.0 Comparison of Cleanup Action Alternatives

This section will include a comparison of cleanup action alternatives using the criteria under WAC 173-340-360(2). This section will also include an evaluation of the financial costs associated with each cleanup action alternative to satisfy Agreed Order Section VI(6)(E).

FS7.0 Recommendation of Preferred Cleanup Action Alternative

This section will recommend a cleanup action alternative for each AOC, where appropriate, based on the presentation of data and analysis and in accordance with Agreed Order Section VI (6)(G) and the analysis under WAC 173-340-360(2) through (4).

FS8.0 References

7.0 SCHEDULE AND REPORTING

Fieldwork is tentatively scheduled for the summer of 2017, pending Ecology approval of this work plan and receipt of Ecology variance for the CMT wells. A detailed schedule for the field activities and reporting is provided below; however, the schedule is subject to change based on agency approval of this work plan.

Field Activities:

- Early June: Annual groundwater monitoring event
- Mid-June: Building 17-07 Sub-slab soil gas installation and sampling
- Late June: AOC A-01 drilling and former Building 17-03 borehole soil gas sampling
- Late July/early August: Building 17-06 drilling and well installation
- Mid-August: Building 17-07 drilling and well installation
- Late August: Well development and surveying; no sooner than 24 hours following well completion; installation of permanent pore water sampling devices
- Early September: Quarterly groundwater monitoring, including initial sampling of new wells; no sooner than 5 days after development, or 14 days after development at CMT well where water is used during drilling
- Early September (weather dependent): Semiannual surface water sampling.

Public and private utility locates will occur at least 5 business days before initiation of subsurface activities. Landau Associates, Inc. (LAI) will also obtain utility drawings from Boeing prior to the start of work.

Reporting:

- Results from the FS field work will be validated and data submittals will be sent to Ecology 4 to 5 weeks after receipt of final data package; air samples will be analyzed on the standard 2-week turnaround time. With completion of data submittals, Boeing will propose additional field activities, as necessary.
- Results from semiannual groundwater sampling will be validated and submitted to Ecology as an attachment to the quarterly status reports; laboratory samples will be analyzed on the standard 2-week turnaround time.
- Additional results from the FS investigation work, including well and boring logs and interpretation of results, etc. will be included in the draft FS report.

8.0 USE OF THIS REPORT

This work plan has been prepared for the exclusive use of Boeing for specific application to the Auburn Fabrication Division facility feasibility study. No other party is entitled to rely on the information, conclusions, and recommendations included in this document without the express written consent of LAI. Further, the reuse of information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by LAI, shall be at the user's sole risk. LAI warrants that within the limitations of scope, schedule, and budget, our services have been provided in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions as this project. We make no other warranty, either express or implied.

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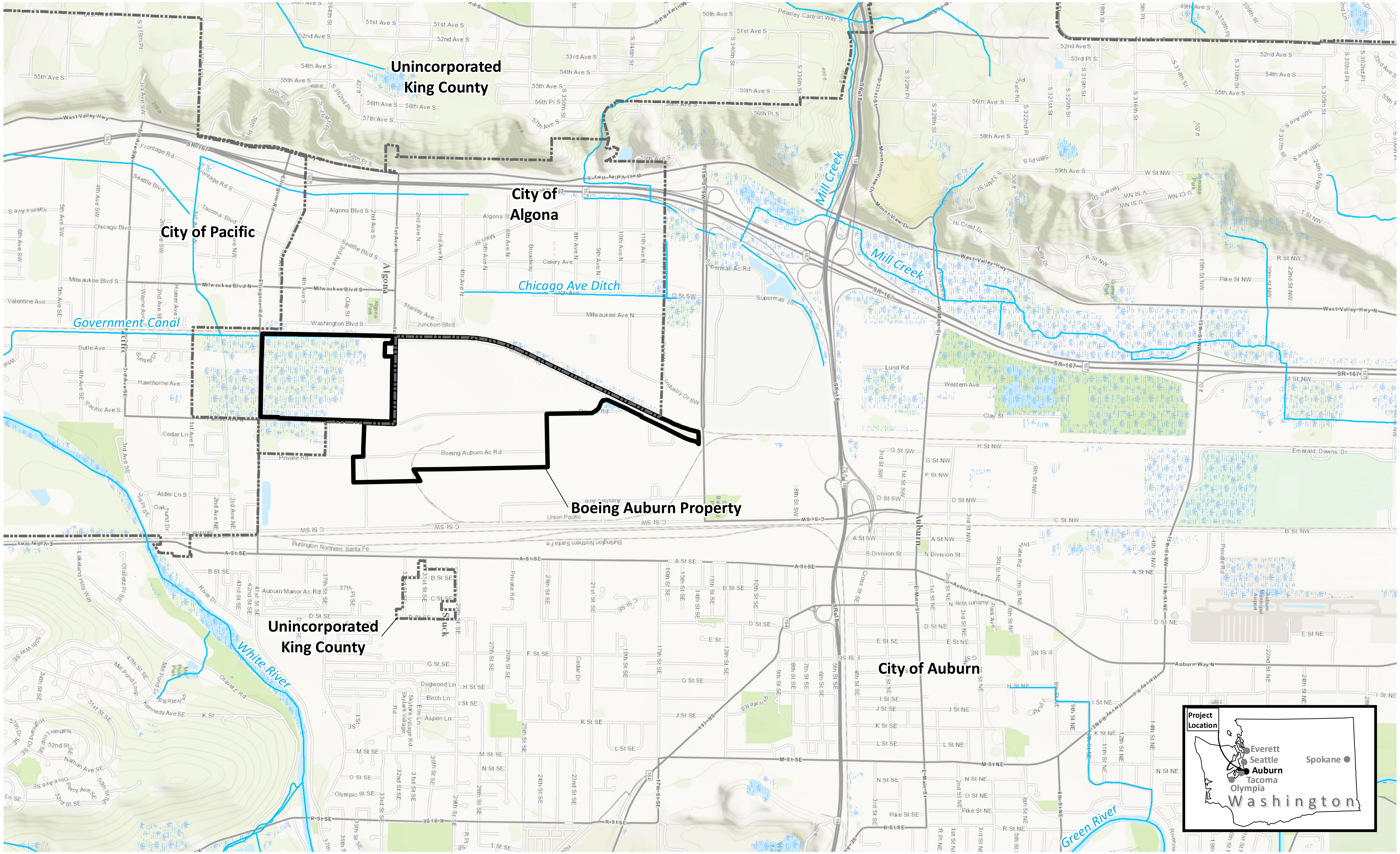

Legend

▬ Boeing Property
▬ City Limits
▬ Waterways
▭ Water Bodies
▨ Wetland Areas

Note

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

N

0 2,000 4,000

Scale in Feet

Data Source:Esri World Topo Map

Boeing Auburn Auburn, Washington	**Vicinity Map**	Figure 1

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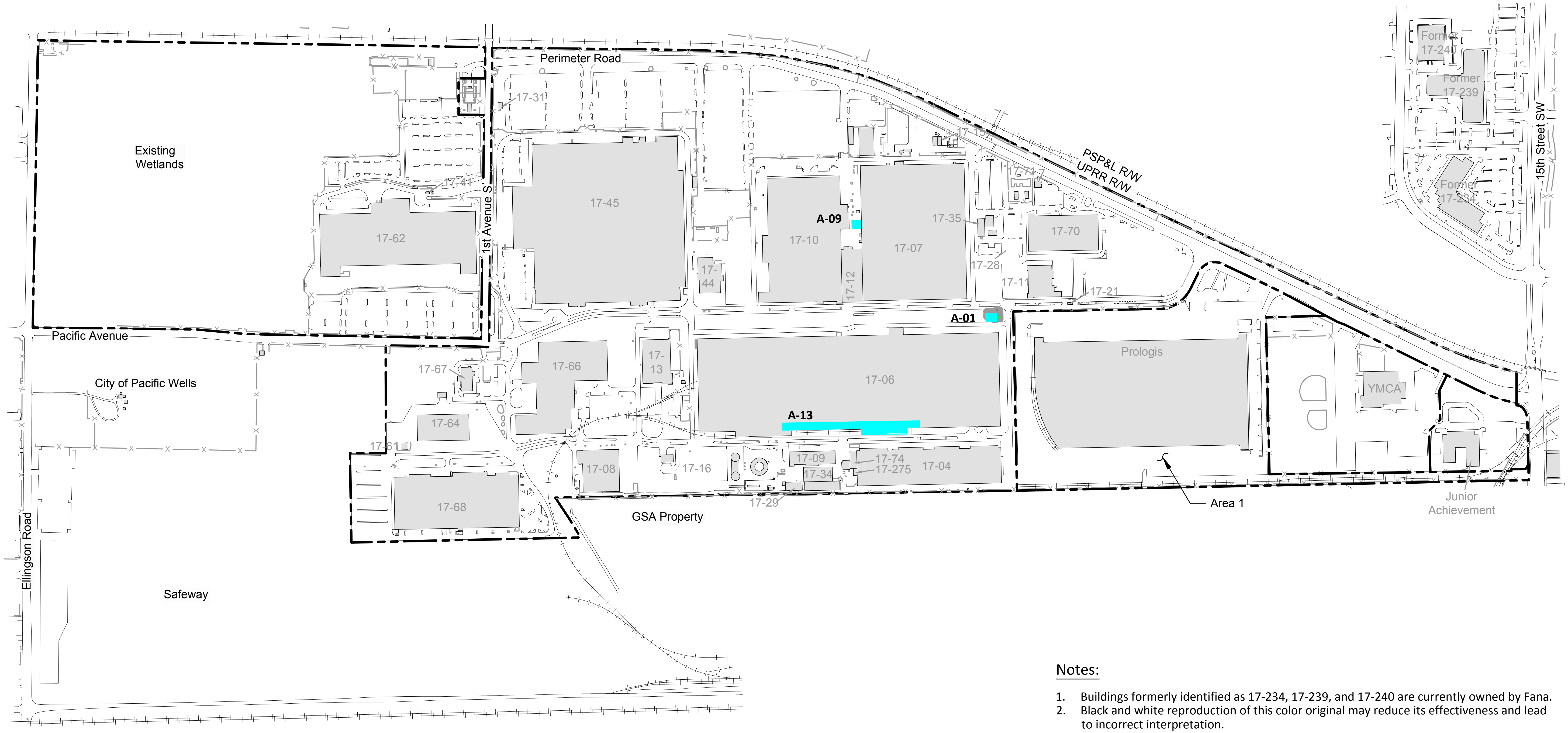
LANDAU ASSOCIATES



Notes:

1. Buildings formerly identified as 17-234, 17-239, and 17-240 are currently owned by Fana.
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

A-01	Area of Concern (AOC)
17-68	Current Building and Number
– · – · –	Property Boundary

N

0 600 1200

Scale in Feet

Base map source: Geomatrix 2003

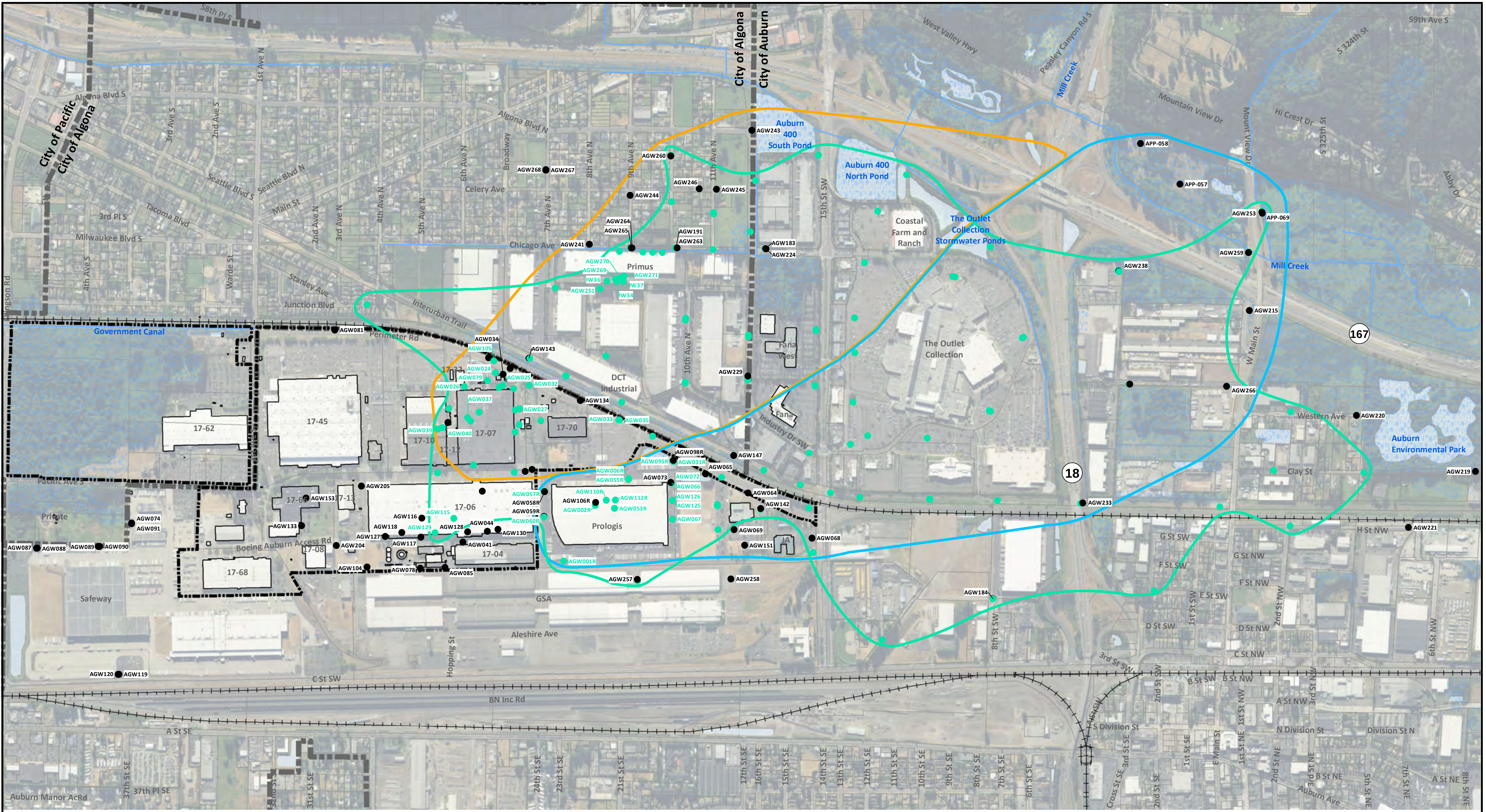
Landau Associates | G:\Projects\025\164\140\112\FS Workplan\F02 AOC's Carried Over To FS.dwg | 5/14/2017

LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

Facility Areas of Concern Carried Forward to the Feasibility Study

Figure
2



Notes

1. Most recent monitoring well data as of December 2015.
2. SL = Screening Level
3. SL Exceedance = TCE and/or VC exceed their respective SL (TCE = 0.54 μg/L, VC = 0.029 μg/L).
4. Exceedances shown at multilevel wells reflect an exceedance in any channel.
5. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

●	No Exceedance	▪▪▪	Boeing Property
●	SL Exceedance	▨	Wetland Areas
▭	SL Exceedance	▭	Water Bodies
▭	Area 1 Plume	—	Waterways
▭	Western Plume		
▬	City Limits		

0 1,000 2,000

Scale in Feet

N

Base map source: Geometrix 2003; Aerial Photo Source: Esri World Imagery; Parcel Data Source: King County GIS 2012

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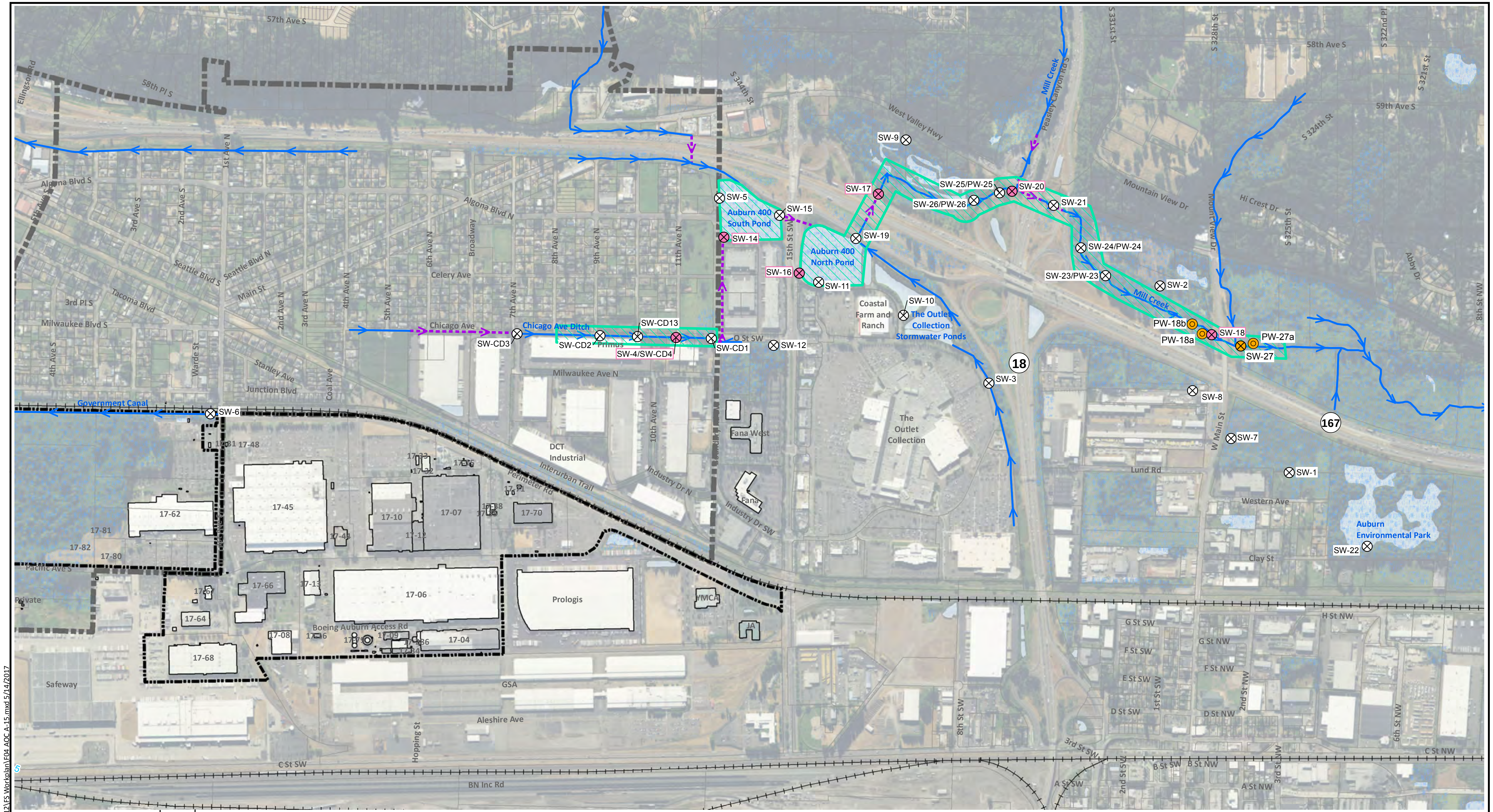
Boeing Auburn
Auburn, Washington

Extent of AOC A-14

Figure
3

G:\Projects\025\164\140\112\FS Workplan\F03 AOC_A-14.mxd 5/14/2017



Legend

- ⊗ Surface Water Sample
- ⊗ Ongoing Surface Water Sample Location
- ⊗ Proposed Surface Water Sample Location
- ○ Proposed Pore Water Sample Location
- ▨ Wetland Areas
- → Open Waterways
- ⇢ Piped Waterways
- ▪▪▪ Boeing Property
- ▬ City Limits
- ▨ AOC A-15

Notes

1. Surface water sampling locations are designated by SW. Pore water sampling locations are designated by PW.
2. The locations of surface water features are approximate.
3. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Base Map Source: Geometrix 2003; Parcel Data Source: King County 2015; Aerial Photo Source: Esri World Imagery.

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Boeing Auburn
Auburn, Washington

Extent of AOC A-15 and Proposed Sample Locations

Figure
4

G:\Projects\025\164\140\112\FS Workplan\F04 AOC A-15.mxd 5/14/2017

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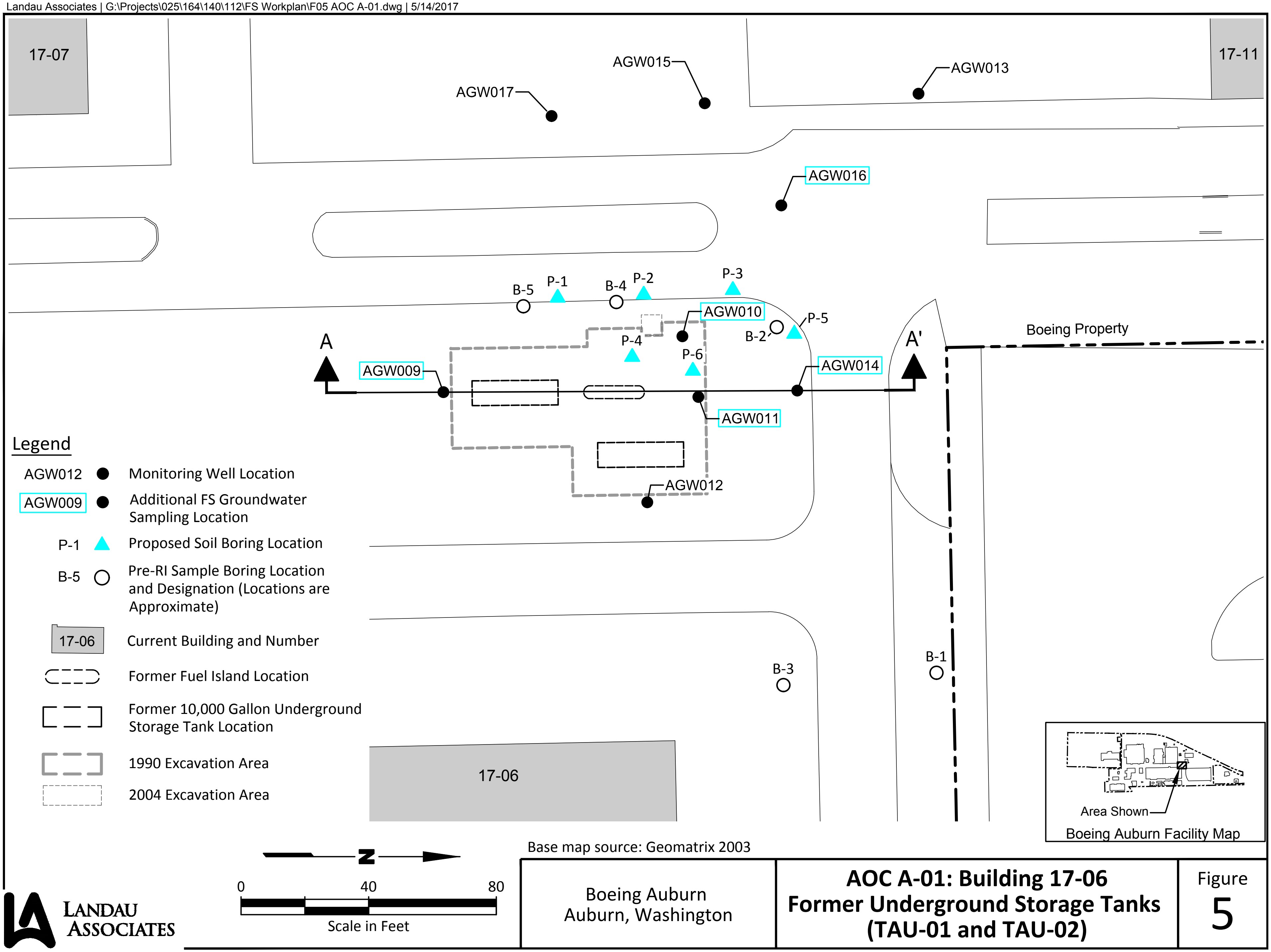


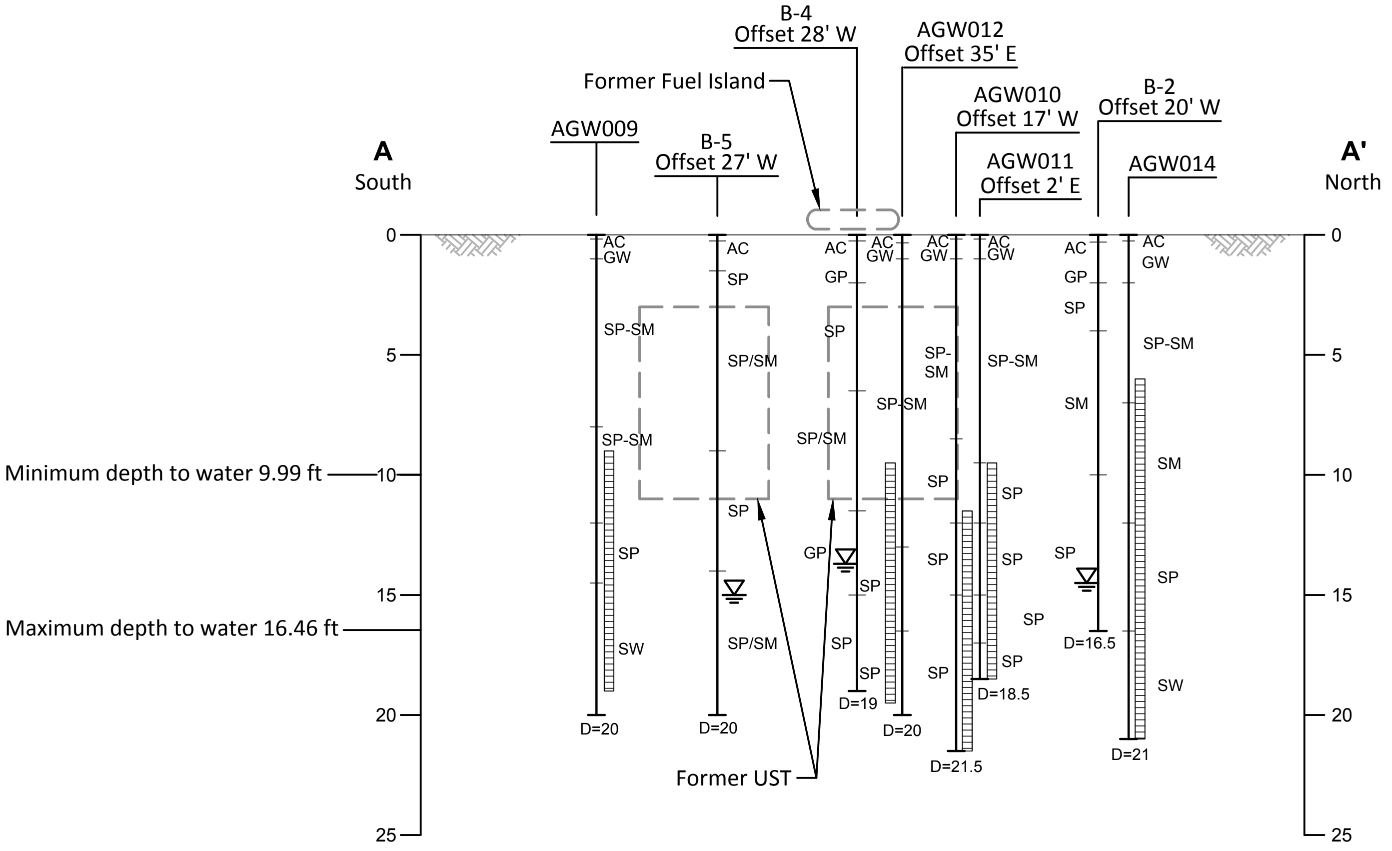
Base map source: Geomatrix 2003

Boeing Auburn
Auburn, Washington

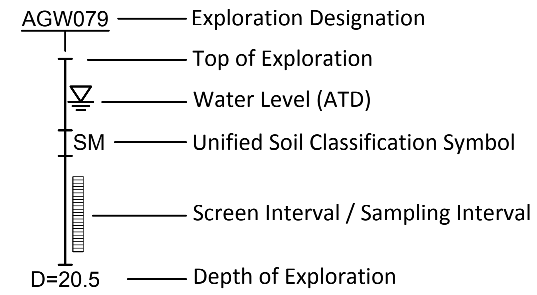
AOC A-01: Building 17-06
Former Underground Storage Tanks
(TAU-01 and TAU-02)

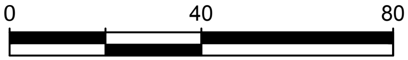
Figure
5

Landau Associates | G:\Projects\025\164\140\112\FS Workplan\F06 AOC A-01 Section.dwg | 5/15/2017 11:38 AM



Legend





Horizontal Scale: 1" = 40'
Vertical Scale: 1" = 8'

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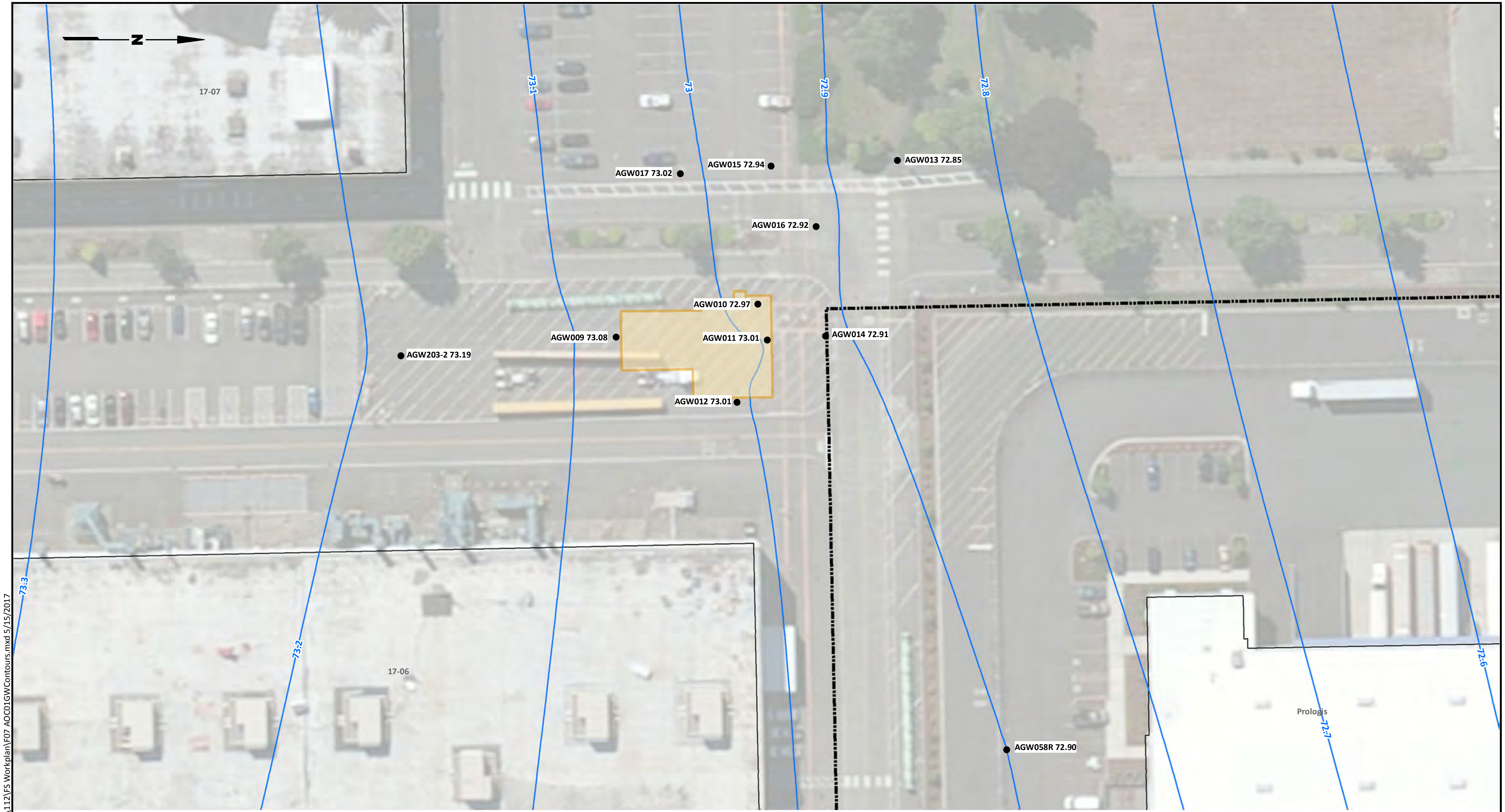
Boeing Auburn
Auburn, Washington

AOC A-01:
Cross Section A-A'

Figure
6



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Legend

● **AGW009** Monitoring Well Designation
73.08 Groundwater Elevation (ft, MSL)

Groundwater Elevation Contour

Boeing Property

🟧 1990 Excavation

Notes

1. All water level data in ft, MSL. Vertical datum is NGVD29. Data collected in June 2015.
2. Multilevel wells have multiple channels. Channel designations are included in the well ID (ex: AGW208-2). Groundwater elevations listed are for the channel closest to 30 ft below ground surface.
3. Wells installed specifically as water table wells are not included.
4. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

0 50 100

Scale in Feet

Base Map Source: Geometrix 2003; Aerial Photo Source: Esri World Imagery.

Landau Associates

Boeing Auburn
Auburn, Washington

**AOC A-01:
Localized Groundwater
Elevation Contours**

Figure
7

AGW017 (8/5/1991)		
Constituent	Concentration	Depth (ft bgs)
Benzene (µg/kg)	1.1 U	3
Ethylbenzene (µg/kg)	1.1 U	3
Toluene (µg/kg)	1.1 U	3
Xylenes, Total (µg/kg)	2.2 U	3
Diesel-Range Organics (mg/kg)	10 U	3
Gasoline-Range Organics (mg/kg)	10 U	3
Total Petroleum Hydrocarbons (mg/kg)	**18**	3
Benzene (µg/kg)	1.2 U	13
Ethylbenzene (µg/kg)	1.2 U	13
Toluene (µg/kg)	1.2 U	13
Xylenes, Total (µg/kg)	1.2 U	13
Diesel-Range Organics (mg/kg)	**10**	13
Gasoline-Range Organics (mg/kg)	10 U	13
Total Petroleum Hydrocarbons (mg/kg)	**12**	13

AGW016 (8/2/1991) 9.5 ft bgs	
Constituent	Concentration
Benzene (µg/kg)	**1.9**
Ethylbenzene (µg/kg)	**0.8 J**
Toluene (µg/kg)	**14**
Xylenes, Total (µg/kg)	**5.3**
Diesel-Range Organics (mg/kg)	10 U
Gasoline-Range Organics (mg/kg)	10 U
Total Petroleum Hydrocarbons (mg/kg)	**47**

AGW015 (8/2/1991) 9 ft bgs	
Constituent	Concentration
Benzene (µg/kg)	**0.9 M**
Ethylbenzene (µg/kg)	**0.6 J**
Toluene (µg/kg)	**7.9**
Xylenes, Total (µg/kg)	**3.8 M**
Diesel-Range Organics (mg/kg)	10 U
Gasoline-Range Organics (mg/kg)	10 U
Total Petroleum Hydrocarbons (mg/kg)	**290**

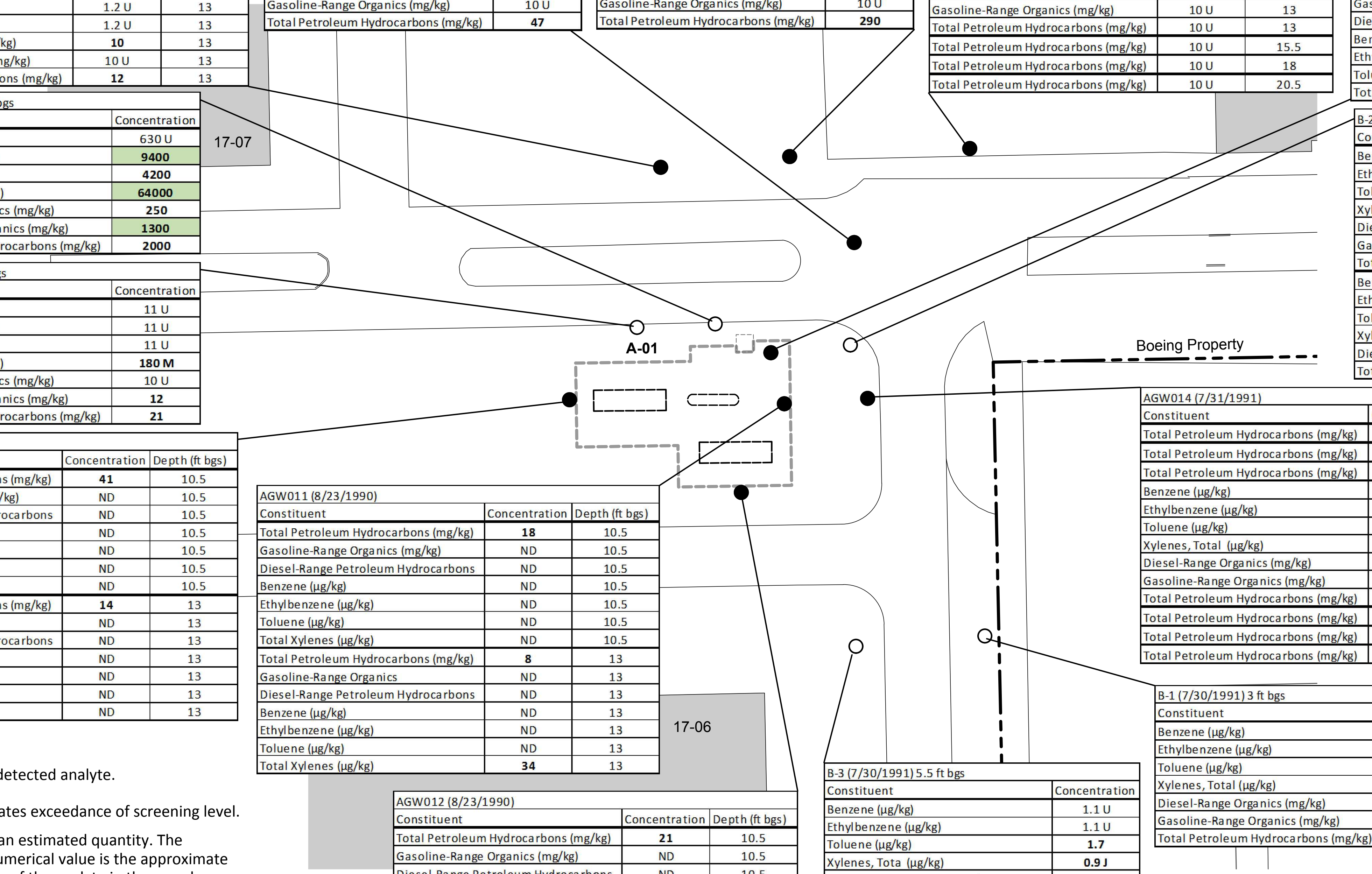
AGW013 (7/31/1991)		
Constituent	Concentration	Depth (ft bgs)
Total Petroleum Hydrocarbons (mg/kg)	10 U	3
Total Petroleum Hydrocarbons (mg/kg)	**76**	5.5
Total Petroleum Hydrocarbons (mg/kg)	**17**	8
Total Petroleum Hydrocarbons (mg/kg)	10 U	10.5
Benzene (µg/kg)	**1.4**	13
Ethylbenzene (µg/kg)	**1.6**	13
Toluene (µg/kg)	**11**	13
Xylenes, Total (µg/kg)	**9.8**	13
Diesel-Range Organics (mg/kg)	10 U	13
Gasoline-Range Organics (mg/kg)	10 U	13
Total Petroleum Hydrocarbons (mg/kg)	10 U	13
Total Petroleum Hydrocarbons (mg/kg)	10 U	15.5
Total Petroleum Hydrocarbons (mg/kg)	10 U	18
Total Petroleum Hydrocarbons (mg/kg)	10 U	20.5

AGW010 (8/23/1990)		
Constituent	Concentration	Depth (ft bgs)
Total Petroleum Hydrocarbons (mg/kg)	**21**	13
Gasoline-Range Organics (mg/kg)	ND	13
Diesel-Range Petroleum Hydrocarbons	ND	13
Benzene (µg/kg)	ND	13
Ethylbenzene (µg/kg)	ND	13
Toluene (µg/kg)	ND	13
Total Xylenes (µg/kg)	ND	13
Total Petroleum Hydrocarbons (mg/kg)	**100**	15.5
Gasoline-Range Organics	ND	15.5
Diesel-Range Petroleum Hydrocarbons	**240**	15.5
Benzene (µg/kg)	ND	15.5
Ethylbenzene (µg/kg)	**250**	15.5
Toluene (µg/kg)	**39**	15.5
Total Xylenes (µg/kg)	**1200**	15.5

B-4 (8/1/1991) 13 ft bgs	
Constituent	Concentration
Benzene (µg/kg)	630 U
Ethylbenzene (µg/kg)	**9400**
Toluene (µg/kg)	**4200**
Xylenes, Total (µg/kg)	**64000**
Diesel-Range Organics (mg/kg)	**250**
Gasoline-Range Organics (mg/kg)	**1300**
Total Petroleum Hydrocarbons (mg/kg)	**2000**

B-2 (7/30/1991)		
Constituent	Concentration	Depth (ft bgs)
Benzene (µg/kg)	1 U	10.5
Ethylbenzene (µg/kg)	1 U	10.5
Toluene (µg/kg)	1 U	10.5
Xylenes, Total (µg/kg)	2.1 U	10.5
Diesel-Range Organics (mg/kg)	10 U	10.5
Gasoline-Range Organics (mg/kg)	10 U	10.5
Total Petroleum Hydrocarbons (mg/kg)	13 U	10.5
Benzene (µg/kg)	**2.5**	15
Ethylbenzene (µg/kg)	**0.7 J**	15
Toluene (µg/kg)	**0.7 J**	15
Xylenes, Total (µg/kg)	2.2 U	15
Diesel-Range Organics (mg/kg)	10 U	15
Total Petroleum Hydrocarbons (mg/kg)	19 U	15

B-5 (8/6/1991) 7 ft bgs	
Constituent	Concentration
Benzene (µg/kg)	11 U
Ethylbenzene (µg/kg)	11 U
Toluene (µg/kg)	11 U
Xylenes, Total (µg/kg)	**180 M**
Diesel-Range Organics (mg/kg)	10 U
Gasoline-Range Organics (mg/kg)	**12**
Total Petroleum Hydrocarbons (mg/kg)	**21**



AGW014 (7/31/1991)		
Constituent	Concentration	Depth (ft bgs)
Total Petroleum Hydrocarbons (mg/kg)	**11**	3
Total Petroleum Hydrocarbons (mg/kg)	**12**	5.5
Total Petroleum Hydrocarbons (mg/kg)	10 U	8
Benzene (µg/kg)	1.2 U	13
Ethylbenzene (µg/kg)	1.2 U	13
Toluene (µg/kg)	**3.2**	13
Xylenes, Total (µg/kg)	**0.9**	13
Diesel-Range Organics (mg/kg)	10 U	13
Gasoline-Range Organics (mg/kg)	10 U	13
Total Petroleum Hydrocarbons (mg/kg)	10 U	13
Total Petroleum Hydrocarbons (mg/kg)	**11**	15.5
Total Petroleum Hydrocarbons (mg/kg)	10 U	18
Total Petroleum Hydrocarbons (mg/kg)	**11**	20.5

AGW009 (8/22/1990)		
Constituent	Concentration	Depth (ft bgs)
Total Petroleum Hydrocarbons (mg/kg)	**41**	10.5
Gasoline-Range Organics (mg/kg)	ND	10.5
Diesel-Range Petroleum Hydrocarbons	ND	10.5
Benzene (µg/kg)	ND	10.5
Ethylbenzene (µg/kg)	ND	10.5
Toluene (µg/kg)	ND	10.5
Total Xylenes (µg/kg)	ND	10.5
Total Petroleum Hydrocarbons (mg/kg)	**14**	13
Gasoline-Range Organics	ND	13
Diesel-Range Petroleum Hydrocarbons	ND	13
Benzene (µg/kg)	ND	13
Ethylbenzene (µg/kg)	ND	13
Toluene (µg/kg)	ND	13
Total Xylenes (µg/kg)	ND	13

AGW011 (8/23/1990)		
Constituent	Concentration	Depth (ft bgs)
Total Petroleum Hydrocarbons (mg/kg)	**18**	10.5
Gasoline-Range Organics (mg/kg)	ND	10.5
Diesel-Range Petroleum Hydrocarbons	ND	10.5
Benzene (µg/kg)	ND	10.5
Ethylbenzene (µg/kg)	ND	10.5
Toluene (µg/kg)	ND	10.5
Total Xylenes (µg/kg)	ND	10.5
Total Petroleum Hydrocarbons (mg/kg)	**8**	13
Gasoline-Range Organics	ND	13
Diesel-Range Petroleum Hydrocarbons	ND	13
Benzene (µg/kg)	ND	13
Ethylbenzene (µg/kg)	ND	13
Toluene (µg/kg)	ND	13
Total Xylenes (µg/kg)	**34**	13

B-1 (7/30/1991) 3 ft bgs	
Constituent	Concentration
Benzene (µg/kg)	1.1 U
Ethylbenzene (µg/kg)	1.1 U
Toluene (µg/kg)	**12**
Xylenes, Total (µg/kg)	**3.1**
Diesel-Range Organics (mg/kg)	10 U
Gasoline-Range Organics (mg/kg)	10 U
Total Petroleum Hydrocarbons (mg/kg)	29 U

B-3 (7/30/1991) 5.5 ft bgs	
Constituent	Concentration
Benzene (µg/kg)	1.1 U
Ethylbenzene (µg/kg)	1.1 U
Toluene (µg/kg)	**1.7**
Xylenes, Tota (µg/kg)	**0.9 J**
Diesel-Range Organics (mg/kg)	10 U
Gasoline-Range Organics (mg/kg)	10 U
Total Petroleum Hydrocarbons (mg/kg)	37 U

AGW012 (8/23/1990)		
Constituent	Concentration	Depth (ft bgs)
Total Petroleum Hydrocarbons (mg/kg)	**21**	10.5
Gasoline-Range Organics (mg/kg)	ND	10.5
Diesel-Range Petroleum Hydrocarbons	ND	10.5
Benzene (µg/kg)	ND	10.5
Ethylbenzene (µg/kg)	ND	10.5
Toluene (µg/kg)	ND	10.5
Total Xylenes (µg/kg)	**48**	10.5
Total Petroleum Hydrocarbons (mg/kg)	**40**	13
Gasoline-Range Organics	ND	13
Diesel-Range Petroleum Hydrocarbons	ND	13
Benzene (µg/kg)	ND	13
Ethylbenzene (µg/kg)	ND	13
Toluene (µg/kg)	ND	13
Total Xylenes (µg/kg)	ND	13

Legend

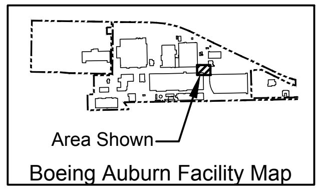
AGW016 ●	Monitoring Well Location and Designation
B-5 ○	Pre-RI Sample Boring Location and Designation (Locations are Approximate)
17-06	Current Building and Number
⊂ – – ⊃	Former Fuel Island Location
[– –]	Former 10,000 Gallon Underground Storage Tank Location
[– –]	1990 Excavation Area
⬚	2004 Excavation Area

Detected Analyte	Screening Level
VOLATILES (µg/kg)	
Benzene	4.48
Ethylbenzene	6,048
Toluene	4,654
Xylenes, Total	14,630
PETROLEUM HYDROCARBONS (mg/kg)	
Diesel-Range Organics	2,000 (b)
Gasoline-Range Organics	100 (b,c)
Total Petroleum Hydrocarbons	NA

Notes

1. **Bold** text indicates detected analyte.
2. Green shading indicates exceedance of screening level.

J = The result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample.
M = Indicates an estimated value of analyte found and confirmed by analyst but with low spectral match.
µg/kg = micrograms per kilogram
mg/kg = milligrams per kilogram
ND = The analyte was analyzed for, but was not detected
U = The analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit.



Boeing Auburn Facility Map

N
0 50 100
Scale in Feet

Base map source: Geomatrix 2003

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Boeing Auburn
Auburn, Washington

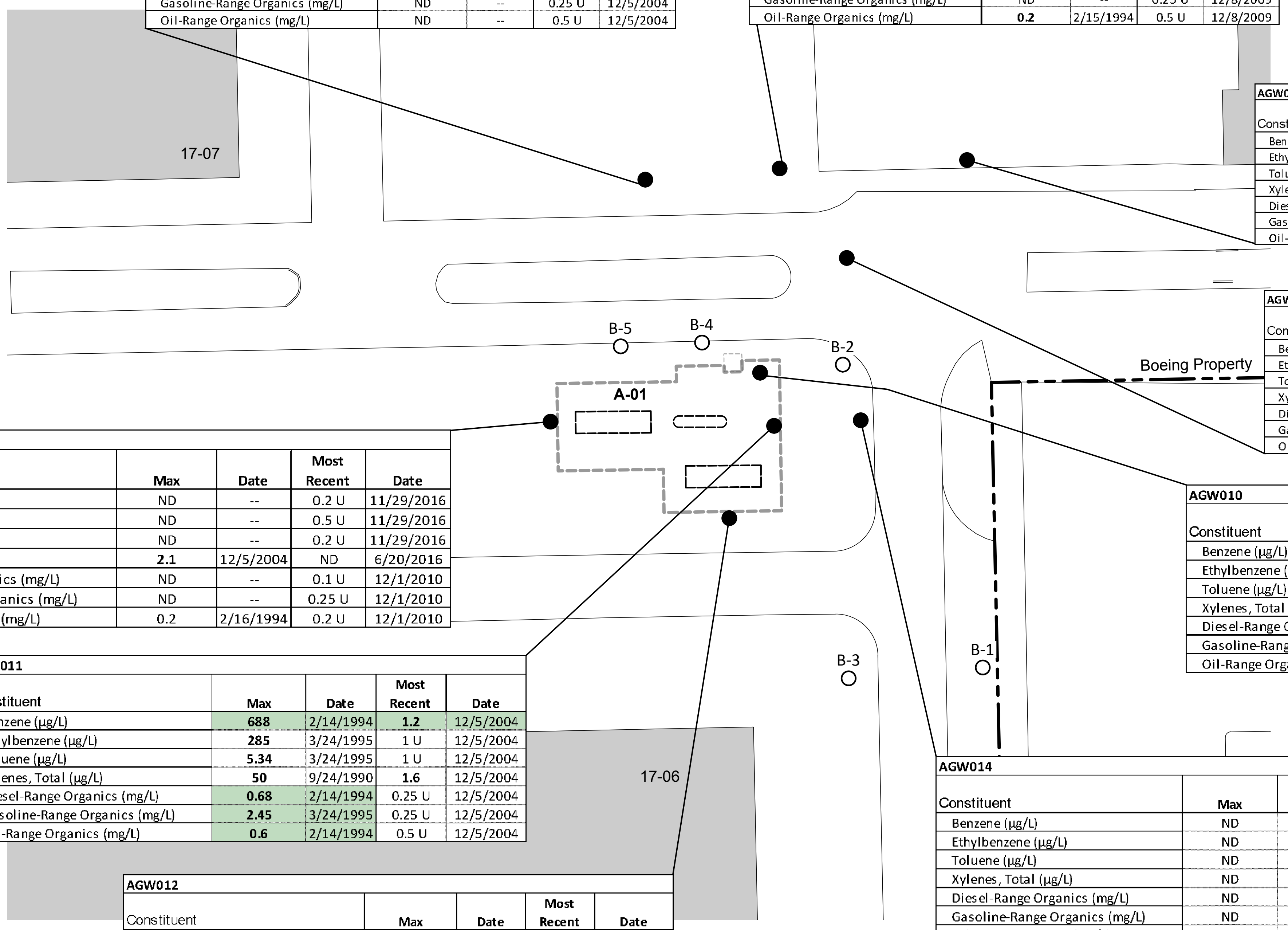
AOC A-01: Soil Detections for Petroleum Hydrocarbon Constituents

Figure
8

Legend

AGW016 ●	Monitoring Well Location and Designation
B-5 ○	Pre-RI Sample Boring Location and Designation (Locations are Approximate)
17-06	Current Building and Number
	Former Fuel Island Location
	Former 10,000 Gallon Underground Storage Tank Location
	1990 Excavation Area
	2004 Excavation Area

Detected Analyte	Screening Level
VOLATILES (µg/L)	
Benzene	0.80
Ethylbenzene	700
Toluene	640
Xylenes, Total	1600
PETROLEUM HYDROCARBONS (mg/L)	
Diesel-Range Organics	0.50
Gasoline-Range Organics	0.80
Total Petroleum Hydrocarbons	0.50



AGW017

Constituent	Max	Date	Most Recent	Date
Benzene (µg/L)	ND	--	0.2 U	6/9/2009
Ethylbenzene (µg/L)	ND	--	0.2 U	6/9/2009
Toluene (µg/L)	ND	--	0.2 U	6/9/2009
Xylenes, Total (µg/L)	ND	--	ND	6/9/2009
Diesel-Range Organics (mg/L)	ND	--	0.25 U	12/5/2004
Gasoline-Range Organics (mg/L)	ND	--	0.25 U	12/5/2004
Oil-Range Organics (mg/L)	ND	--	0.5 U	12/5/2004

AGW015

Constituent	Max	Date	Most Recent	Date
Benzene (µg/L)	**1.6**	10/1/1996	0.2 U	6/9/2009
Ethylbenzene (µg/L)	**7.6**	12/5/2006	0.2 U	6/9/2009
Toluene (µg/L)	**1.6**	3/20/1997	0.2 U	6/9/2009
Xylenes, Total (µg/L)	**23.4**	12/5/2006	ND	6/9/2009
Diesel-Range Organics (mg/L)	**0.59**	12/5/2004	0.25 U	12/8/2009
Gasoline-Range Organics (mg/L)	ND	--	0.25 U	12/8/2009
Oil-Range Organics (mg/L)	**0.2**	2/15/1994	0.5 U	12/8/2009

AGW013

Constituent	Max	Date	Most Recent	Date
Benzene (µg/L)	ND	--	1 U	12/5/2004
Ethylbenzene (µg/L)	ND	--	1 U	12/5/2004
Toluene (µg/L)	ND	--	1 U	12/5/2004
Xylenes, Total (µg/L)	ND	--	ND	12/5/2004
Diesel-Range Organics (mg/L)	ND	--	0.25 U	12/5/2004
Gasoline-Range Organics (mg/L)	ND	--	0.25 U	12/5/2004
Oil-Range Organics (mg/L)	**0.1**	2/16/1994	0.5 U	12/5/2004

AGW016

Constituent	Max	Date	Most Recent	Date
Benzene (µg/L)	**24.98**	2/15/1994	1 U	12/5/2004
Ethylbenzene (µg/L)	**49.54**	2/15/1994	1 U	12/5/2004
Toluene (µg/L)	**0.3**	9/4/1998	1 U	12/5/2004
Xylenes, Total (µg/L)	**160**	8/8/1991	ND	12/5/2004
Diesel-Range Organics (mg/L)	**0.59**	2/15/1994	0.25 U	12/5/2004
Gasoline-Range Organics (mg/L)	**2.07**	2/15/1994	0.25 U	12/5/2004
Oil-Range Organics (mg/L)	**0.4**	2/15/1994	0.5 U	12/5/2004

AGW009

Constituent	Max	Date	Most Recent	Date
Benzene (µg/L)	ND	--	0.2 U	11/29/2016
Ethylbenzene (µg/L)	ND	--	0.5 U	11/29/2016
Toluene (µg/L)	ND	--	0.2 U	11/29/2016
Xylenes, Total (µg/L)	**2.1**	12/5/2004	ND	6/20/2016
Diesel-Range Organics (mg/L)	ND	--	0.1 U	12/1/2010
Gasoline-Range Organics (mg/L)	ND	--	0.25 U	12/1/2010
Oil-Range Organics (mg/L)	0.2	2/16/1994	0.2 U	12/1/2010

AGW010

Constituent	Max	Date	Most Recent	Date
Benzene (µg/L)	**5250**	3/24/1995	2.0 U	11/29/2016
Ethylbenzene (µg/L)	**3600**	12/5/2004	**630**	11/26/2016
Toluene (µg/L)	**15000**	9/12/1997	**5.9**	11/29/2016
Xylenes, Total (µg/L)	**19000**	8/30/1993	**526**	42703.512
Diesel-Range Organics (mg/L)	**18.7**	3/24/1995	**0.53**	11/29/2016
Gasoline-Range Organics (mg/L)	**120 J**	8/26/1999	**10**	11/29/2016
Oil-Range Organics (mg/L)	**276**	3/24/1995	0.24 U	11/29/2016

AGW011

Constituent	Max	Date	Most Recent	Date
Benzene (µg/L)	**688**	2/14/1994	**1.2**	12/5/2004
Ethylbenzene (µg/L)	**285**	3/24/1995	1 U	12/5/2004
Toluene (µg/L)	**5.34**	3/24/1995	1 U	12/5/2004
Xylenes, Total (µg/L)	**50**	9/24/1990	**1.6**	12/5/2004
Diesel-Range Organics (mg/L)	**0.68**	2/14/1994	0.25 U	12/5/2004
Gasoline-Range Organics (mg/L)	**2.45**	3/24/1995	0.25 U	12/5/2004
Oil-Range Organics (mg/L)	**0.6**	2/14/1994	0.5 U	12/5/2004

AGW014

Constituent	Max	Date	Most Recent	Date
Benzene (µg/L)	ND	--	1 U	12/5/2004
Ethylbenzene (µg/L)	ND	--	1 U	12/5/2004
Toluene (µg/L)	ND	--	1 U	12/5/2004
Xylenes, Total (µg/L)	ND	--	ND	12/5/2004
Diesel-Range Organics (mg/L)	ND	--	0.25 U	12/5/2004
Gasoline-Range Organics (mg/L)	ND	--	0.25 U	12/5/2004
Oil-Range Organics (mg/L)	**0.2**	2/14/1994	0.5 U	12/5/2004

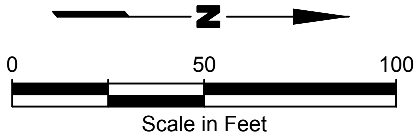
AGW012

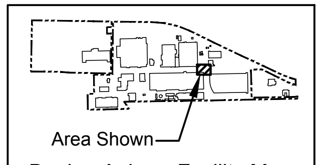
Constituent	Max	Date	Most Recent	Date
Benzene (µg/L)	ND	--	1 U	12/5/2004
Ethylbenzene (µg/L)	ND	--	1 U	12/5/2004
Toluene (µg/L)	**1.3**	3/26/1996	1 U	12/5/2004
Xylenes, Total (µg/L)	**1.4**	3/26/1996	ND	12/5/2004
Diesel-Range Organics (mg/L)	**0.37**	2/14/1994	0.25 U	12/5/2004
Gasoline-Range Organics (mg/L)	ND	--	0.25 U	12/5/2004
Oil-Range Organics (mg/L)	**0.1**	2/14/1994	0.5 U	12/5/2004

Note

1. Monitoring well results presented are maximum concentration detected above the level of the reported sample quantitation limit.
2. **Bold** text indicates detected analyte.
3. Green shading indicates exceedance of screening level.
4. Monitoring well results presented are maximum concentration detected and most recent concentration detected (as of December 2016).

-- = Not analyzed or not applicable
J = The result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample.
µg/kg = micrograms per kilogram
mg/kg = milligrams per kilogram
ND = The analyte was analyzed for, but was not detected
U = The analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit.





Boeing Auburn Facility Map

Base map source: Geomatrix 2003

LANDAU ASSOCIATES

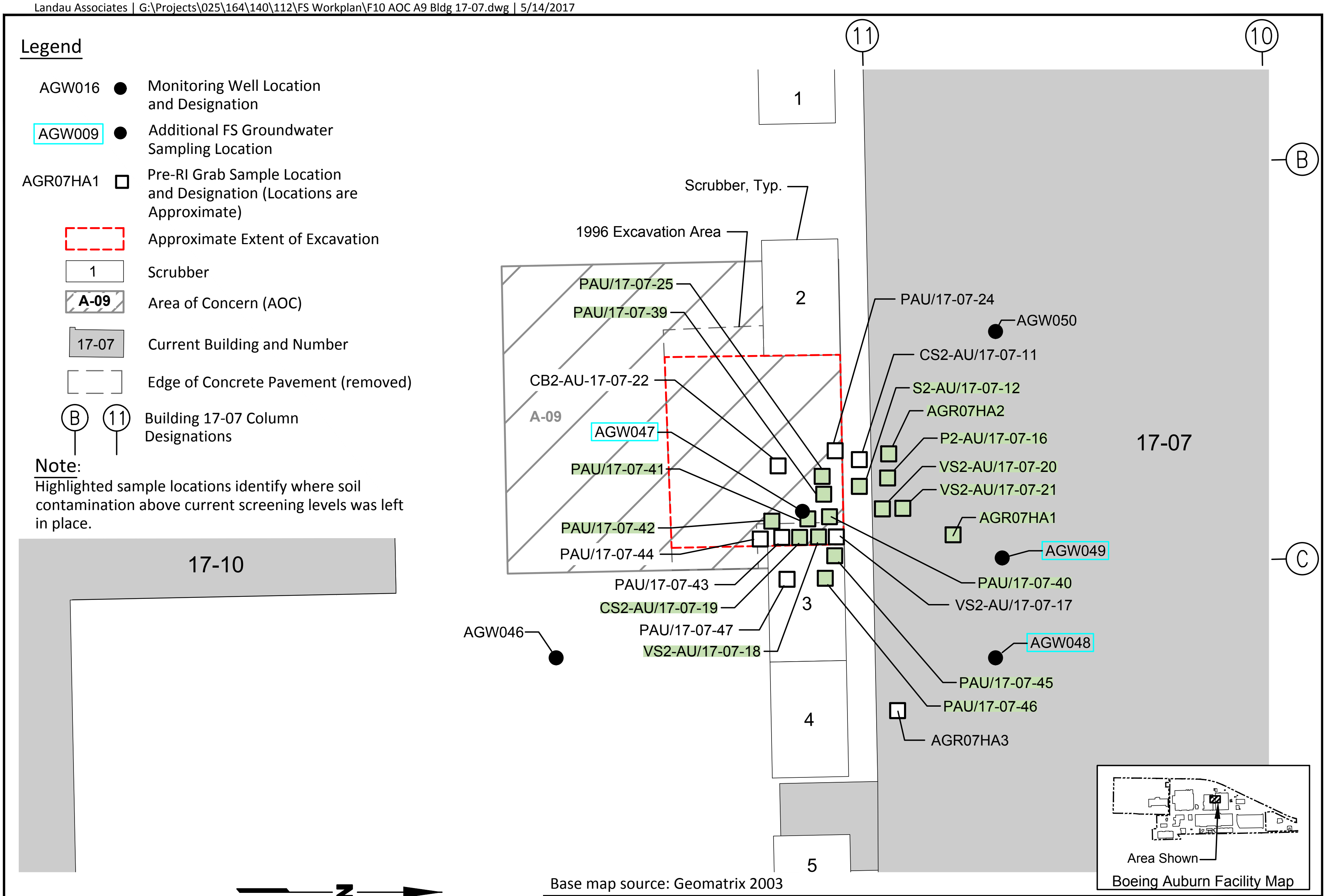
Boeing Auburn
Auburn, Washington

AOC A-01: Maximum and Most Recent Groundwater Detections for Petroleum Hydrocarbon Constituents

Figure 9

Landau Associates | G:\Projects\025\164\140\112\FS Workplan\F09 AOC A-01Max&MostRecentGroundwaterBTEX&PetroleumHydrocarbons.dwg | 5/14/2017

Landau Associates | G:\Projects\025\164\140\112\FS Workplan\F10 AOC A9 Bldg 17-07.dwg | 5/14/2017



Note:
Highlighted sample locations identify where soil contamination above current screening levels was left in place.

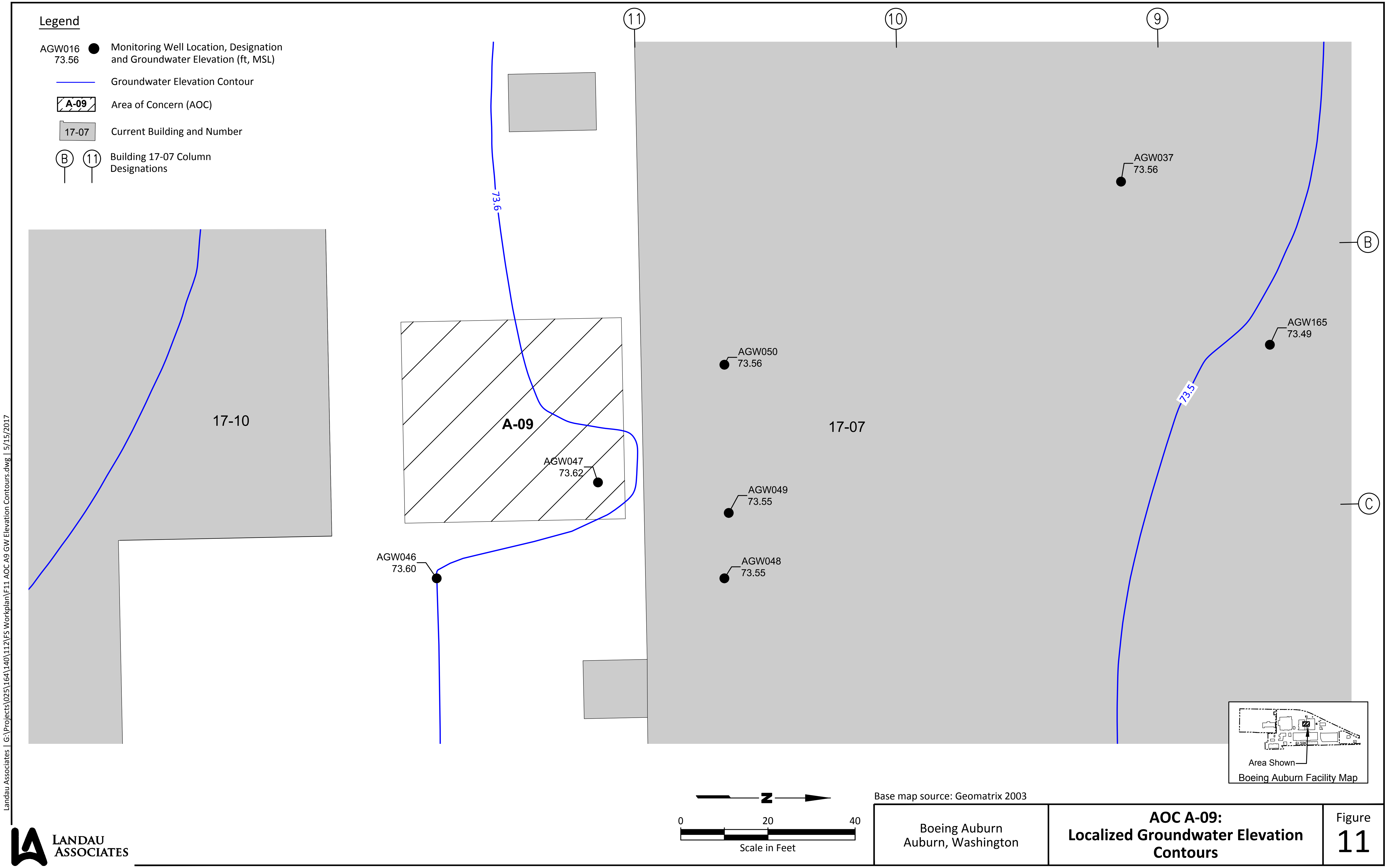
Base map source: Geomatrix 2003

Landau Associates

Boeing Auburn
Auburn, Washington

AOC A-09: Building 17-07
Acid Scrubber Drain Line Leak

Figure
10



Base map source: Geomatrix 2003

Landau Associates | G:\Projects\025\164\140\112\FS Workplan\F11 AOC A9 GW Elevation Contours.dwg | 5/15/2017

LANDAU ASSOCIATES

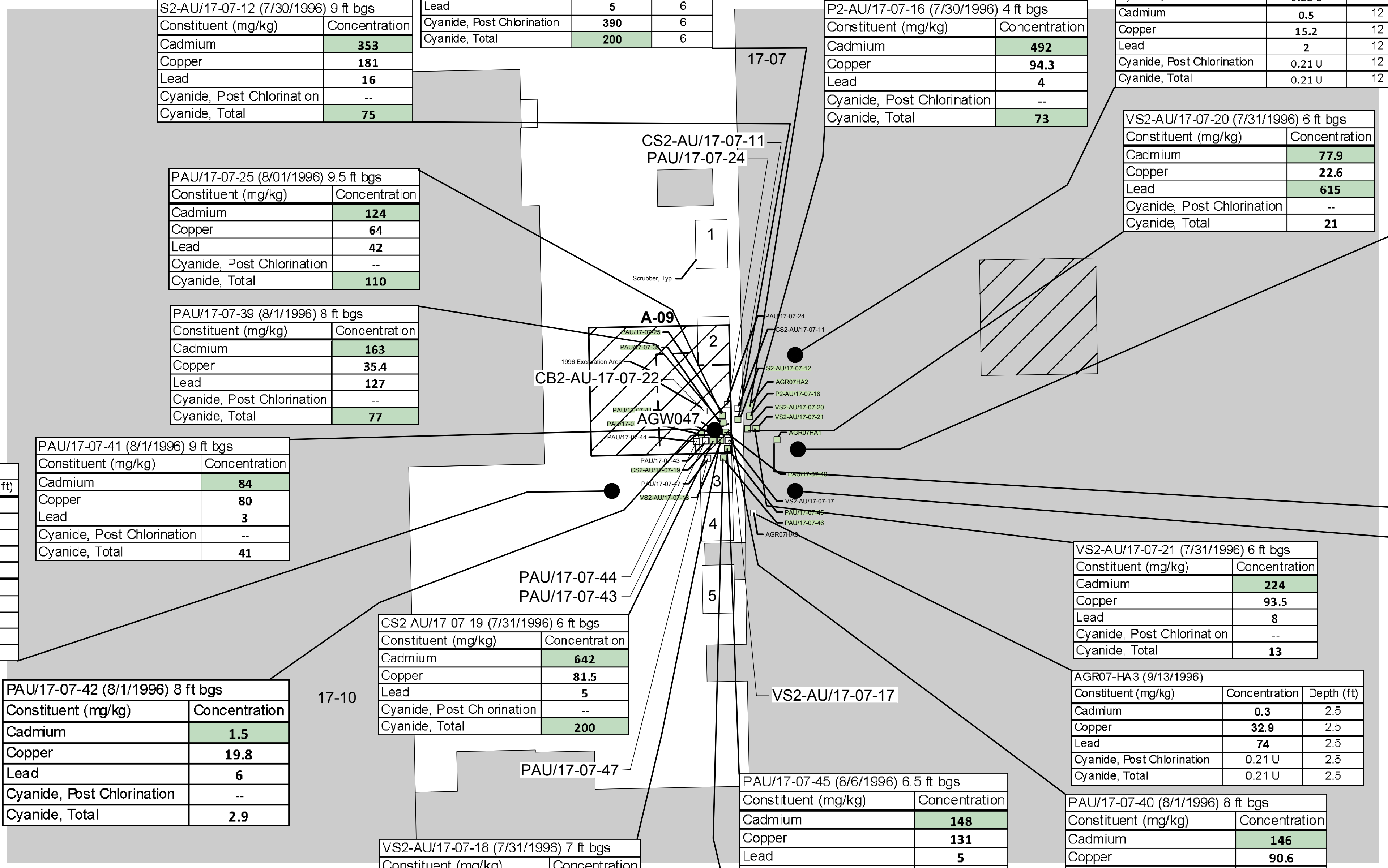
Boeing Auburn
Auburn, Washington

AOC A-09:
Localized Groundwater Elevation Contours

Figure
11

Legend

AGW016 ●	Monitoring Well Location and Designation
AGR08-AU18-EW1 □	Pre-RI Grab Sample Location and Designation (Locations are Approximate)
5	Scrubber
A-09 ▨	Area of Concern (AOC)
17-07	Current Building and Number
┌ ┐	Excavation Area 1996



AGR07-HA2 (9/13/1996)

Constituent (mg/kg)	Concentration	Depth (ft)
Cadmium	**0.3**	3.75
Copper	**21.9**	3.75
Lead	**5**	3.75
Cyanide, Post Chlorination	**1.9**	3.75
Cyanide, Total	**1.6**	3.75
Cadmium	0.2 U	6
Copper	**385**	6
Lead	**5**	6
Cyanide, Post Chlorination	**390**	6
Cyanide, Total	**200**	6

S2-AU/17-07-12 (7/30/1996) 9 ft bgs

Constituent (mg/kg)	Concentration
Cadmium	**353**
Copper	**181**
Lead	**16**
Cyanide, Post Chlorination	--
Cyanide, Total	**75**

P2-AU/17-07-16 (7/30/1996) 4 ft bgs

Constituent (mg/kg)	Concentration
Cadmium	**492**
Copper	**94.3**
Lead	**4**
Cyanide, Post Chlorination	--
Cyanide, Total	**73**

AGW050 (9/12/1996)

Constituent (mg/kg)	Concentration	Depth (ft)
Cadmium	**0.3**	5
Copper	**17.2**	5
Lead	**4**	5
Cyanide, Post Chlorination	**0.38**	5
Cyanide, Total	0.22 U	5
Cadmium	**0.5**	12
Copper	**15.2**	12
Lead	**2**	12
Cyanide, Post Chlorination	0.21 U	12
Cyanide, Total	0.21 U	12

AGW049 (9/13/1996)

Constituent (mg/kg)	Concentration	Depth (ft)
Cadmium	0.2 U	2
Copper	**19.4**	2
Lead	**6**	2
Cyanide, Post Chlorination	0.21 U	2
Cyanide, Total	0.2 U	2
Cadmium	**37.8**	7.5
Copper	**242**	7.5
Lead	**5**	7.5
Cyanide, Post Chlorination	**530**	7.5
Cyanide, Total	**350**	7.5
Cadmium	**0.5**	10
Copper	**619**	10
Lead	**5**	10
Cyanide, Post Chlorination	**21**	10
Cyanide, Total	**19**	10
Cadmium	0.2 U	12.5
Copper	**123**	12.5
Lead	2 U	12.5
Cyanide, Post Chlorination	**1.7**	12.5
Cyanide, Total	**0.53**	12.5

PAU/17-07-25 (8/01/1996) 9.5 ft bgs

Constituent (mg/kg)	Concentration
Cadmium	**124**
Copper	**64**
Lead	**42**
Cyanide, Post Chlorination	--
Cyanide, Total	**110**

VS2-AU/17-07-20 (7/31/1996) 6 ft bgs

Constituent (mg/kg)	Concentration
Cadmium	**77.9**
Copper	**22.6**
Lead	**615**
Cyanide, Post Chlorination	--
Cyanide, Total	**21**

AGR07-HA1 (9/12/1996)

Constituent (mg/kg)	Concentration	Depth (ft)
Cadmium	0.2 U	1
Copper	**19.2**	1
Lead	**6**	1
Cyanide, Post Chlorination	**1.4**	1
Cyanide, Total	0.21 U	1
Cadmium	0.2 U	3
Copper	**26.5**	3
Lead	**5**	3
Cyanide, Post Chlorination	**0.36**	3
Cyanide, Total	0.21 U	3
Cadmium	**248**	6.5
Copper	**378**	6.5
Lead	2 U	6.5
Cyanide, Post Chlorination	**89**	6.5
Cyanide, Total	**62**	6.5

PAU/17-07-39 (8/1/1996) 8 ft bgs

Constituent (mg/kg)	Concentration
Cadmium	**163**
Copper	**35.4**
Lead	**127**
Cyanide, Post Chlorination	--
Cyanide, Total	**77**

PAU/17-07-41 (8/1/1996) 9 ft bgs

Constituent (mg/kg)	Concentration
Cadmium	**84**
Copper	**80**
Lead	**3**
Cyanide, Post Chlorination	--
Cyanide, Total	**41**

AGW046 (9/13/1996)

Constituent (mg/kg)	Concentration	Depth (ft)
Cadmium	0.2 U	5
Copper	**12.4**	5
Lead	**5**	5
Cyanide, Post Chlorination	**0.86**	5
Cyanide, Total	0.23 U	5
Cadmium	0.2 U	15
Copper	**11.6**	15
Lead	**3**	15
Cyanide, Post Chlorination	0.23 U	15
Cyanide, Total	0.24 U	15

AGW048 (9/13/1996)

Constituent (mg/kg)	Concentration	Depth (ft)
Cadmium	0.2 U	5
Copper	**20.3**	5
Lead	**6**	5
Cyanide, Post Chlorination	**0.33**	5
Cyanide, Total	0.22 U	5
Cadmium	**0.3**	15
Copper	**11.8**	15
Lead	2 U	15
Cyanide, Post Chlorination	**0.7**	15
Cyanide, Total	**0.76**	15

VS2-AU/17-07-21 (7/31/1996) 6 ft bgs

Constituent (mg/kg)	Concentration
Cadmium	**224**
Copper	**93.5**
Lead	**8**
Cyanide, Post Chlorination	--
Cyanide, Total	**13**

CS2-AU/17-07-19 (7/31/1996) 6 ft bgs

Constituent (mg/kg)	Concentration
Cadmium	**642**
Copper	**81.5**
Lead	**5**
Cyanide, Post Chlorination	--
Cyanide, Total	**200**

AGR07-HA3 (9/13/1996)

Constituent (mg/kg)	Concentration	Depth (ft)
Cadmium	**0.3**	2.5
Copper	**32.9**	2.5
Lead	**74**	2.5
Cyanide, Post Chlorination	0.21 U	2.5
Cyanide, Total	0.21 U	2.5

PAU/17-07-42 (8/1/1996) 8 ft bgs

Constituent (mg/kg)	Concentration
Cadmium	**1.5**
Copper	**19.8**
Lead	**6**
Cyanide, Post Chlorination	--
Cyanide, Total	**2.9**

PAU/17-07-45 (8/6/1996) 6.5 ft bgs

Constituent (mg/kg)	Concentration
Cadmium	**148**
Copper	**131**
Lead	**5**
Cyanide, Post Chlorination	--
Cyanide, Total	**5.3**

PAU/17-07-40 (8/1/1996) 8 ft bgs

Constituent (mg/kg)	Concentration
Cadmium	**146**
Copper	**90.6**
Lead	**11**
Cyanide, Post Chlorination	--
Cyanide, Total	**28**

VS2-AU/17-07-18 (7/31/1996) 7 ft bgs

Constituent (mg/kg)	Concentration
Cadmium	**169**
Copper	**108**
Lead	**6**
Cyanide, Post Chlorination	--
Cyanide, Total	**16**

PAU/17-07-46 (8/6/1996) 7 ft bgs

Constituent (mg/kg)	Concentration
Cadmium	**15**
Copper	**102**
Lead	**8**
Cyanide, Post Chlorination	--
Cyanide, Total	**18**

Notes

1. **Bold** text indicates detected analyte.
2. Green Shading indicates exceedance of screening level.

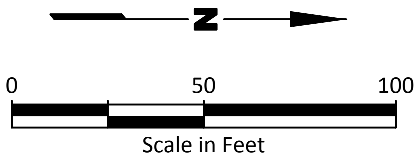
mg/kg = milligrams per kilogram

U = The analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit.

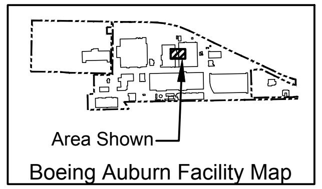
NA = Not Applicable

-- = Not analyzed

Constituant	Screening Level (mg/kg)
Cadmium	1
Copper	284
Lead	250
Cyanide, Post Chlorination	NA
Cyanide, Total	48



Base map source: Geomatrix 2003



Boeing Auburn Facility Map

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LANDAU ASSOCIATES

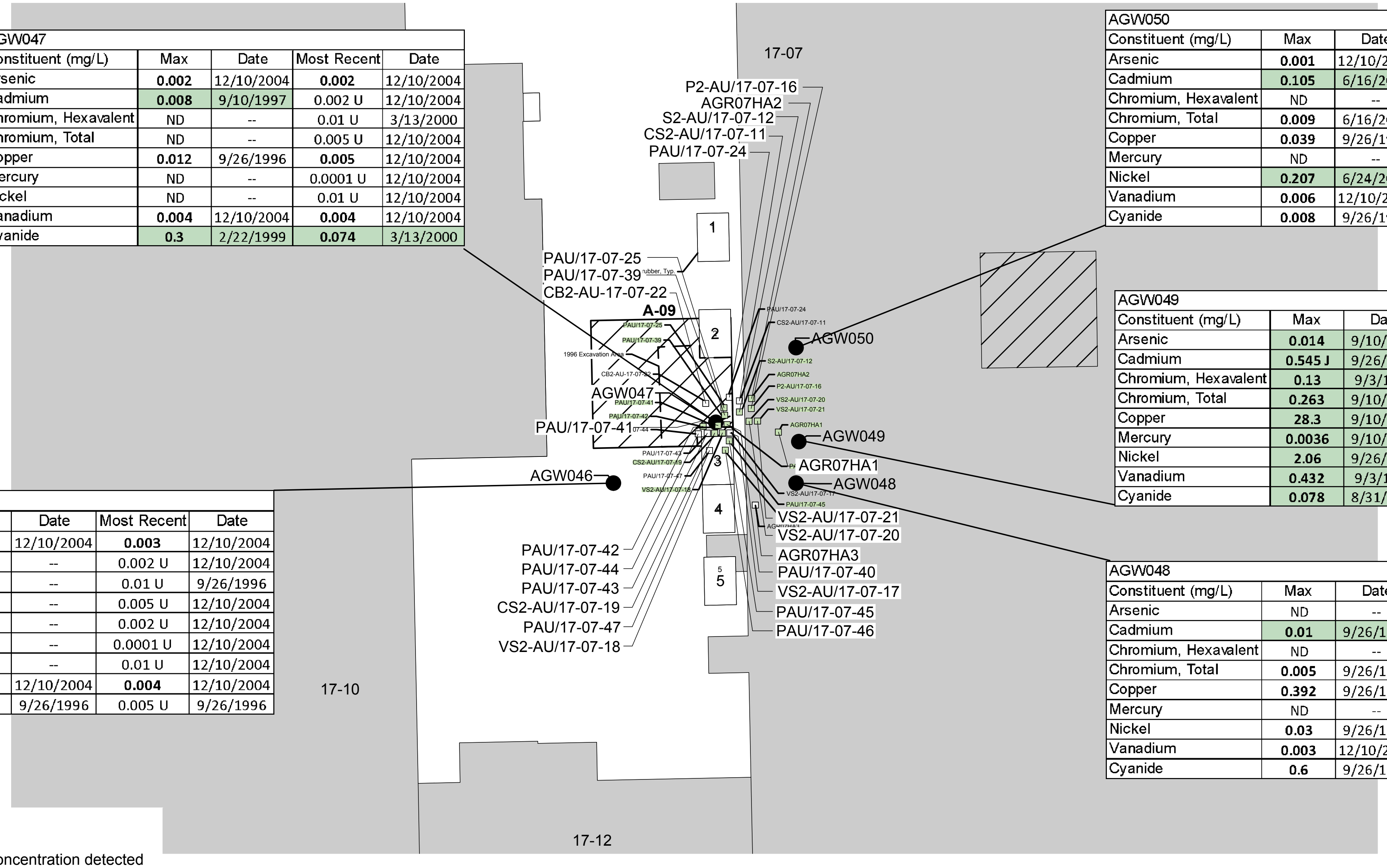
Boeing Auburn
Auburn, Washington

AOC A-09: Soil Detections for Metals and Cyanide

Figure
12

Legend

AGW016 ●	Monitoring Well Location and Designation
AGR08-AU18-EW1 ☐	Pre-RI Grab Sample Location and Designation (Locations are Approximate)
5	Scrubber
A-09 ▨	Area of Concern (AOC)
17-07	Current Building and Number
⌜ ⌝	1996 Excavation Area



AGW047				
Constituent (mg/L)	Max	Date	Most Recent	Date
Arsenic	**0.002**	12/10/2004	**0.002**	12/10/2004
Cadmium	**0.008**	9/10/1997	0.002 U	12/10/2004
Chromium, Hexavalent	ND	--	0.01 U	3/13/2000
Chromium, Total	ND	--	0.005 U	12/10/2004
Copper	**0.012**	9/26/1996	**0.005**	12/10/2004
Mercury	ND	--	0.0001 U	12/10/2004
Nickel	ND	--	0.01 U	12/10/2004
Vanadium	**0.004**	12/10/2004	**0.004**	12/10/2004
Cyanide	**0.3**	2/22/1999	**0.074**	3/13/2000

AGW050				
Constituent (mg/L)	Max	Date	Most Recent	Date
Arsenic	**0.001**	12/10/2004	**0.001**	12/10/2004
Cadmium	**0.105**	6/16/2011	**0.0162**	11/29/2016
Chromium, Hexavalent	ND	--	0.01 U	9/26/1996
Chromium, Total	**0.009**	6/16/2004	**0.008**	12/10/2004
Copper	**0.039**	9/26/1996	**0.021**	12/10/2004
Mercury	ND	--	0.0001 U	12/10/2004
Nickel	**0.207**	6/24/2014	**0.0164**	11/29/2016
Vanadium	**0.006**	12/10/2004	**0.006**	12/10/2004
Cyanide	**0.008**	9/26/1996	**0.008**	9/26/1996

AGW049				
Constituent (mg/L)	Max	Date	Most Recent	Date
Arsenic	**0.014**	9/10/1997	**0.003**	12/10/2004
Cadmium	**0.545 J**	9/26/1996	**0.0124**	11/29/2016
Chromium, Hexavalent	**0.13**	9/3/1998	0.5 U	3/13/2000
Chromium, Total	**0.263**	9/10/1997	**0.007**	12/10/2004
Copper	**28.3**	9/10/1997	**1.47**	12/10/2004
Mercury	**0.0036**	9/10/1997	**0.0002**	12/10/2004
Nickel	**2.06**	9/26/1996	**0.0667**	11/29/2016
Vanadium	**0.432**	9/3/1998	**0.026**	12/10/2004
Cyanide	**0.078**	8/31/1999	**0.022**	3/13/2000

AGW046				
Constituent (mg/L)	Max	Date	Most Recent	Date
Arsenic	**0.003**	12/10/2004	**0.003**	12/10/2004
Cadmium	ND	--	0.002 U	12/10/2004
Chromium, Hexavalent	ND	--	0.01 U	9/26/1996
Chromium, Total	ND	--	0.005 U	12/10/2004
Copper	ND	--	0.002 U	12/10/2004
Mercury	ND	--	0.0001 U	12/10/2004
Nickel	ND	--	0.01 U	12/10/2004
Vanadium	**0.004**	12/10/2004	**0.004**	12/10/2004
Cyanide	0.005 U	9/26/1996	0.005 U	9/26/1996

AGW048				
Constituent (mg/L)	Max	Date	Most Recent	Date
Arsenic	ND	--	0.001 U	12/10/2004
Cadmium	**0.01**	9/26/1996	**0.0012**	6/16/2016
Chromium, Hexavalent	ND	--	0.01 U	9/26/1996
Chromium, Total	**0.005**	9/26/1996	0.005 U	12/10/2004
Copper	**0.392**	9/26/1996	**0.01**	12/10/2004
Mercury	ND	--	0.0001 U	12/10/2004
Nickel	**0.03**	9/26/1996	**0.0021**	6/16/2016
Vanadium	**0.003**	12/10/2004	**0.003**	12/10/2004
Cyanide	**0.6**	9/26/1996	**0.6**	9/26/1996

Notes

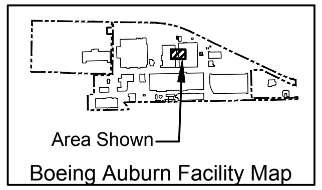
1. Monitoring well results presented are maximum concentration detected and most recent concentration detected (as of December 2016).

2. **Bold** text indicates detected analyte.

3. Green shading indicates exceedance of screening level.

-- = not analyzed or not applicable
J = The result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample.
mg/L = milligrams per liter
ND = The analyte was analyzed for, but was not detected.
U = The analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit.

Constituant	Screening Level (mg/L)
Arsenic	0.008
Cadmium	0.005
Chromium, Hexavalent	0.048
Chromium, Total	0.1
Copper	0.64
Mercury	0.002
Nickel	0.1
Vanadium	0.08
Cyanide	0.0096



Boeing Auburn Facility Map

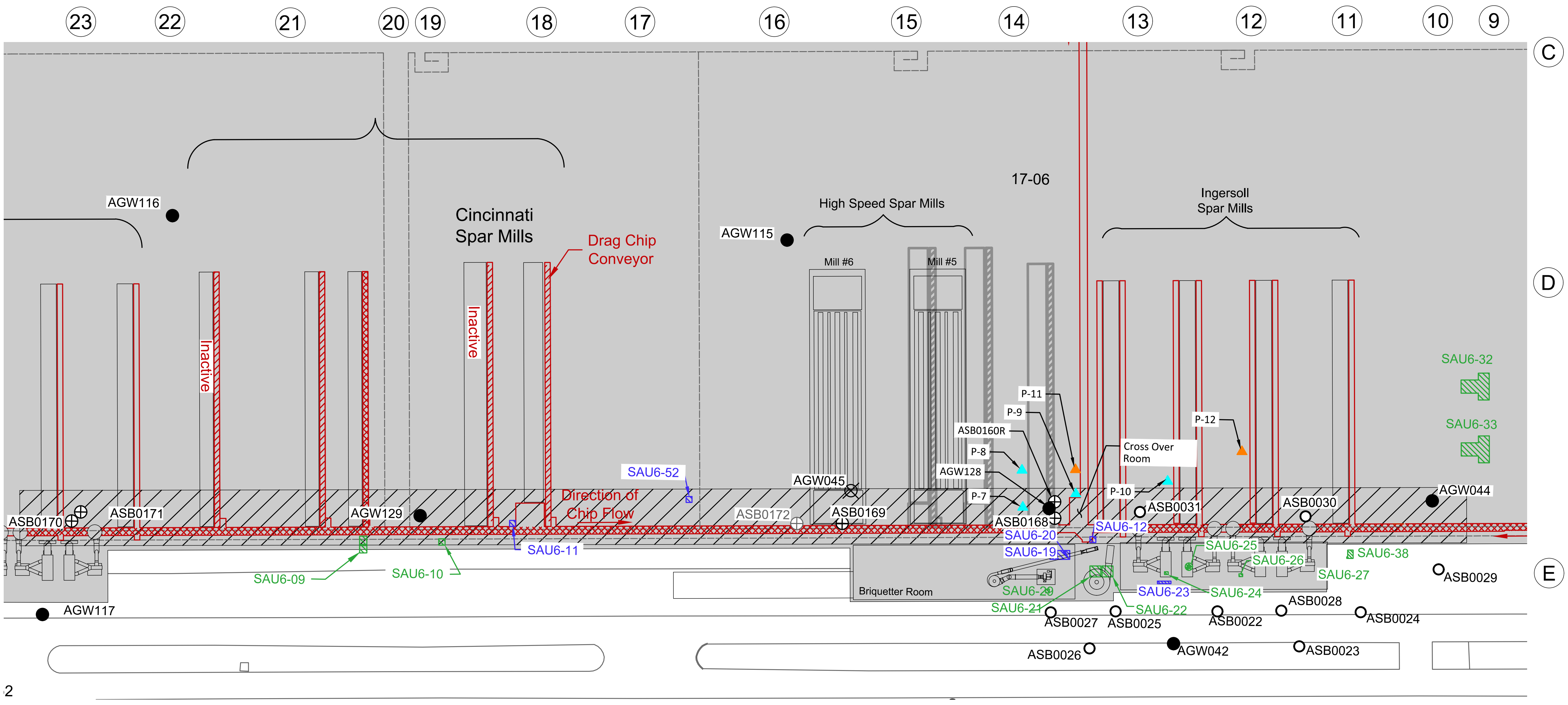
Base map source: Geomatrix 2003

LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

AOC A-09: Groundwater Detections for Metals and Cyanide

Figure
13



Legend

AGW016 73.21	●	Monitoring Well Location, Designation and Groundwater Elevation
ASB0149	⊕	Soil Boring Location and Designation
AGW045	⊠	Abandoned Monitoring Well Location and Designation
ASB0089	○	Pre-RI Sample Boring Location and Designation (Locations are Approximate)
	▲	Proposed Soil Boring Location
	▲	Proposed Contingent Soil Boring Location
	Ⓒ ④	Building 17-06 Column Designations
	═	Pneumatic or Jet Stream Type Conveyor
	▩	Push Bar Type Conveyor
	▨	Drag Type Conveyor
	A-13	Area of Concern (AOC)
	17-06	Current Building and Number
SAU6-34	▨	Chip runoff Sump Location and Designation
SAU6-34	▨	Water Sump Location and Designation (Cooling water, Storm/Rain water, Condensate)

Note

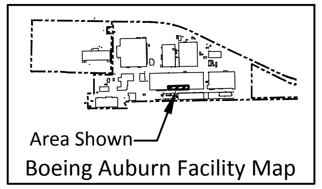
1. Up to two boring locations will be converted to permanent monitoring wells, identified as A(S) and B(S) in this work plan.

N

0 60 120

Scale in Feet

Base map source: Geomatrix 2003a



Boeing Auburn Facility Map

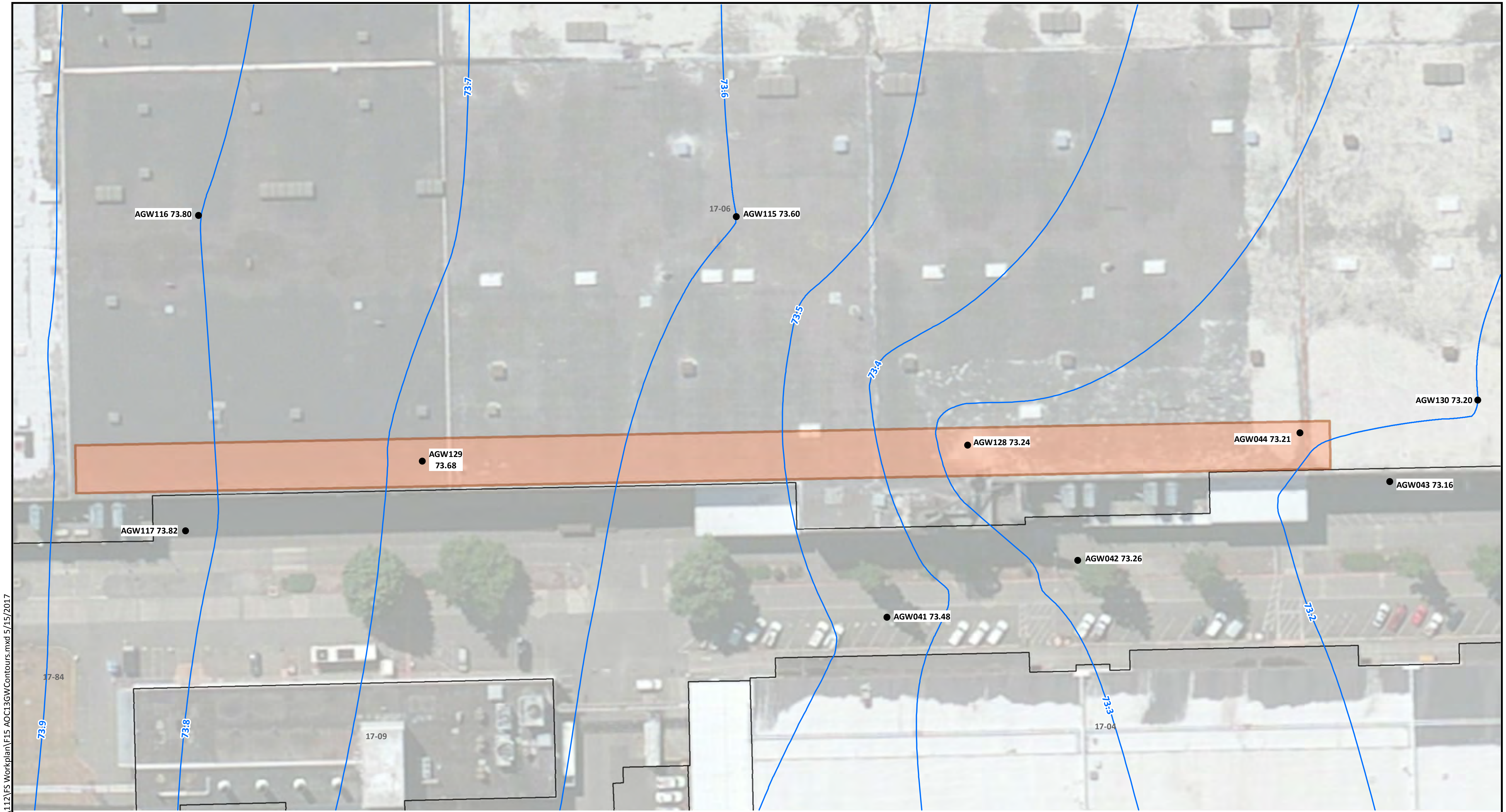
LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

AOC A-13:
Petroleum Hydrocarbon Contamination on East Side of Building 17-06

Figure
14

Landau Associates | G:\Projects\025\164\140\112\FS Workplan\F14 AOC A13 PetroleumHydrocarbonRelease.dwg | 5/15/2017



Legend

● **AGW009** Monitoring Well Designation
73.08 Groundwater Elevation (ft, MSL)
Groundwater Elevation Contour
Boeing Property
🟧 AOC A-13

Notes

1. All water level data in ft, MSL. Vertical datum is NGVD29. Data collected in June 2015.
2. Multilevel wells have multiple channels. Channel designations are included in the well ID (ex: AGW208-2). Groundwater elevations listed are for the channel closest to 30 ft below ground surface.
3. Wells installed specifically as water table wells are not included.
4. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

N

0 60 120

Scale in Feet

Base Map Source: Geometrix 2003; Aerial Photo Source: Esri World Imagery.

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Boeing Auburn
Auburn, Washington

AOC A-13:
Localized Groundwater Elevation Contours

Figure
15

G:\Projects\025\164\140\112\FS Workplan\F15 AOC13GWContours.mxd 5/15/2017

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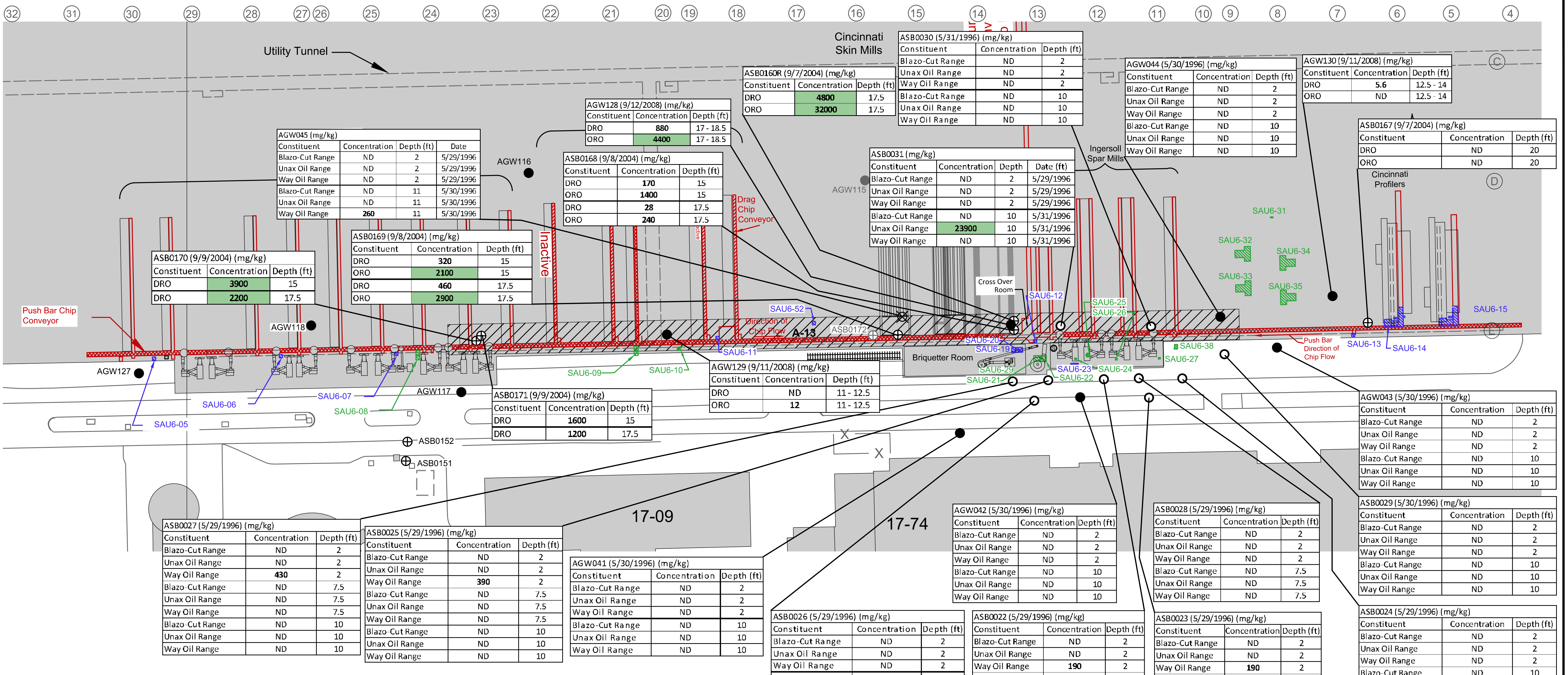


ASB0170 (9/9/2004) (mg/kg)

Constituent	Concentration	Depth (ft)
DRO	**3900**	15
DRO	**2200**	17.5

AGW045 (mg/kg)

Constituent	Concentration	Depth (ft)	Date
Blazo-Cut Range	ND	2	5/29/1996
Unax Oil Range	ND	2	5/29/1996
Way Oil Range	ND	2	5/29/1996
Blazo-Cut Range	ND	11	5/30/1996
Unax Oil Range	ND	11	5/30/1996
Way Oil Range	**260**	11	5/30/1996

ASB0169 (9/8/2004) (mg/kg)

Constituent	Concentration	Depth (ft)
DRO	**320**	15
ORO	**2100**	15
DRO	**460**	17.5
ORO	**2900**	17.5

AGW128 (9/12/2008) (mg/kg)

Constituent	Concentration	Depth (ft)
DRO	**880**	17 - 18.5
ORO	**4400**	17 - 18.5

ASB0168 (9/8/2004) (mg/kg)

Constituent	Concentration	Depth (ft)
DRO	**170**	15
ORO	**1400**	15
DRO	**28**	17.5
ORO	**240**	17.5

ASB0160R (9/7/2004) (mg/kg)

Constituent	Concentration	Depth (ft)
DRO	**4800**	17.5
ORO	**32000**	17.5

ASB0030 (5/31/1996) (mg/kg)

Constituent	Concentration	Depth (ft)
Blazo-Cut Range	ND	2
Unax Oil Range	ND	2
Way Oil Range	ND	2
Blazo-Cut Range	ND	10
Unax Oil Range	ND	10
Way Oil Range	ND	10

ASB0031 (mg/kg)

Constituent	Concentration	Depth	Date (ft)
Blazo-Cut Range	ND	2	5/29/1996
Unax Oil Range	ND	2	5/29/1996
Way Oil Range	ND	2	5/29/1996
Blazo-Cut Range	ND	10	5/31/1996
Unax Oil Range	**23900**	10	5/31/1996
Way Oil Range	ND	10	5/31/1996

AGW044 (5/30/1996) (mg/kg)

Constituent	Concentration	Depth (ft)
Blazo-Cut Range	ND	2
Unax Oil Range	ND	2
Way Oil Range	ND	2
Blazo-Cut Range	ND	10
Unax Oil Range	ND	10
Way Oil Range	ND	10

AGW130 (9/11/2008) (mg/kg)

Constituent	Concentration	Depth (ft)
DRO	**5.6**	12.5 - 14
ORO	ND	12.5 - 14

ASB0167 (9/7/2004) (mg/kg)

Constituent	Concentration	Depth (ft)
DRO	ND	20
ORO	ND	20

AGW129 (9/11/2008) (mg/kg)

Constituent	Concentration	Depth (ft)
DRO	ND	11 - 12.5
ORO	**12**	11 - 12.5

ASB0171 (9/9/2004) (mg/kg)

Constituent	Concentration	Depth (ft)
DRO	**1600**	15
DRO	**1200**	17.5

AGW043 (5/30/1996) (mg/kg)

Constituent	Concentration	Depth (ft)
Blazo-Cut Range	ND	2
Unax Oil Range	ND	2
Way Oil Range	ND	2
Blazo-Cut Range	ND	10
Unax Oil Range	ND	10
Way Oil Range	ND	10

ASB0029 (5/30/1996) (mg/kg)

Constituent	Concentration	Depth (ft)
Blazo-Cut Range	ND	2
Unax Oil Range	ND	2
Way Oil Range	ND	2
Blazo-Cut Range	ND	10
Unax Oil Range	ND	10
Way Oil Range	ND	10

ASB0027 (5/29/1996) (mg/kg)

Constituent	Concentration	Depth (ft)
Blazo-Cut Range	ND	2
Unax Oil Range	ND	2
Way Oil Range	**430**	2
Blazo-Cut Range	ND	7.5
Unax Oil Range	ND	7.5
Way Oil Range	ND	7.5
Blazo-Cut Range	ND	10
Unax Oil Range	ND	10
Way Oil Range	ND	10

ASB0025 (5/29/1996) (mg/kg)

Constituent	Concentration	Depth (ft)
Blazo-Cut Range	ND	2
Unax Oil Range	ND	2
Way Oil Range	**390**	2
Blazo-Cut Range	ND	7.5
Unax Oil Range	ND	7.5
Way Oil Range	ND	7.5
Blazo-Cut Range	ND	10
Unax Oil Range	ND	10
Way Oil Range	ND	10

AGW041 (5/30/1996) (mg/kg)

Constituent	Concentration	Depth (ft)
Blazo-Cut Range	ND	2
Unax Oil Range	ND	2
Way Oil Range	ND	2
Blazo-Cut Range	ND	10
Unax Oil Range	ND	10
Way Oil Range	ND	10

AGW042 (5/30/1996) (mg/kg)

Constituent	Concentration	Depth (ft)
Blazo-Cut Range	ND	2
Unax Oil Range	ND	2
Way Oil Range	ND	2
Blazo-Cut Range	ND	10
Unax Oil Range	ND	10
Way Oil Range	ND	10

ASB0028 (5/29/1996) (mg/kg)

Constituent	Concentration	Depth (ft)
Blazo-Cut Range	ND	2
Unax Oil Range	ND	2
Way Oil Range	ND	2
Blazo-Cut Range	ND	7.5
Unax Oil Range	ND	7.5
Way Oil Range	ND	7.5

ASB0026 (5/29/1996) (mg/kg)

Constituent	Concentration	Depth (ft)
Blazo-Cut Range	ND	2
Unax Oil Range	ND	2
Way Oil Range	ND	2
Blazo-Cut Range	ND	11
Unax Oil Range	ND	11
Way Oil Range	ND	11

ASB0022 (5/29/1996) (mg/kg)

Constituent	Concentration	Depth (ft)
Blazo-Cut Range	ND	2
Unax Oil Range	ND	2
Way Oil Range	**190**	2
Blazo-Cut Range	ND	7
Unax Oil Range	ND	7
Way Oil Range	ND	7
Blazo-Cut Range	ND	10
Unax Oil Range	ND	10
Way Oil Range	ND	10

ASB0023 (5/29/1996) (mg/kg)

Constituent	Concentration	Depth (ft)
Blazo-Cut Range	ND	2
Unax Oil Range	ND	2
Way Oil Range	**190**	2
Blazo-Cut Range	ND	5
Unax Oil Range	ND	5
Way Oil Range	ND	5
Blazo-Cut Range	ND	11
Unax Oil Range	ND	11
Way Oil Range	ND	11

ASB0024 (5/29/1996) (mg/kg)

Constituent	Concentration	Depth (ft)
Blazo-Cut Range	ND	2
Unax Oil Range	ND	2
Way Oil Range	ND	2
Blazo-Cut Range	ND	10
Unax Oil Range	ND	10
Way Oil Range	ND	10

Legend

AGW016 ●	Monitoring Well Location and Designation
ASB0149 ⊕	Soil Boring Location and Designation
ASB0149 ⊠	Abandoned Monitoring Well Location and Designation
ASB0089 ○	Pre-RI Sample Boring Location and Designation (Locations are Approximate)
AGW115 ●	Soil Samples were not Collected at these Locations
(C) (4)	Building 17-06 Column Designations
═	Pneumatic or Jet Stream Type Conveyor
▦	Push Bar Type Conveyor
▨	Drag Type Conveyor
17-06	Current Building and Number
SAU6-34 ▨	Chip runoff Sump Location and Designation
SAU6-34 ▨	Water Sump Location and Designation (Cooling water, Storm/Rain water, Condensate)
SAU6-34 ▨	Anodizing & Penetrant Sumps

N

0 100 200

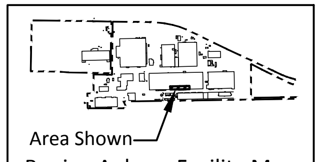
Scale in Feet

Notes

1. Model Toxics Control Act Method A soil cleanup levels for unrestricted land uses are used for petroleum hydrocarbons (2,000 mg/kg).
2. Blazo-cut, Unax, and Way Oil fall in the diesel and oil hydrocarbon range; thus, the Model Toxics Control Act Method A cleanup level of 2,000 mg/kg for diesel-range organics and oil-range organics is used.
3. **Bold** text indicates detected analyte.
4. Green shading indicates exceedance of screening level.

DRO = diesel-range organics
ORO = oil-range organics
mg/kg = milligrams per kilogram
ft = feet
ND = The analyte was analyzed for, but was not detected.

Base map source: Geomatrix 2003a



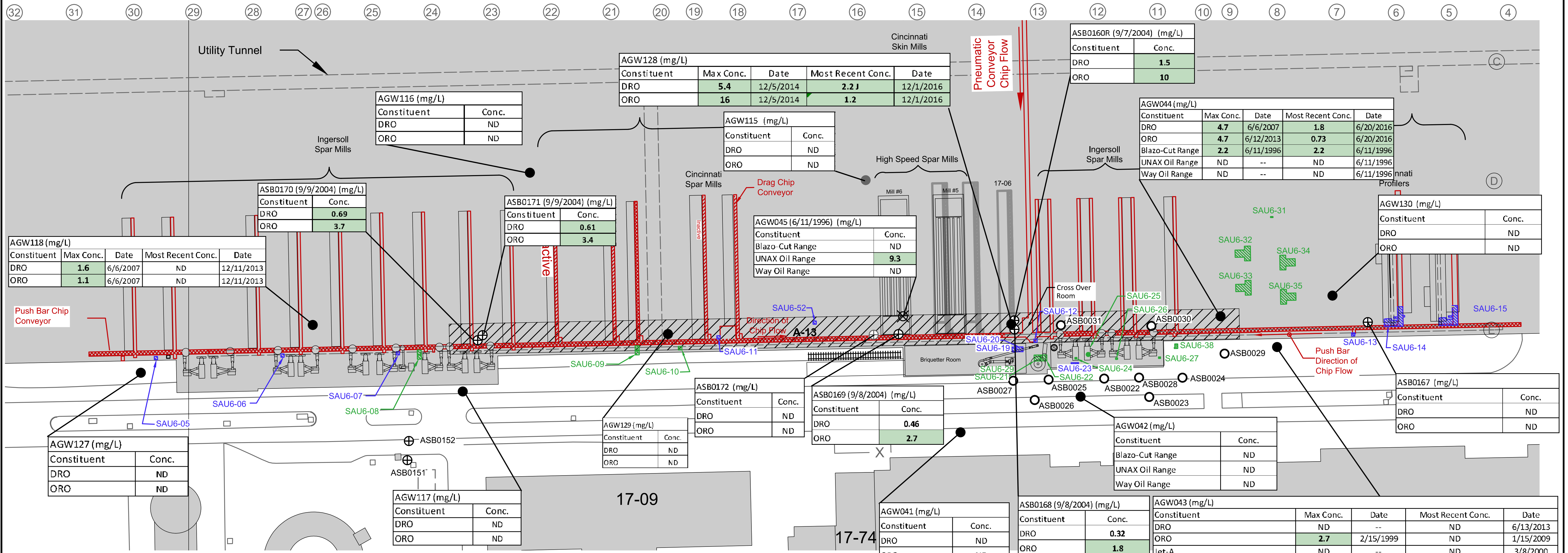
Boeing Auburn Facility Map

LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

AOC A-13: Soil Detections for Petroleum Hydrocarbon Constituents

Figure
16



AGW118 (mg/L)

Constituent	Max Conc.	Date	Most Recent Conc.	Date
DRO	**1.6**	6/6/2007	ND	12/11/2013
ORO	**1.1**	6/6/2007	ND	12/11/2013

AGW116 (mg/L)

Constituent	Conc.
DRO	ND
ORO	ND

ASB0170 (9/9/2004) (mg/L)

Constituent	Conc.
DRO	**0.69**
ORO	**3.7**

ASB0171 (9/9/2004) (mg/L)

Constituent	Conc.
DRO	**0.61**
ORO	**3.4**

AGW128 (mg/L)

Constituent	Max Conc.	Date	Most Recent Conc.	Date
DRO	**5.4**	12/5/2014	**2.2 J**	12/1/2016
ORO	**16**	12/5/2014	**1.2**	12/1/2016

AGW115 (mg/L)

Constituent	Conc.
DRO	ND
ORO	ND

AGW045 (6/11/1996) (mg/L)

Constituent	Conc.
Blazo-Cut Range	ND
UNAX Oil Range	**9.3**
Way Oil Range	ND

ASB0160R (9/7/2004) (mg/L)

Constituent	Conc.
DRO	**1.5**
ORO	**10**

AGW044 (mg/L)

Constituent	Max Conc.	Date	Most Recent Conc.	Date
DRO	**4.7**	6/6/2007	**1.8**	6/20/2016
ORO	**4.7**	6/12/2013	**0.73**	6/20/2016
Blazo-Cut Range	**2.2**	6/11/1996	**2.2**	6/11/1996
UNAX Oil Range	ND	--	ND	6/11/1996
Way Oil Range	ND	--	ND	6/11/1996

AGW130 (mg/L)

Constituent	Conc.
DRO	ND
ORO	ND

AGW127 (mg/L)

Constituent	Conc.
DRO	ND
ORO	ND

AGW117 (mg/L)

Constituent	Conc.
DRO	ND
ORO	ND

AGW129 (mg/L)

Constituent	Conc.
DRO	ND
ORO	ND

ASB0172 (mg/L)

Constituent	Conc.
DRO	ND
ORO	ND

ASB0169 (9/8/2004) (mg/L)

Constituent	Conc.
DRO	**0.46**
ORO	**2.7**

ASB0167 (mg/L)

Constituent	Conc.
DRO	ND
ORO	ND

AGW042 (mg/L)

Constituent	Conc.
Blazo-Cut Range	ND
UNAX Oil Range	ND
Way Oil Range	ND

AGW041 (mg/L)

Constituent	Conc.
DRO	ND
ORO	ND
Blazo-Cut Range	ND
UNAX Oil Range	ND
Way Oil Range	ND

ASB0168 (9/8/2004) (mg/L)

Constituent	Conc.
DRO	**0.32**
ORO	**1.8**

AGW043 (mg/L)

Constituent	Max Conc.	Date	Most Recent Conc.	Date
DRO	ND	--	ND	6/13/2013
ORO	**2.7**	2/15/1999	ND	1/15/2009
Jet-A	ND	--	ND	3/8/2000
Blazo-Cut Range	ND	--	ND	6/11/1996
UNAX Oil Range	ND	--	ND	6/11/1996
Way Oil Range	ND	--	ND	6/11/1996

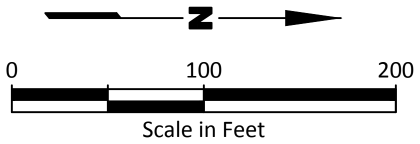
Legend

AGW016	●	Monitoring Well Location and Designation
ASB0149	⊕	Soil Boring Location and Designation
ASB0149	⊠	Abandoned Monitoring Well Location and Designation
ASB0089	○	Pre-RI Sample Boring Location and Designation (Locations are Approximate). Groundwater samples were not collected at these locations.
	🟥	Pneumatic or Jet Stream Type Conveyor
	▨	Push Bar Type Conveyor
	▨	Drag Type Conveyor
	17-06	Current Building and Number
	Ⓒ ④	Building 17-06 Column Designations
SAU6-34	▨	Chip runoff Sump Location and Designation
SAU6-34	▨	Water Sump Location and Designation (Cooling water, Storm/Rain water, Condensate)
SAU6-34	▨	Anodizing & Penetrant Sumps

Notes

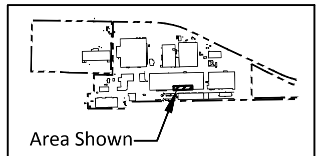
1. Model Toxins Control Act Method A groundwater cleanup levels for unrestricted land uses are used for petroleum hydrocarbons (0.5 mg/L).
2. Blazo-cut, Jet-A, Unax, and Way Oil fall in the diesel and oil hydrocarbon range; thus, the Model Toxics Control Act Method A cleanup level of 0.5 mg/L for diesel-range organics and oil-range organics is used.
3. Analytical data presented are the maximum and most recent detections for each location. Some locations were only sampled once, and therefore only one sample date is presented. For locations that were sampled multiple times, but never had a detection for these constituents, no date is presented.
4. Monitoring well results presented are maximum concentrations detected and most recent concentrations detected (as of December 2016).
5. **Bold** text indicates detected analyte.
6. Green shading indicates exceedance of screening level.

DRO = diesel-range organics
ORO = oil-range organics
-- = not analyzed or not applicable
Conc. = concentration
mg/L = milligrams per liter
ND = The analyte was analyzed for, but was not detected.



Scale in Feet

Base map source: Geomatrix 2003a



Boeing Auburn Facility Map

LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

AOC A-13: Groundwater Detections for Petroleum Hydrocarbon Constituents

Figure
17

Legend

- ▲ Proposed Sub-Slab Soil Gas Sample Location
- ◑ Boring Location
- ● Monitoring Well Location
- Ⓔ Sub-slab Vapor Sampling Location (Floor Level)
- Ⓔ Sub-slab Vapor Sampling Location (Underground)
- ─── Tank Line Area
- Ⓓ ⑪ Building 17-07 Column Designations

Notes

1. Sub-slab soil gas sample results will indicate the location of a permanent multi-level well, identified as C(M) in this work plan.
2. Sub-slab vapor samples collected on April 22, 2011, October 6, 2011 or August 16, 2011.
3. Detected concentrations of Trichloroethene (TCE), Tetrachloroethene (PCE), and Vinyl Chloride (VC) results are shown in micrograms per cubic meter ($\mu g/m^3$) for sub-slab vapor, and micrograms per liter (µg/L) for groundwater.
4. Green Shading indicates exceedance of screening level.
5. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

ND = The analyte was analyzed for, but was not detected

NS = Not Sampled

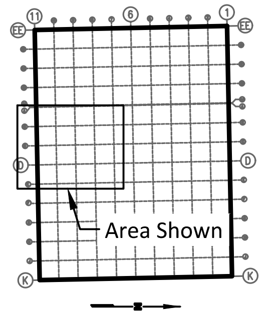
SSV-29 (10) — Sub-slab Vapor Sampling Designation and Depth in Inches

Sub-slab Soil Vapor Industrial Screening Levels ($\mu g/m^3$)

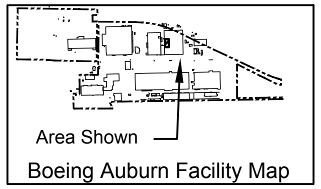
Constituent	Screening Level ($\mu g/m^3$)
PCE	1,300
TCE	67
VC	95

Groundwater Screening Levels (µg/L)

Constituent	Screening Level (µg/L)
PCE	5
TCE	0.54
VC	0.029



17-07 Building



Boeing Auburn Facility Map

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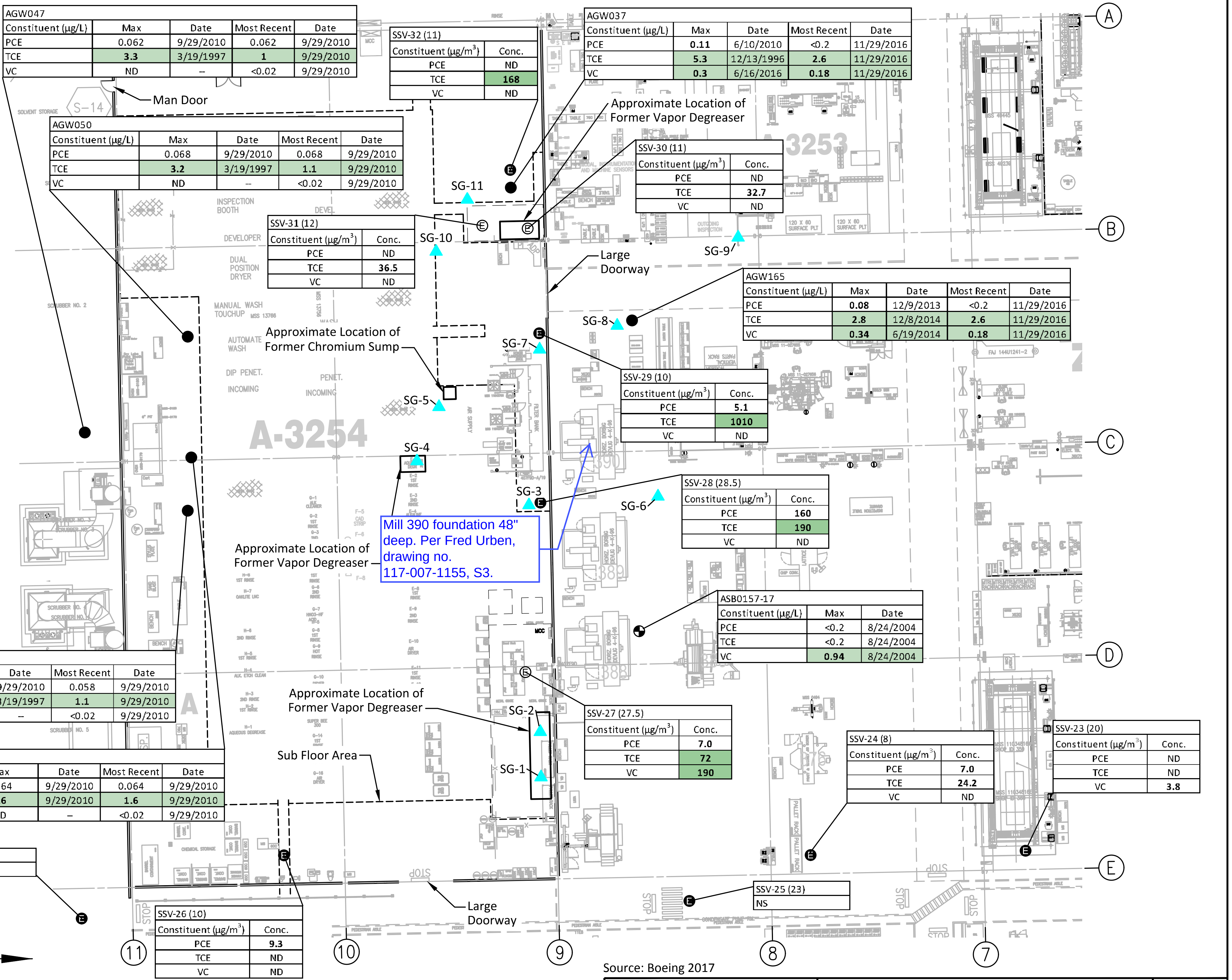
Scale in Feet



Mill 390 foundation 48" deep. Per Fred Urben, drawing no. 117-007-1155, S3.

Source: Boeing 2017

AGW047

Constituent (µg/L)	Max	Date	Most Recent	Date
PCE	0.062	9/29/2010	0.062	9/29/2010
TCE	3.3	3/19/1997	1	9/29/2010
VC	ND	--	<0.02	9/29/2010

SSV-32 (11)

Constituent ($\mu g/m^3$)	Conc.
PCE	ND
TCE	168
VC	ND

AGW037

Constituent (µg/L)	Max	Date	Most Recent	Date
PCE	0.11	6/10/2010	<0.2	11/29/2016
TCE	5.3	12/13/1996	2.6	11/29/2016
VC	0.3	6/16/2016	0.18	11/29/2016

AGW050

Constituent (µg/L)	Max	Date	Most Recent	Date
PCE	0.068	9/29/2010	0.068	9/29/2010
TCE	3.2	3/19/1997	1.1	9/29/2010
VC	ND	--	<0.02	9/29/2010

SSV-30 (11)

Constituent ($\mu g/m^3$)	Conc.
PCE	ND
TCE	32.7
VC	ND

SSV-31 (12)

Constituent ($\mu g/m^3$)	Conc.
PCE	ND
TCE	36.5
VC	ND

AGW165

Constituent (µg/L)	Max	Date	Most Recent	Date
PCE	0.08	12/9/2013	<0.2	11/29/2016
TCE	2.8	12/8/2014	2.6	11/29/2016
VC	0.34	6/19/2014	0.18	11/29/2016

SSV-29 (10)

Constituent ($\mu g/m^3$)	Conc.
PCE	5.1
TCE	1010
VC	ND

SSV-28 (28.5)

Constituent ($\mu g/m^3$)	Conc.
PCE	160
TCE	190
VC	ND

ASB0157-17

Constituent (µg/L)	Max	Date
PCE	<0.2	8/24/2004
TCE	<0.2	8/24/2004
VC	0.94	8/24/2004

AGW048

Constituent (µg/L)	Max	Date	Most Recent	Date
PCE	0.058	9/29/2010	0.058	9/29/2010
TCE	4.9	3/19/1997	1.1	9/29/2010
VC	ND	--	<0.02	9/29/2010

SSV-27 (27.5)

Constituent ($\mu g/m^3$)	Conc.
PCE	7.0
TCE	72
VC	190

SSV-24 (8)

Constituent ($\mu g/m^3$)	Conc.
PCE	7.0
TCE	24.2
VC	ND

SSV-23 (20)

Constituent ($\mu g/m^3$)	Conc.
PCE	ND
TCE	ND
VC	3.8

AGW049

Constituent (µg/L)	Max	Date	Most Recent	Date
PCE	0.064	9/29/2010	0.064	9/29/2010
TCE	1.6	9/29/2010	1.6	9/29/2010
VC	ND	--	<0.02	9/29/2010

SSV-13 (17)

NS

SSV-25 (23)

NS

SSV-26 (10)

Constituent ($\mu g/m^3$)	Conc.
PCE	9.3
TCE	ND
VC	ND

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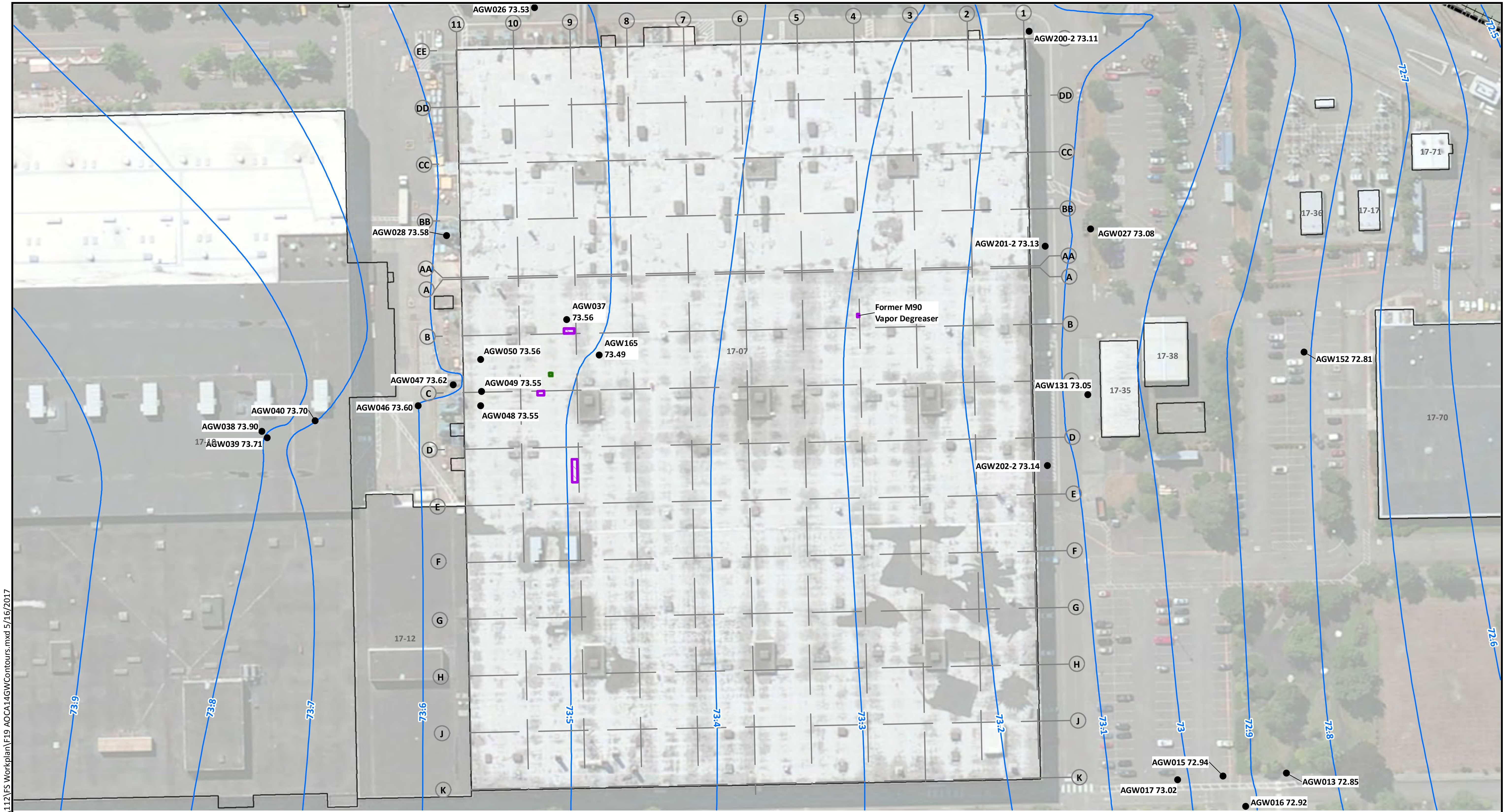
Boeing Auburn
Auburn Washington

AOC A-14: 17-07 Tank Line Area Sub-Slab Soil Vapor and Groundwater VOC Results

Figure
18



Legend

- ● **AGW009** Monitoring Well Designation
  73.08 Groundwater Elevation (ft, MSL)
- ▬ ▪ ▪ Boeing Property
- ▨ Former Chromium Sump
- ▨ Former Vapor Degreaser

Notes

1. All water level data in ft, MSL.
   Vertical datum is NGVD29.
   Data collected in June 2015.
2. Multilevel wells have multiple channels. Channel designations are included in the well ID (ex: AGW208-2). Groundwater elevations listed are for the channel closest to 30 ft below ground surface.
3. Wells installed specifically as water table wells are not included.
4. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

N →

0 100 200

Scale in Feet

Base Map Source: Geometrix 2003; Aerial Photo Source: Esri World Imagery.

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LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

AOC A-14: Building 17-07 Localized Groundwater Elevation Contours

Figure
19

Legend

▲ Proposed Sub-Slab Soil Gas Sample Location

● Monitoring Well Location

Ⓔ Sub-slab Vapor Sampling Location

Ⓓ ① Building 17-07 Column Designations

Notes

1. Sub-slab soil gas sample results will indicate the location of a permanent multi-level well, identified as D(M) in this work plan.
2. Sub-slab vapor samples collected on April 22, 2011, October 6, 2011 or August 16, 2011
3. Detected concentrations of Trichloroethene (TCE),Tetrachloroethene (PCE), and Vinyl Chloride (VC) results are shown in micrograms per cubic meter (µg/m^3) for sub-slab vapor, and micrograms per liter (µg/L) for groundwater.
4. Green shading indicates exceedance of screening level.
5. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

ND = The analyte was analyzed for, but was not detected

NS = Not Sampled

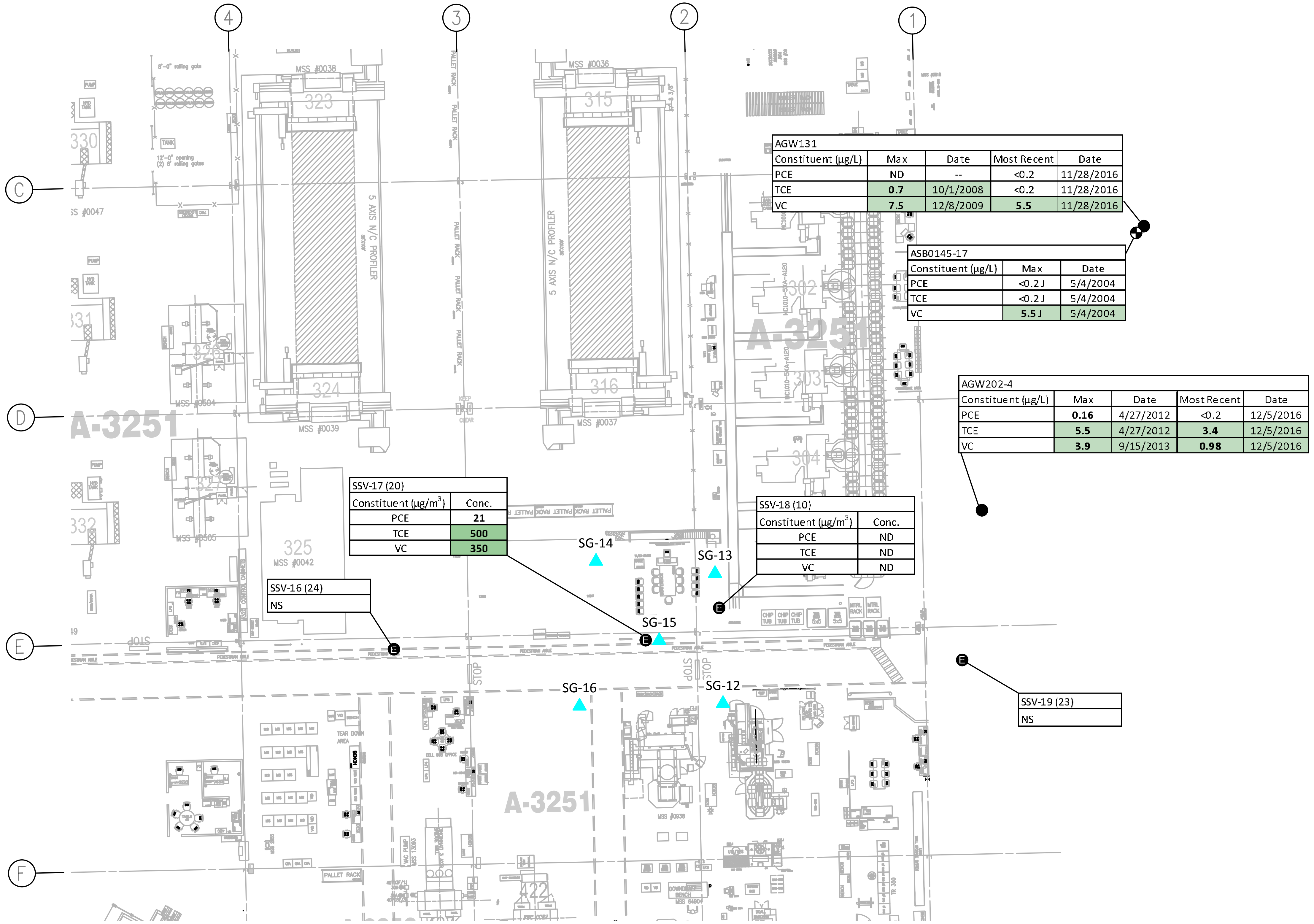
SSV-17 (20) — Sub-slab Vapor Sampling Designation and Depth in Inches

Sub-slab Soil Vapor Industrial Screening Levels (µg/m^3)

Constituent	Screening Level (µg/m^3)
PCE	1,300
TCE	67
VC	95

Groundwater Screening Levels (µg/L)

Constituent	Screening Level (µg/L)
PCE	5
TCE	0.54
VC	0.029



AGW131

Constituent (µg/L)	Max	Date	Most Recent	Date
PCE	ND	--	<0.2	11/28/2016
TCE	**0.7**	10/1/2008	<0.2	11/28/2016
VC	**7.5**	12/8/2009	**5.5**	11/28/2016

ASB0145-17

Constituent (µg/L)	Max	Date
PCE	<0.2 J	5/4/2004
TCE	<0.2 J	5/4/2004
VC	**5.5 J**	5/4/2004

AGW202-4

Constituent (µg/L)	Max	Date	Most Recent	Date
PCE	**0.16**	4/27/2012	<0.2	12/5/2016
TCE	**5.5**	4/27/2012	**3.4**	12/5/2016
VC	**3.9**	9/15/2013	**0.98**	12/5/2016

SSV-17 (20)

Constituent (µg/m^3)	Conc.
PCE	**21**
TCE	**500**
VC	**350**

SSV-18 (10)

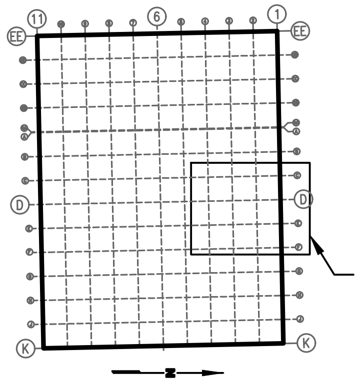
Constituent (µg/m^3)	Conc.
PCE	ND
TCE	ND
VC	ND

SSV-16 (24)

NS

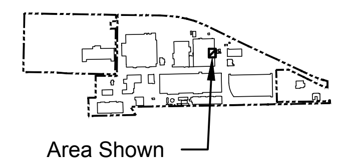
SSV-19 (23)

NS

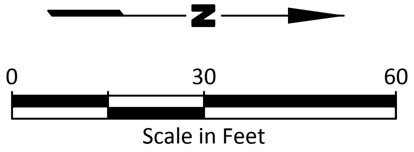


Area Shown

17-07 Building



Boeing Auburn Facility Map



Source: Boeing 2017

Boeing Auburn
Auburn, Washington

AOC A-14:
Building 17-07 Column E2 Sub-Slab Soil Vapor and Groundwater VOC Results

Figure
20

LANDAU ASSOCIATES

Legend

▲ Proposed Sub-Slab Soil Gas Sample Location

● Monitoring Well Location

Ⓔ Sub-slab Vapor Sampling Location (Floor Level)

Ⓒ ⑤ Building 17-07 Column Designations

Notes

1. Sub-slab soil gas sample results will indicate the location of a permanent multi-level well, identified as E(M) in this work plan.
2. Sub-slab vapor samples collected on April 22, 2011, October 6, 2011 or August 16, 2011.
3. Detected concentrations of Trichloroethene (TCE), Tetrachloroethene (PCE), and Vinyl Chloride (VC) results are shown in micrograms per cubic meter (µg/m^3) for sub-slab vapor, and micrograms per liter (µg/L) for groundwater.
4. Green Shading indicates exceedance of screening level.
5. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

ND = The analyte was analyzed for, but was not detected

NS = Not Sampled

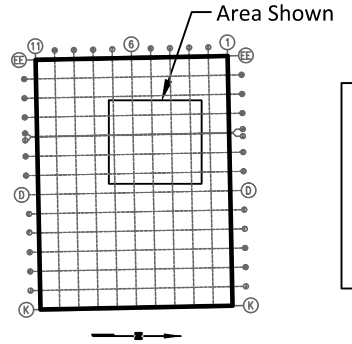
SSV-10 (10) — Sub-slab Vapor Sampling Designation and Depth in Inches

Sub-slab Soil Vapor Industrial Screening Levels (µg/m^3)

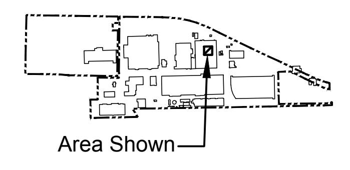
Constituent	Screening Level (µg/m^3)
PCE	1,300
TCE	67
VC	95

Groundwater Screening Levels (µg/L)

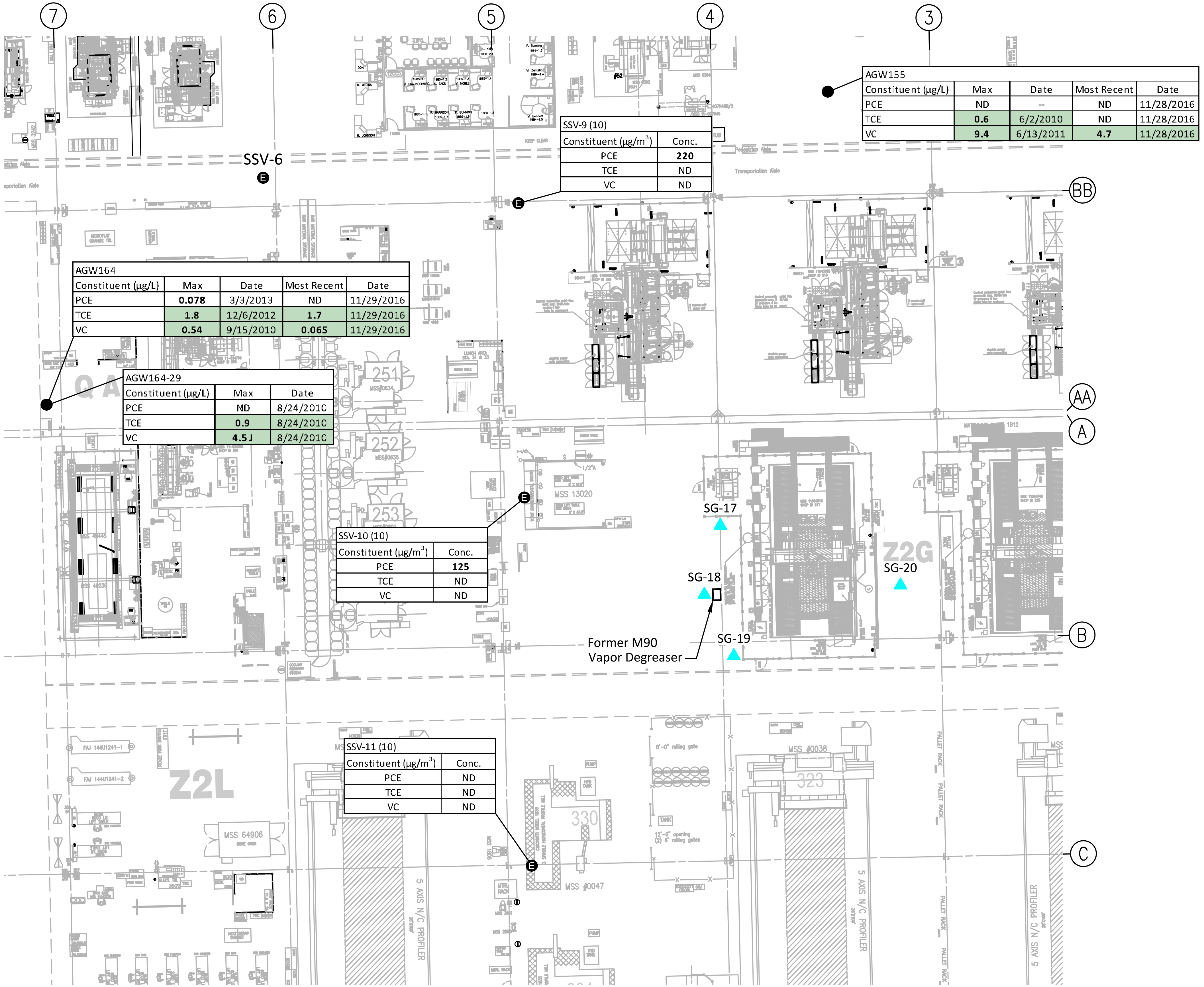
Constituent	Screening Level (µg/L)
PCE	5
TCE	0.54
VC	0.029



17-07 Building



Boeing Auburn Facility Map



AGW155

Constituent (µg/L)	Max	Date	Most Recent	Date
PCE	ND	--	ND	11/28/2016
TCE	**0.6**	6/2/2010	ND	11/28/2016
VC	**9.4**	6/13/2011	**4.7**	11/28/2016

SSV-9 (10)

Constituent (µg/m^3)	Conc.
PCE	**220**
TCE	ND
VC	ND

AGW164

Constituent (µg/L)	Max	Date	Most Recent	Date
PCE	**0.078**	3/3/2013	ND	11/29/2016
TCE	**1.8**	12/6/2012	**1.7**	11/29/2016
VC	**0.54**	9/15/2010	**0.065**	11/29/2016

AGW164-29

Constituent (µg/L)	Max	Date
PCE	ND	8/24/2010
TCE	**0.9**	8/24/2010
VC	**4.5 J**	8/24/2010

SSV-10 (10)

Constituent (µg/m^3)	Conc.
PCE	**125**
TCE	ND
VC	ND

SSV-11 (10)

Constituent (µg/m^3)	Conc.
PCE	ND
TCE	ND
VC	ND

Source: Boeing 2017

N

0 30 60

Scale in Feet

Landau Associates | G:\Projects\025\164\140\112\FS Workplan\F21 AOC A-14 Column B4.dwg | 5/14/2017 4:49 PM

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Boeing Auburn
Auburn, Washington

AOC A-14:
Building 17-07 Column B4 Degreaser Sub-Slab Soil Vapor and Groundwater VOC Results

Figure
21

Legend

SG-21 ▲ Proposed Soil Gas Sampling Location
18 ⊕ Soil Gas Location
SS-33 ◐ Boring Location
AGW001 R ● Well Location
AGW001 ● Decommissioned Well Location
17-07 Current Building and Number
17-14 Former Building and Number
Boeing Property Line
Adjacent Property Line
Existing Fence Line
Existing Railroad Track
Chrome Waste Line

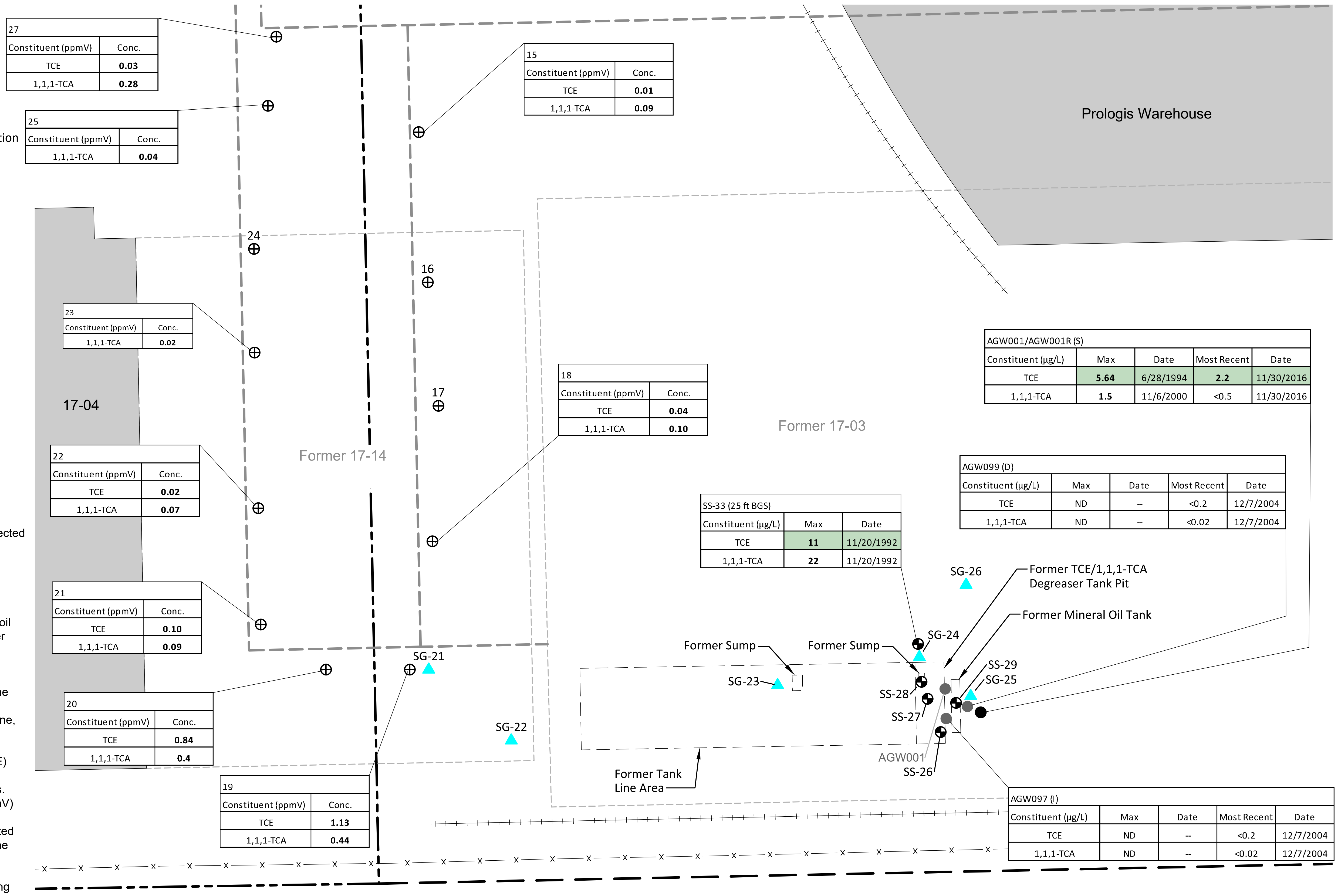
Groundwater Screening Levels (µg/L)

Constituent	Screening Level (µg/L)
TCE	0.54
1,1,1-TCA	200

ND = The analyte was analyzed for, but was not detected

Notes

1. Soil and soil gas samples that were part of the Chrome Waste Line investigation (samples 15 through 27) were collected in December 1996. Soil samples (SS-26 through SS-29) and groundwater borehole grab samples (SS-33) were collected in October 1992.
2. Groundwater monitoring wells are identified by the AGW prefix. The designations beside the identifications indicate the zone (S) = Shallow zone, (I) = Intermediate zone, (D) = deep zone.
3. Detected concentrations of Trichloroethene (TCE) and 1,1,1-Trichloroethane (1,1,1-TCA) are presented for source area identification purposes. Result units are parts per million by volume (ppmV) for soil gas and micrograms per liter (µg/L) for groundwater. These constituents were not detected in the soil samples collected from borings or at the soil gas sampling locations.
4. Green Shading indicates exceedance of screening level.
5. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.



27

Constituent (ppmV)	Conc.
TCE	0.03
1,1,1-TCA	0.28

25

Constituent (ppmV)	Conc.
1,1,1-TCA	0.04

15

Constituent (ppmV)	Conc.
TCE	0.01
1,1,1-TCA	0.09

23

Constituent (ppmV)	Conc.
1,1,1-TCA	0.02

18

Constituent (ppmV)	Conc.
TCE	0.04
1,1,1-TCA	0.10

22

Constituent (ppmV)	Conc.
TCE	0.02
1,1,1-TCA	0.07

21

Constituent (ppmV)	Conc.
TCE	0.10
1,1,1-TCA	0.09

20

Constituent (ppmV)	Conc.
TCE	0.84
1,1,1-TCA	0.4

19

Constituent (ppmV)	Conc.
TCE	1.13
1,1,1-TCA	0.44

SS-33 (25 ft BGS)

Constituent (µg/L)	Max	Date
TCE	11	11/20/1992
1,1,1-TCA	22	11/20/1992

AGW001/AGW001R (S)

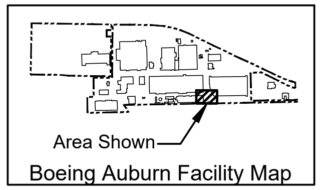
Constituent (µg/L)	Max	Date	Most Recent	Date
TCE	5.64	6/28/1994	2.2	11/30/2016
1,1,1-TCA	1.5	11/6/2000	<0.5	11/30/2016

AGW099 (D)

Constituent (µg/L)	Max	Date	Most Recent	Date
TCE	ND	--	<0.2	12/7/2004
1,1,1-TCA	ND	--	<0.02	12/7/2004

AGW097 (I)

Constituent (µg/L)	Max	Date	Most Recent	Date
TCE	ND	--	<0.2	12/7/2004
1,1,1-TCA	ND	--	<0.02	12/7/2004



Boeing Auburn Facility Map

0 40 80
Scale in Feet

Base map source: Geomatrix 2003; Kennedy Jenks

Boeing Auburn
Auburn, Washington

AOC A-14: Former Building 17-03 VOC Results and Proposed Feasibility Study Sampling Locations

Figure
22

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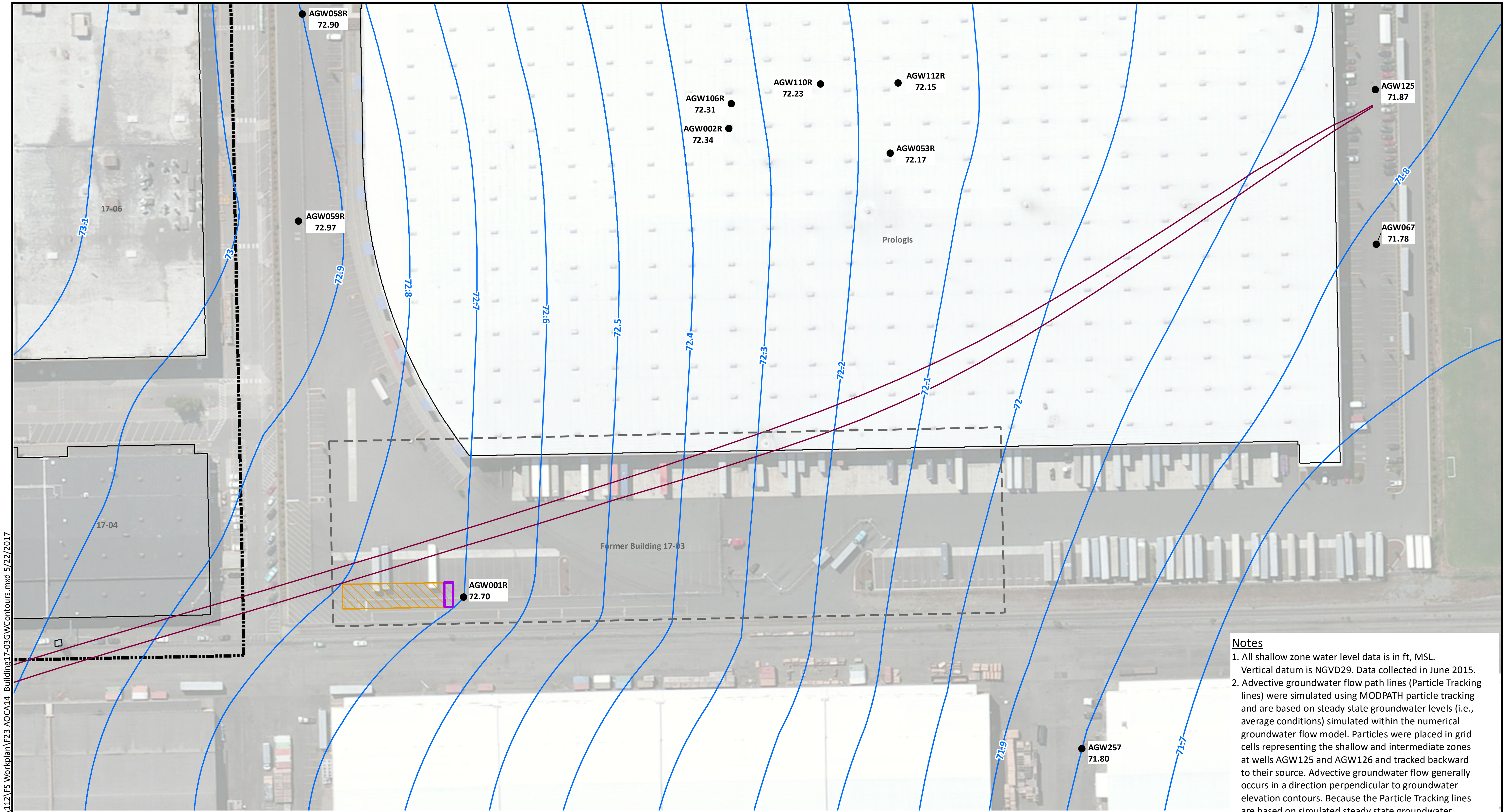
Landau Associates | G:\Projects\025\164\140\112\FS Workplan\F22 Former Bldg 17-03.dwg | 5/15/2017 4:32 PM



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Legend

- ● **AGW009** Monitoring Well Designation
  73.08 Groundwater Elevation (ft, MSL)
- Former Buildings 17-03
- Former Degreaser Tank Pit
- Former Tank Line Area
- Particle Track Pathlines
- Boeing Property

N

0 120 240
Scale in Feet

Notes

1. All shallow zone water level data is in ft, MSL. Vertical datum is NGVD29. Data collected in June 2015.
2. Advective groundwater flow path lines (Particle Tracking lines) were simulated using MODPATH particle tracking and are based on steady state groundwater levels (i.e., average conditions) simulated within the numerical groundwater flow model. Particles were placed in grid cells representing the shallow and intermediate zones at wells AGW125 and AGW126 and tracked backward to their source. Advective groundwater flow generally occurs in a direction perpendicular to groundwater elevation contours. Because the Particle Tracking lines are based on simulated steady state groundwater levels, they may not reflect groundwater level conditions observed at any given time (e.g., June 2015, shown here).
3. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

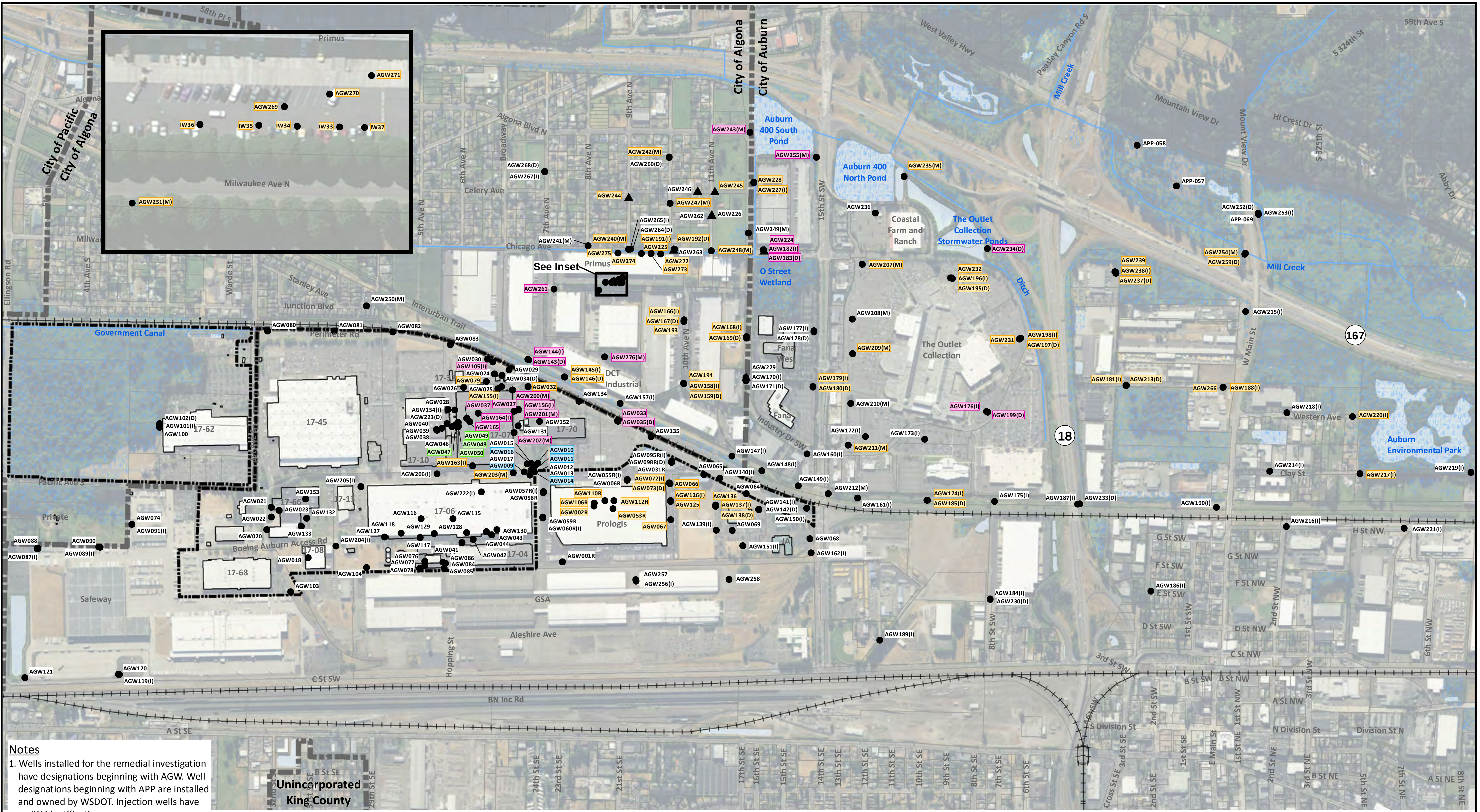
Base Map Source: Geometrix 2003; Aerial Photo Source: Esri World Imagery.

LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

**AOC A-14: Former Building 17-03
Localized Groundwater
Elevation Contours**

Figure
23



G:\Projects\025\164\140\112\FS Workplan\F24 MWNetwork.mxd 5/19/2017

Notes

1. Wells installed for the remedial investigation have designations beginning with AGW. Well designations beginning with APP are installed and owned by WSDOT. Injection wells have an IW identification.
2. Wells designated as water table wells are locations off Boeing property that were specifically installed as water table wells.
3. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

▲	Offsite Water Table Well		Wetland Areas	AGW194	Historical or Current NA Assessment Location
●	Shallow Zone Monitoring Well		Water Bodies	AGW261	June 2017 NA Assessment Location
(I) ●	Intermediate Zone Monitoring Well		Waterways	AGW016	Additional AOC A-01 Sampling Location
(D) ●	Deep Zone Monitoring Well		Boeing Property	AGW047	Additional AOC A-09 Sampling Location
(M) ●	Multi-Level Well		City Limits		

N

0 1,000 2,000

Scale in Feet

Base Map Source: Geometrix 2003; Parcel Data Source: King County 2015; Aerial Photo Source: Esri World Imagery.

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Boeing Auburn
Remedial Investigation
Auburn, Washington

Current Monitoring Well Network and FS Sampling Locations

Figure
24

Table 1
Areas of Concern Summaries to be Addressed in the Feasibility Study
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

AOC	Building	Description	Primary Constituents of Concern	Comments	Scope of Additional Investigation	FS Work Plan Section
A-01	17-06	Former USTs (TAU-01 and TAU-02)	TPH, ethylbenzene	Petroleum hydrocarbon related constituents (DRO, GRO, ethylbenzene) are above screening levels. Concentrations of VOCs at this area will be addressed as part of the Site-wide groundwater impacts.	Subsurface investigation of soil and groundwater.	2.1 and 3.1
A-09	17-07	Acid Scrubber Drain Line Leak	Metals, Cyanide	Metals contamination in soil above screening levels under building and has resulted in metals contaminated groundwater.	One-time total cyanide and dissolved copper groundwater sampling.	2.2 and 3.2
A-13	17-06	Petroleum contamination in soil and groundwater	TPH	Soil and groundwater exceedances of screening levels for petroleum hydrocarbons (DRO and ORO).	Soil borings and monitoring wells.	2.3 and 3.3
A-14	Site-wide	Site-wide TCE and VC concentrations in groundwater	TCE, VC	Groundwater exceedances of screening levels for TCE and VC.	Source area investigation at Building 17-07: Monitoring wells, sub-slab soil gas samples; Site-wide groundwater sampling: MNA parameters.	2.4 and 3.4
A-15	Site-wide	Site-wide TCE and VC concentrations in surface water	TCE, VC	Detections of TCE and VC in surface water.	Surface water sampling, pore water sampling.	2.5 and 3.5

Note:

TPH refers to petroleum hydrocarbons (can include DRO, ORO, or GRO).

Abbreviations/Acronyms:

AOC = area of concern
BTEX = benzene, toluene, ethylbenzene, and xylenes
DRO = diesel-range organic
GRO = gasoline-range organic
MNA = monitored natural attenuation
ORO = oil-range organic
SVE = soil vapor extraction
TCE = trichloroethene
TPH = total petroleum hydrocarbon
UST = underground storage tank
VC = vinyl chloride
VOC = volatile organic compounds

Table 2
Phase VII Groundwater Monitoring Plan
June 2017 Sampling Matrix
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Well	CMT Channel Depth (ft)	Groundwater Zone	Description	Location	Phase VII Frequency	VOCs 8260 (a)	VOCs VC 8260 SIM (b)	NA Parameters (c)	Metals 200.8 (d)	Cyanide	TPH-D (e)(f)	TPH-G (g)
AGW001R	--	S	Property Boundary	SE of Prologis Bldg	SA	X	A					
AGW002R	--	S	Area 1	In Prologis Bldg	SA	X	X	X (c)				
AGW006R	--	S	Area 1	W of Prologis Bldg	SA	X	X					
AGW009	--	S	AOC A-01	NW of Bldg 17-06	A	X	X	X (h)			X	X
AGW010	--	S	AOC A-01	NW of Bldg 17-06	SA	X	X	X (h)			X	X
AGW011	--	S	AOC A-01	NW of Bldg 17-06	One-time	BTEX		X (h)			X	X
AGW014	--	S	AOC A-01	NW of Bldg 17-06	One-time	BTEX		X (h)			X	X
AGW016	--	S	AOC A-01	NW of Bldg 17-06	One-time	BTEX		X (h)			X	X
AGW024	--	S	SWMU S-06/Bldg 17-15	WWPTP	SA	X						
AGW025	--	S	SWMU S-06/Bldg 17-15	E of WWPTP	SA	X						
AGW026	--	S	SWMU-13	W of Bldg 17-07	SA	X	X					
AGW027	--	S	SWMU S-13	N of Bldg 17-07	SA	X	X	X (c) + nitrate				
AGW029	--	S	Property Boundary	W of WWPTP	A	X	X					
AGW030	--	S	Property Boundary	W of WWPTP	A	X	X					
AGW031R	--	S	Property Boundary	NW of Prologis Bldg	SA	X	X					
AGW032	--	S	Property Boundary	N of WWPTP	SA	X	X					
AGW033	--	S	Property Boundary	N of Bldg 17-70	SA	X	X	X (c) + nitrate				
AGW034	--	D	Property Boundary	WWPTP	A	X	X					
AGW035	--	D	Property Boundary	N of Bldg 17-70	A	X	X	X (c) + nitrate				
AGW037	--	S	SWMU S-13	S Part of Bldg 17-07	SA	X	X	X (c) + nitrate				
AGW039	--	S	AOC A-10	N Part of Bldg 17-10	A	X	X		As			
AGW040	--	S	AOC A-10	N Part of Bldg 17-10	A	X	X					
AGW041	--	S	Bldg 17-06 -SWMU S-16	E of Bldg 17-06	A	X	X					
AGW044	--	S	Bldg 17-06 -SWMU S-16	Bldg 17-06; Col E10	A	X	X				X	

Table 2
Phase VII Groundwater Monitoring Plan
June 2017 Sampling Matrix
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Well	CMT Channel Depth (ft)	Groundwater Zone	Description	Location	Phase VII Frequency	VOCs 8260 (a)	VOCs VC 8260 SIM (b)	NA Parameters (c)	Metals 200.8 (d)	Cyanide	TPH-D (e)(f)	TPH-G (g)
AGW047	--	S	Acid Scrubber-AOC A-09	Between Bldgs 17-07 and 17-10	One-time					X		
AGW048	--	S	Acid Scrubber-AOC A-09	Between Bldgs 17-07 and 17-10	A				Cd, Ni	X		
AGW049	--	S	Acid Scrubber-AOC A-09	Between Bldgs 17-07 and 17-10	SA				Cd, Ni, Cu	X		
AGW050	--	S	Acid Scrubber-AOC A-09	Between Bldgs 17-07 and 17-10	SA				Cd, Ni	X		
AGW053R	--	S	Area 1	In Prologis Bldg	SA	X	X					
AGW055R	--	I	Area 1	W of Prologis Bldg	SA	X	X					
AGW057R	--	I	S End of Area 1	S of Prologis Bldg	SA	X	A					
AGW058R	--	S	S End of Area 1	S of Prologis Bldg	A	X	X					
AGW059R	--	S	S End of Area 1	S of Prologis Bldg	A	X	X					
AGW060R	--	I	S End of Area 1	S of Prologis Bldg	SA	X	X					
AGW064	--	S	Area 1	W of YMCA Bldg	SA	X	A					
AGW065	--	S	Area 1	SW of YMCA Bldg	A	X	A					
AGW066	--	S	Area 1	N of Prologis Bldg	SA	X	A					
AGW067	--	S	Area 1	N of Prologis Bldg	SA	X	A					
AGW068	--	S	Area 1	N End of YMCA/JA	A	X	A					
AGW069	--	S	Area 1	E of YMCA Bldg	SA	X	A					
AGW072	--	I	Area 1	NW of Prologis Bldg	SA	X	A					
AGW073	--	D	Area 1	NW of Prologis Bldg	SA	X	A					
AGW074	--	S	Sentry	N of City of Pacific Wells	SA	X	X					
AGW078	--	S	Property Boundary	Building 17-34 S	A	X	A					
AGW079	--	S	SWMU S-06	S of Bldg 17-15	SA	X						
AGW081	--	S	Property Boundary	Perimeter Rd W of Bldg 17-45	A	X	X					
AGW085	--	S	Property Boundary	E of Bldg 17-34	SA	X	A					
AGW087	--	I	Sentry	E of City of Pacific Wells	SA	X	X					

Table 2
Phase VII Groundwater Monitoring Plan
June 2017 Sampling Matrix
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Well	CMT Channel Depth (ft)	Groundwater Zone	Description	Location	Phase VII Frequency	VOCs 8260 (a)	VOCs VC 8260 SIM (b)	NA Parameters (c)	Metals 200.8 (d)	Cyanide	TPH-D (e)(f)	TPH-G (g)
AGW088	--	S	Sentry	E of City of Pacific Wells	SA	X	X					
AGW089	--	I	Sentry	NE of City of Pacific Wells	SA	X	X					
AGW090	--	S	Sentry	NE of City of Pacific Wells	SA	X	X					
AGW091	--	I	Sentry	N of City of Pacific Wells	SA	X	X					
AGW095R	--	I	Area 1	NW of Prologis Bldg	SA	X	X					
AGW098R	--	D	Area 1	NW of Prologis Bldg	SA	X	A					
AGW104	--	S	Property Boundary	Former Bldg 17-16	A	X	A					
AGW105	--	I	Property Boundary	Perimeter Rd W of WWPTP	SA	X	X	X (c) + nitrate				
AGW106R	--	S	Area 1	In Prologis Bldg	SA	X	A	X (c)				
AGW110R	--	S	Area 1	In Prologis Bldg	SA	X	X	X (c)				
AGW112R	--	S	Area 1	In Prologis Bldg	SA	X	X					
AGW115	--	S	Bldg. 17-06 - SWMU S-16	In Bldg 17-06	SA	X	X					
AGW116	--	S	Bldg. 17-06 - SWMU S-16	In Bldg 17-06	SA	X	A					
AGW117	--	S	Bldg. 17-06 - SWMU S-16	In Bldg 17-06	SA	X	A					
AGW118	--	S	Bldg. 17-06 - SWMU S-16	In Bldg 17-06	SA	X	A					
AGW119	--	I	Safeway	E Side of Safeway Prop	SA	X	X					
AGW120	--	S	Safeway	E Side of Safeway Prop	SA	X	X					
AGW125	--	S	Area 1	N of Prologis Bldg	SA	X	X					
AGW126	--	I	Area 1	N of Prologis Bldg	SA	X	X					
AGW127	--	S	Bldg. 17-06 - SWMU S-16	In Bldg 17-06	A	X	A					
AGW128	--	S	Bldg. 17-06 - SWMU S-16	In Bldg 17-06	SA	X	X				X	
AGW129	--	S	Bldg. 17-06 - SWMU S-16	In Bldg 17-06	SA	X	A					
AGW130	--	S	Bldg. 17-06 - SWMU S-16	In Bldg 17-06	SA	X	A				X	
AGW131	--	S	SWMU S-18/Bldg 17-35	N of Bldg 17-07	SA	X						

Table 2
Phase VII Groundwater Monitoring Plan
June 2017 Sampling Matrix
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Well	CMT Channel Depth (ft)	Groundwater Zone	Description	Location	Phase VII Frequency	VOCs 8260 (a)	VOCs VC 8260 SIM (b)	NA Parameters (c)	Metals 200.8 (d)	Cyanide	TPH-D (e)(f)	TPH-G (g)
AGW133	--	S	AOC A-06	E of Bldg 17-66	A	X	X					
AGW134	--	S	Property Boundary	Perimeter Rd W of Bldg 17-70	SA	X	X					
AGW135	--	S	Property Boundary	Perimeter Rd N of Bldg 17-70	SA	X	X					
AGW136	--	S	Area 1	S of YMCA Bldg	SA	X	X					
AGW137	--	I	Area 1	S of YMCA Bldg	SA	X	X					
AGW138	--	D	Area 1	S of YMCA Bldg	SA	X	A					
AGW139	--	I	Area 1	SE of YMCA Bldg	SA	X	A					
AGW140	--	I	Area 1	SW of YMCA Bldg	SA	X	X					
AGW141	--	I	Area 1	N of YMCA Bldg	SA	X	A					
AGW142	--	D	Area 1	N of YMCA Bldg	SA	X	A					
AGW143	--	D	Offsite	Interurban Trail, NW of WWPTP	SA	X	A	X (c) + nitrate				
AGW144	--	I	Offsite	Interurban Trail, NW of WWPTP	SA	X	X	X (c) + nitrate				
AGW145	--	I	Offsite	Interurban Trail, NW of WWPTP	SA	X						
AGW146	--	D	Offsite	Interurban Trail, NW of WWPTP	SA	X	X					
AGW147	--	I	Offsite	Interurban Trail, W of YMCA/JA	SA	X	X					
AGW148	--	I	Offsite	Interurban Trail, W of YMCA/JA	SA	X	X					
AGW149	--	I	Offsite	Interurban Trail, W of YMCA/JA	SA	X	A					
AGW150	--	I	Offsite	W of YMCA/JA	SA	X	A					
AGW151	--	I	Area 1	E of YMCA Bldg	SA	X	A					
AGW152	--	S	SWMU S-18/Bldg 17-35	N of Bldg 17-07	SA	X						
AGW153	--	S	AOC A-06	In Bldg 17-66	A	X	X					
AGW154	--	I	S of Former Vapor Degreaser, Bldg 17-07	S of Bldg 17-07	SA	X	X					
AGW155	--	I	W of Bldg 17-07	W of Bldg 17-07	SA	X						
AGW156	--	I	N of Bldg 17-07	N of Bldg 17-07	SA	X		X (c) + nitrate				

Table 2
Phase VII Groundwater Monitoring Plan
June 2017 Sampling Matrix
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Well	CMT Channel Depth (ft)	Groundwater Zone	Description	Location	Phase VII Frequency	VOCs 8260 (a)	VOCs VC 8260 SIM (b)	NA Parameters (c)	Metals 200.8 (d)	Cyanide	TPH-D (e)(f)	TPH-G (g)
AGW157	--	I	Property Boundary	NW of Bldg 17-21	SA	X	X					
AGW158	--	I	Offsite	10th St SW	SA	X	X					
AGW159	--	D	Offsite	10th St SW	SA	X	X					
AGW160	--	I	Offsite	W of YMCA/JA - Industry Dr	SA	X	A					
AGW161	--	I	Offsite	Interurban Trail, N of 15th St SW	SA	X	A					
AGW162	--	I	Offsite	NE corner of YMCA/JA	SA	X	A					
AGW163	--	I	E of Bldg 17-07	E of 17-07, near large door	SA	X	X					
AGW164	--	I	Inside Bldg 17-07	Bldg 17-07, near col A7	SA	X	X	X (c) + nitrate				
AGW165	--	S	Inside Bldg 17-07	Bldg 17-07, near col B9	SA	X	X	X (c) + nitrate				
AGW166	--	I	Offsite	10th St SW	SA	X	X					
AGW167	--	D	Offsite	10th St SW	SA	X	X					
AGW168	--	I	Offsite	Boundary Blvd	SA	X	X					
AGW169	--	D	Offsite	Boundary Blvd	SA	X	X					
AGW170	--	I	Offsite	Boundary Blvd	SA	X	X					
AGW171	--	D	Offsite	Boundary Blvd	SA	X	A					
AGW172	--	I	Offsite	SE corner - Outlet Collection Lot	SA	X	A					
AGW173	--	I	Offsite	E side of Outlet Collection Lot	SA	X	X					
AGW174	--	I	Offsite	Interurban Trail, N of 15th St SW	SA	X	A					
AGW175	--	I	Offsite	Interurban Trail, N of 15th St SW	SA	X	A					
AGW176	--	I	Offsite	NE corner - Outlet Collection Lot	SA	X	X	X (c) + nitrate				
AGW177	--	I	Offsite	Western Fana Property	SA	X	X					
AGW178	--	D	Offsite	Western Fana Property	SA	X	X					
AGW179	--	I	Offsite	Eastern Fana Property	SA	X	X					
AGW180	--	D	Offsite	Eastern Fana Property	SA	X	A					

Table 2
Phase VII Groundwater Monitoring Plan
June 2017 Sampling Matrix
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Well	CMT Channel Depth (ft)	Groundwater Zone	Description	Location	Phase VII Frequency	VOCs 8260 (a)	VOCs VC 8260 SIM (b)	NA Parameters (c)	Metals 200.8 (d)	Cyanide	TPH-D (e)(f)	TPH-G (g)
AGW181	--	I	Offsite	S end of Lund Rd	SA	X	X					
AGW182	--	I	Offsite	O St at Boundary Blvd	SA	X	X	X (c) + nitrate				
AGW183	--	D	Offsite	O St at Boundary Blvd	SA	X	X	X (c) + nitrate				
AGW184	--	I	Offsite	8th St at cul-de-sac	SA	X	A					
AGW185	--	D	Offsite	Interurban Trail E Outlet Collection	SA	X	A					
AGW186	--	I	Offsite	E St and 3rd	SA	X	A					
AGW187	--	I	Offsite	Interurban Trail N side of SR 18	SA	X	A					
AGW188	--	I	Offsite	Lund Rd at Main St	SA	X	X					
AGW189	--	I	Offsite	City of Auburn Maintenance Fac	SA	X	A					
AGW190	--	I	Offsite	Interurban Trail at Main St	SA	X	A					
AGW191	--	I	Offsite	Chicago Ave and 10th Ave, Algona	Q	X	X					
AGW192	--	D	Offsite	Chicago Ave and 10th Ave, Algona	Q	X	X					
AGW193	--	S	Offsite	10th St SW, Algona	SA	X	X					
AGW194	--	S	Offsite	10th St SW, Algona	SA	X	X					
AGW195	--	D	Offsite	Outlet Collection-delivery area, W side	SA	X	X					
AGW196	--	I	Offsite	Outlet Collection-delivery area, W side	SA	X						
AGW197	--	D	Offsite	Outlet Collection-W of Sam's Club	SA	X	A					
AGW198	--	I	Offsite	Outlet Collection-W of Sam's Club	SA	X	X					
AGW199	--	D	Offsite	NE corner - Outlet Collection Lot	SA	X	X	X (c) + nitrate				
AGW200-2	30	S	On-site CMT	Outside Bldg 17-07, NW Corner	SA	X		X (c) + nitrate				
AGW200-5	60	I	On-site CMT	Outside Bldg 17-07, NW Corner	SA	X		X (c) + nitrate				
AGW200-6	80	D	On-site CMT	Outside Bldg 17-07, NW Corner	SA	X		X (c) + nitrate				
AGW201-2	30	S	On-site CMT	Outside Bldg 17-07, N Central	SA	X		X (c) + nitrate				
AGW201-5	60	I	On-site CMT	Outside Bldg 17-07, N Central	SA	X		X (c) + nitrate				

Table 2
Phase VII Groundwater Monitoring Plan
June 2017 Sampling Matrix
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Well	CMT Channel Depth (ft)	Groundwater Zone	Description	Location	Phase VII Frequency	VOCs 8260 (a)	VOCs VC 8260 SIM (b)	NA Parameters (c)	Metals 200.8 (d)	Cyanide	TPH-D (e)(f)	TPH-G (g)
AGW201-6	80	D	On-site CMT	Outside Bldg 17-07, N Central	SA	X	X	X (c) + nitrate				
AGW202-2	30	S	On-site CMT	Outside Bldg 17-07, E Central	SA	X	X	X (c) + nitrate				
AGW202-4	51	I	On-site CMT	Outside Bldg 17-07, E Central	SA	X		X (c) + nitrate				
AGW202-6	81	D	On-site CMT	Outside Bldg 17-07, E Central	SA	X	A	X (c) + nitrate				
AGW203-2	30	S	On-site CMT	Staging area btwn Bldgs 17-07 & 17-06	SA	X	A					
AGW203-4	49	I	On-site CMT	Staging area btwn Bldgs 17-07 & 17-06	SA	X	A					
AGW203-6	80	D	On-site CMT	Staging area btwn Bldgs 17-07 & 17-06	SA	X	A					
AGW204	--	I	On-site	In grass NW of Bldg 17-08	A	X	A					
AGW205	--	I	On-site	In pavement NW of Bldg 17-13	A	X	A					
AGW206	--	I	On-site	In parking area E of Bldg 17-10	SA	X	A					
AGW207-2	30	S	Offsite CMT	Outlet Collection parking lot SW corner	SA	X	X					
AGW207-4	49	I	Offsite CMT	Outlet Collection parking lot SW corner	SA	X	X					
AGW207-7	80	D	Offsite CMT	Outlet Collection parking lot SW corner	SA	X	X					
AGW208-2	29	S	Offsite CMT	Outlet Collection parking lot across from Taco Del Mar	SA	X		X (c) + nitrate				
AGW208-4	49	I	Offsite CMT	Outlet Collection parking lot across from Taco Del Mar	SA	X	X	X (c) + nitrate				
AGW208-6	80	D	Offsite CMT	Outlet Collection parking lot across from Taco Del Mar	SA	X	A	X (c) + nitrate				
AGW209-2	30	S	Offsite CMT	Outlet Collection parking lot across from Starbucks	SA	X						
AGW209-5	60	I	Offsite CMT	Outlet Collection parking lot across from Starbucks	SA	X	X					
AGW209-6	80	D	Offsite CMT	Outlet Collection parking lot across from Starbucks	SA	X	X					
AGW210-2	30	S	Offsite CMT	Outlet Collection parking lot across from IHOP	A	X	X	X (c) + nitrate				
AGW210-5	60	I	Offsite CMT	Outlet Collection parking lot across from IHOP	SA	X	X	X (c) + nitrate				
AGW210-6	80	D	Offsite CMT	Outlet Collection parking lot across from IHOP	SA	X	A	X (c) + nitrate				
AGW211-2	30	S	Offsite CMT	Outlet Collection parking lot across from Red Robin	A	X	X					
AGW211-5	60	I	Offsite CMT	Outlet Collection parking lot across from Red Robin	SA	X	X					

Table 2
Phase VII Groundwater Monitoring Plan
June 2017 Sampling Matrix
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Well	CMT Channel Depth (ft)	Groundwater Zone	Description	Location	Phase VII Frequency	VOCs 8260 (a)	VOCs VC 8260 SIM (b)	NA Parameters (c)	Metals 200.8 (d)	Cyanide	TPH-D (e)(f)	TPH-G (g)
AGW211-6	80	D	Offsite CMT	Outlet Collection parking lot across from Red Robin	SA	X	A					
AGW212-2	30	S	Offsite CMT	Interurban Trail at 15th St SW	A	X	X					
AGW212-5	60	I	Offsite CMT	Interurban Trail at 15th St SW	SA	X	A					
AGW212-7	100	D	Offsite CMT	Interurban Trail at 15th St SW	SA	X	A					
AGW213	--	D	Offsite	S End of Lund Rd	SA	X	X					
AGW214	--	I	Offsite	S end Clay St, W side of street in parking lane next to driveway	SA	X	X					
AGW215	--	I	Offsite	W Main St access Rd, N side of road	SA	X	X	X (c) + nitrate				
AGW216	--	I	Offsite	H St, intersection with 2nd St W side	SA	X	A					
AGW217	--	I	Offsite	Clay St, halfway up W side	SA	X	X					
AGW218	--	I	Offsite	Western Ave W side, in grass next to sidewalk N of driveway	SA	X	X					
AGW219	--	I	Offsite	Clay St, W side of cul-de-sac at N end	SA	X	X					
AGW220	--	I	Offsite	Western Ave, N end	SA	X	X					
AGW221	--	I	Offsite	H St intersection w/6th, W side in gravel	SA	X	X					
AGW222	--	I	On-site	Inside Bldg 17-06	SA	X	A					
AGW223	--	D	On-site	Scrubber Alley	A	X	X					
AGW224	--	S (WT)	Offsite	O St at Boundary Blvd	A	X	A	X (c) + nitrate				
AGW225	--	S (WT)	Offsite	Chicago Ave & 10th Ave, Algona	Q	X	X	X (c)				
AGW226	--	S (WT)	Offsite	11th Ave, Algona	Q	X	X	X (c)				
AGW227	--	I	Offsite	W end of Boundary Blvd	SA	X	X					
AGW228	--	S	Offsite	W end of Boundary Blvd	SA	X	X					
AGW229	--	S (WT)	Offsite	Boundary Blvd	SA	X	X					
AGW230	--	D	Offsite	8th St at cul-de-sac	SA	X	A					
AGW231	--	S	Offsite	Outlet Collection-N of Marshalls	SA	X						
AGW232	--	S	Offsite	Outlet Collection-delivery area, W side	SA	X						

Table 2
Phase VII Groundwater Monitoring Plan
June 2017 Sampling Matrix
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Well	CMT Channel Depth (ft)	Groundwater Zone	Description	Location	Phase VII Frequency	VOCs 8260 (a)	VOCs VC 8260 SIM (b)	NA Parameters (c)	Metals 200.8 (d)	Cyanide	TPH-D (e)(f)	TPH-G (g)
AGW233	--	D	Offsite	Interurban Trail, N side of SR 18	SA	X	A					
AGW234	--	D	Offsite	Access road to Outlet Collection stormwater ponds	SA	X	X	X (c) + nitrate				
AGW235-2	19	S	Offsite CMT	Access road to Outlet Collection stormwater ponds	SA	X	X					
AGW235-4	39	I	Offsite CMT	Access road to Outlet Collection stormwater ponds	SA	X	X					
AGW235-7	71	D	Offsite CMT	Access road to Outlet Collection stormwater ponds	SA	X	A					
AGW236	--	S	Offsite	Coastal Farm & Ranch Parking Lot	SA	X	X	X (c) + nitrate				
AGW237	--	D	Offsite	Auburn School District, NW corner of property	SA	X	X					
AGW238	--	I	Offsite	Auburn School District, NW corner of property	SA	X	X					
AGW239	--	S	Offsite	Auburn School District, NW corner of property	SA	X	X					
AGW240-1	7	S (WT)	Offsite CMT	Chicago Ave & 9th Ave, Algona	Q	X	X	X (c)				
AGW240-5	28	S	Offsite CMT	Chicago Ave & 9th Ave, Algona	Q	X	X	X (c)				
AGW241-1	6	S (WT)	Offsite CMT	Chicago Ave & 8th Ave, Algona	SA	X	X					
AGW241-5	27	S	Offsite CMT	Chicago Ave & 8th Ave, Algona	SA	X	X					
AGW242-1	6	S (WT)	Offsite CMT	10th Ave N & Algona Blvd, Algona	SA	X	X					
AGW242-2	16	S	Offsite CMT	10th Ave N & Algona Blvd, Algona	SA	X	A					
AGW242-5	60	I	Offsite CMT	10th Ave N & Algona Blvd, Algona	SA	X	A					
AGW243-1	6	S (WT)	Offsite CMT	Boundary Blvd & Algona Blvd, Algona	SA	X	X	X (c) + nitrate				
AGW243-3	25	S	Offsite CMT	Boundary Blvd & Algona Blvd, Algona	SA	X	A	X (c) + nitrate				
AGW243-5	50	I	Offsite CMT	Boundary Blvd & Algona Blvd, Algona	SA	X	A	X (c) + nitrate				
AGW244	--	S (WT)	Offsite	Celery Ave & 9th Ave, Algona	Q	X	X	X (c) + nitrate				
AGW245	--	S (WT)	Offsite	11th Ave btwn Algona Blvd & Celery Ave, Algona	SA	X	X					
AGW246	--	S (WT)	Offsite	Celery Ave btwn 11th Ave & 10th Ave, Algona	SA	X	X					
AGW247-1	6	S (WT)	Offsite CMT	10th Ave E of Algona Blvd, Algona	Q	X	X	X (c)				
AGW247-5	27	S	Offsite CMT	10th Ave E of Algona Blvd, Algona	Q	X	X	X (c)				

Table 2
Phase VII Groundwater Monitoring Plan
June 2017 Sampling Matrix
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Well	CMT Channel Depth (ft)	Groundwater Zone	Description	Location	Phase VII Frequency	VOCs 8260 (a)	VOCs VC 8260 SIM (b)	NA Parameters (c)	Metals 200.8 (d)	Cyanide	TPH-D (e)(f)	TPH-G (g)
AGW248-1	5	S (WT)	Offsite CMT	Chicago Ave & 11th Ave, Algona	SA	X	X					
AGW248-5	26	S	Offsite CMT	Chicago Ave & 11th Ave, Algona	SA	X	X					
AGW249-1	8	S (WT)	Offsite CMT	Boundary Blvd, Algona	SA	X	X					
AGW249-5	29	S	Offsite CMT	Boundary Blvd, Algona	SA	X	X					
AGW250-1	9	S (WT)	Offsite CMT	Junction Blvd, Algona	SA	X	X					
AGW250-2	26	S	Offsite CMT	Junction Blvd, Algona	SA	X	X					
AGW250-3	41	I	Offsite CMT	Junction Blvd, Algona	SA	X	X					
AGW250-6	81	D	Offsite CMT	Junction Blvd, Algona	SA	X	X					
AGW251-1	8	S (WT)	Offsite CMT	Milwaukee Blvd, Algona	Q	X	X	X (c)				
AGW251-2	25	S	Offsite CMT	Milwaukee Blvd, Algona	Q	X	X	X (c)				
AGW251-3	40	I	Offsite CMT	Milwaukee Blvd, Algona	Q	X	X	X (c)				
AGW251-6	76	D	Offsite CMT	Milwaukee Blvd, Algona	SA	X	X					
AGW252	--	D	Offsite	N Access Rd, W Main St	SA	X	X					
AGW253	--	I	Offsite	N Access Rd, W Main St	A	X	X					
AGW254-1	6	S (WT)	Offsite CMT	S Access Rd, W Main St	SA	X	X					
AGW254-2	20	S	Offsite CMT	S Access Rd, W Main St	SA	X	X					
AGW254-5	50	I	Offsite CMT	S Access Rd, W Main St	SA	X	X					
AGW255-1	13	S (WT)	Offsite CMT	15th St SW, N of O St	SA	X	X	X (c) + nitrate				
AGW255-3	30	S	Offsite CMT	15th St SW, N of O St	SA	X	X	X (c) + nitrate				
AGW255-5	55	I	Offsite CMT	15th St SW, N of O St	SA	X	X	X (c) + nitrate				
AGW256	--	I	Offsite	GSA, S of NW Building	SA	X	A					
AGW257	--	S	Offsite	GSA, S of NW Building	SA	X	A					
AGW258	--	S	Offsite	GSA, N of NW Building	SA	X	A					
AGW259	--	D	Offsite	S Access Rd, W Main St	SA	X	X					

Table 2
Phase VII Groundwater Monitoring Plan
June 2017 Sampling Matrix
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Well	CMT Channel Depth (ft)	Groundwater Zone	Description	Location	Phase VII Frequency	VOCs 8260 (a)	VOCs VC 8260 SIM (b)	NA Parameters (c)	Metals 200.8 (d)	Cyanide	TPH-D (e)(f)	TPH-G (g)
AGW260	--	D	Offsite	10th Ave N & Algona Blvd, Algona	SA	X	X					
AGW261	--	S	Offsite	S end of Milwaukee Blvd, Algona	SA	X	X	X (c) + nitrate				
AGW262	--	S(WT)	Offsite	11th Ave, Algona	Q	X	X					
AGW263	--	S(WT)	Offsite	Chicago Ave & 10th Ave, Algona	Q	X	X					
AGW264	--	D	Offsite	Chicago Ave & 9th Ave, Algona	SA	X	X					
AGW265	--	I	Offsite	Chicago Ave & 9th Ave, Algona	SA	X	X					
AGW266	--	S	Offsite	Lund Rd at Main St	SA	X	X					
AGW267	--	I	Offsite	7th Ave & Celery Ave, Algona	SA	X	X					
AGW268	--	D	Offsite	7th Ave & Celery Ave, Algona	SA	X	X					
AGW269	--	S	Offsite	Primus, E of Warehouse	Q	X	X	X (c)				
AGW270	--	S	Offsite	Primus, E of Warehouse	Q	X	X	X (c)				
AGW271	--	S	Offsite	Primus, E of Warehouse	Q	X	X	X (c)				
AGW272	--	S	Offsite	Primus, W of Warehouse	Q	X	X	X (c)				
AGW273	--	S	Offsite	Primus, W of Warehouse	Q	X	X	X (c)				
AGW274	--	S	Offsite	Primus, W of Warehouse	Q	X	X	X (c)				
AGW275	--	S	Offsite	Primus, W of Warehouse	Q	X	X	X (c)				
AGW276-2	25	S	Offsite CMT	DCT Industrial	SA	X	X	X (c) + nitrate				
AGW276-5	60	I	Offsite CMT	DCT Industrial	SA	X	X	X (c) + nitrate				
AGW276-6	80	D	Offsite CMT	DCT Industrial	SA	X	X	X (c) + nitrate				
IW34	--	S	Offsite	Primus, E of Warehouse	Q	X	X	X (c)				
IW36	--	S	Offsite	Primus, E of Warehouse	Q	X	X	X (c)				
IW37	--	S	Offsite	Primus, E of Warehouse	Q	X	X	X (c)				
APP-057	--	S	WSDOT well - offsite	E of W Valley Hwy, S of W Main St	SA	X	X					

Table 3
Soil Boring and Sampling Matrix
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Location ID	Description	Total Exploration Depth	Drilling Technology	Soil Samples (a)	Groundwater Samples (b)
AOC A-01					
P-1	Near historical boring location B-5	20 ft	Direct-Push	TPH-D (c), TPH-G (d) + BTEX	TPH-D (c), TPH-G (d) + BTEX
P-2	Near historical boring location B-4	20 ft	Direct-Push	TPH-D (c), TPH-G (d) + BTEX	TPH-D (c), TPH-G (d) + BTEX
P-3	North west corner of the historical excavation area	20 ft	Direct-Push	TPH-D (c), TPH-G (d) + BTEX	TPH-D (c), TPH-G (d) + BTEX
P-4	South (upgradient) of AGW010	20 ft	Direct-Push	TPH-D (c), TPH-G (d) + BTEX	TPH-D (c), TPH-G (d) + BTEX
P-5	Near historical boring location B-2	20 ft	Direct-Push	TPH-D (c), TPH-G (d) + BTEX	TPH-D (c), TPH-G (d) + BTEX
P-6	Near AGW011	20 ft	Direct-Push	TPH-D (c), TPH-G (d) + BTEX	TPH-D (c), TPH-G (d) + BTEX
AOC A-13					
P-7	South of AGW128	20 ft	Rotosonic	TPH-D (c)	TPH-D (c) (e)
P-8	Southwest of AGW128	20 ft	Rotosonic	TPH-D (c)	TPH-D (c) (e)
P-9	10 ft north-northwest of AGW128	20 ft	Rotosonic	TPH-D (c)	TPH-D (c) (e)
P-10	60 ft north-northwest of AGW128	20 ft	Rotosonic	TPH-D (c)	TPH-D (c) (e)
P-11	CONTINGENT: 12 ft west of P-9	20 ft	Rotosonic	TPH-D (c)	TPH-D (c) (e)
P-12	CONTINGENT: 55 ft north-northwest of P-9	20 ft	Rotosonic	TPH-D (c)	TPH-D (c) (e)

Notes:

(a) If field screening indicates no evidence of contamination, one sample will be collected from directly above the water table. If contamination is encountered in a boring, one sample will be collected from the area with the highest apparent contamination and one will be collected below the contamination.

(b) One duplicate sample will be collected per 20 water samples.

(c) Analyzed by Method NWTPH-Dx

(d) Analyzed by Method NWTPH-Gx

(e) A Groundwater sample will be collected from a temporary screen at each boring location, excepting those locations identified for installation of a permanent monitoring well.

1. For Method NWTPH-Dx, containers used for soil samples were 8-oz glass jars and containers used for groundwater samples were two, 1-L amber glass jars.
2. For Method NWTPH-Gx + BTEX, containers used for soil samples: two, 40-mL VOA vials with CH^3OH. Containers used for groundwater samples: three, 40-mL VOA vials with HCl.

Abbreviations/Acronyms:

AOC = area of concern
BTEX = benzene, toluene, ethyl-benzene and total xylenes by Method 8260C
CH3OH = methanol
ft = feet
HCl = hydrochloric acid
ID = identification
L = liter
mL = milliliter
NWTPH-Dx = diesel-range petroleum hydrocarbons by Method NWTPH-Dx
NWTPH-Gx = gasoline-range petroleum hydrocarbons by Method NWTPH-Gx
oz = ounce
TPH-D = diesel-range total petroleum hydrocarbon
TPH-G = gasoline-range total petroleum hydrocarbon
VOA = volatile organic analysis

Table 4
Monitoring Well Installation Matrix
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Location ID	Description	Well Type	Total Exploration Depth	Screen Depth(s)
AOC A-13				
A(S)	Possible boring converted to monitoring well, depending on field screening results. East side of Building 17-07 near monitoring well AGW128.	Conventional Shallow Zone	20 ft	10 to 20 ft
B(S)	Possible boring converted to monitoring well, depending on field screening results. East side of Building 17-07 near monitoring well AGW128.	Conventional Shallow Zone	20 ft	10 to 20 ft
AOC A-14				
C(M)	Located in the tank line area of Building 17-07. Exact location to be determined based on results of sub-slab soil gas sampling.	Multilevel	90 ft (a)	(b)
D(M)	Possible multilevel well to be installed depending on results of sub-slab soil gas sampling. Location between Columns E2 and E3 of Building 17-07.	Multilevel	90 ft (a)	(b)
E(M)	Possible multilevel well to be installed depending on results of sub-slab soil gas sampling. Location near Column B4 of Building 17-07.	Multilevel	90 ft (a)	(b)

Notes:

(a) Total exploration depth may be adjusted depending on the depth of the Osceola Mudflow deposit. Total depth will be until reaching the Osceola Mudflow or a maximum depth of 110 ft bgs.

(b) Screen depths will be determined based on field screening results. Seven screen intervals will be selected with at least one screened interval installed in each groundwater zone: shallow zone (5 to 35 ft bgs), intermediate zone (35 to 75 ft bgs), deep zone (75 to 105 ft bgs).

Abbreviations/Acronyms:

bgs = below ground surface
ft = feet
ID = identification

Table 5
Soil Gas Sample Locations
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Location ID	Description
AOC A-14 (Building 17-07)	
SG-1	Tank Line: Approximate location of former vapor degreaser (basement)
SG-2	Tank Line: Approximate location of former vapor degreaser (basement)
SG-3	Tank Line: Adjacent to SSV-28
SG-4	Tank Line: Approximate location of former vapor degreaser (basement)
SG-5	Tank Line: Adjacent to former chromium sump (basement)
SG-6	Tank Line: North of SSV-28
SG-7	Tank Line: Adjacent to SSV-29
SG-8	Tank Line: Adjacent to AGW165
SG-9	Tank Line: In aisle way northwest of AGW165
SG-10	Tank Line: South of SSV-31
SG-11	Tank Line: South of AGW037
SG-12	Column E3: Northeast SSV-17
SG-13	Column E3: Northwest of SSV-17
SG-14	Column E3:Southwest of SSV-17
SG-15	Column E3: Adjacent to SSV-17
SG-16	Column E3: Southeast of SSV-17
SG-17	Column B4: West of former M90 vapor degreaser
SG-18	Column B4: Adjacent to former M90 vapor degreaser
SG-19	Column B4: East of former M90 vapor degreaser
SG-20	Column B4:North of former M90 vapor degreaser

Location ID	Description
AOC A-14 (Former Building 17-03)	
SG-21	South of Former Building 17-03, adjacent to Chrome Waste Line sample location 19.
SG-22	South of Former Building 17-03, sourth of former tank line area.
SG-23	Former Building 17-03 Tank Line Area, adjacent to former sump.
SG-24	Former Building 17-03 Tank Line Area, adjacent to groundwater sample location SS-33.
SG-25	Former Building 17-03 Tank Line Area, north of former degreaser tank pit.
SG-26	Former Building 17-03, northwest of former degreaser tank pit.

Abbreviations/Acronyms:

AOC = area of concern
ID = identification

Notes:

1. Sub-slab soil gas sampling locations in the basement of Building 17-07 will be temporary. All other sub-slab soil gas sampling locations in Building 17-07 will be installed as permanent locations. Soil gas sampling locations at former Building 17-03 will be temporary.
2. All soil gas sampling locations will be sampled using a 1 Liter Summa Canister and analyzed for a short-list of VOCs using EPA Method TO-15.
3. Analyte list and laboratory target Limits of Quantitation (LOQs):

Analyte (abbreviation)	Laboratory Target LOQ (µg/m^3)
1,1,1-Trichloroethane (1,1,1-TCA)	1.64
1,1,2,2-Tetrachloroethane (1,1,2,2-TeCA)	2.75
1,1,2-Trichloroethane (1,1,2-TCA)	2.18
1,1-Dichloroethane (1,1-DCA)	1.21
1,1-Dichloroethene (1,1-DCE)	3.17
cis-1,2-Dichloroethene (cDCE)	1.59
Tetrachloroethene (PCE)	2.71
trans-1,2-Dichlorethene (tDCE)	1.59
Trichloroethene (TCE)	2.15
Vinyl Chloride (VC)	1.02

Table 6
Rationale for Proposed Monitored Natural Attenuation Sampling Locations
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Well	Zone	MAROS Concentration Trend	NA Assessment Previously Completed?	Co-Located Wells to be evaluated
AGW027	S	PI	No	AGW156(I), AGW200-2(S), AGW200-5(I), AGW200-6(D), AGW201-2(S), AGW201-5(I), AGW201-6(D), AGW202-2(S), AGW202-4(I), AGW202-6(D) (a)
AGW035	D	PI	No	AGW033(S)
AGW037	S	I	No	NA
AGW105	I	I	No	NA
AGW144	I	PI	No	AGW143(D)
AGW163	I	PI	Yes	NA
AGW165	S	I	No	AGW164(I)
AGW166	I	I	Yes	NA
AGW182	I	PI	No	AGW183(D), AGW224(WT)
AGW199	D	I	No	AGW176(I)
AGW209-5	I	I	Yes	N/A
AGW232	S	I	Yes	N/A
AGW234	D	I	No	N/A
AGW235-2	S	I	Yes	N/A
AGW235-4	I	I	Yes	N/A
AGW239	S	I	Yes	N/A
AGW247-1	S	PI	Yes	AGW243-1(WT), AGW243-3(S), AGW243-5(I) (b)
AGW255-5	I	I	No	AGW255-1(WT), AGW255-3(S)
AGW261	S	PI	No	N/A
AGW276-6	D	I	No	AGW276-2(S), AGW276-6(D)

Note:

(a) AGW202-2, AGW202-4, and AGW202-6 were added by request of Ecology.
(b) AGW243 was selected because it is downgradient from AGW247.

Abbreviations/Acronyms:

NA = natural attenuation
N/A = not applicable
MAROS = Monitoring and Remediation Optimization System

MAROS Trend

I = increasing
PI = possibly increasing

Zone

D = deep
I = intermediate
S = shallow

Table 7
Surface Water Sampling Matrix
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Surface Water Body	Sample ID	Sample Location Description	Mar	Sept
Surface Water Samples				
Chicago Avenue ditch	SW-CD4	At the intersection of Chicago Avenue and 11th Avenue North.	X	X
Auburn 400 south pond	SW-14	Stormwater inlet structure discharge pipe located at southeast corner of pond.		X
Auburn 400 north pond	SW-16	Near previous SW-11 along southeastern edge of pond where access allows.		X
Auburn 400 north pond outflow	SW-17	Stormwater outflow culvert from the Auburn 400 north pond to the wetland on the west side of SR 167.		X
Wetlands west of SR 167 to Mill Creek	SW-20	Before the channelized portion of the wetland west of SR 167 connects with Mill Creek just south of the intersection of Peasley Canyon Road South with the West Valley Highway near SR 18.		X
Mill Creek	SW-18	Channelized portion of Mill Creek where it passes beneath the south side of West Main Street via a box culvert.	X	X
Mill Creek, north of SR 167	SW-27	Channelized portion of Mill Creek where it passes beneath the north side of West Main Street via a box culvert.		X
Pore Water Samples				
Mill Creek	PW-18a-2.5	Channelized portion of Mill Creek where it passes beneath the south side of West Main Street via a box culvert. Screened from 1.5 to 2.5 ft bgs.		X
Mill Creek	PW-18a-5	Channelized portion of Mill Creek where it passes beneath the south side of West Main Street via a box culvert. Screened from 4 to 5 ft bgs.		X
Mill Creek	PW-18b-2.5	Approximately 50 meters south of W Main Street, on east side of Mill Creek. Screened form 1.5 - 2.5 ft bgs.		X
Mill Creek	PW-18b-5	Approximately 50 meters south of W Main Street, on east side of Mill Creek. Screened from 4 to 5 ft bgs.		X
Mill Creek, north of SR 167	PW-27-2.5	Channelized portion of Mill Creek where it passes beneath the north side of West Main Street via a box culvert. Screened from 1.5 to 2.5 ft bgs.		X
Mill Creek, north of SR 167	PW-27-5	Channelized portion of Mill Creek where it passes beneath the north side of West Main Street via a box culvert. Screened from 4 to 5 ft bgs.		X

Notes:

1. Field parameters pH, conductivity, DO, temperature, and ORP will be collected at all sample locations.
2. All surface water samples will be analyzed by EPA Method 8260 (standard Boeing VOC list) and EPA Method 8260 SIM (for VC only).

Abbreviations/Acronyms:

bgs = below ground surface
DO = dissolved oxygen
ft = feet
ID = identification
Mar = March
ORP = oxidation-reduction potential
PW = pore water
Sept = September
SIM = selected ion method
SR = State Route
SW = surface water
SW-CD = surface water Chicago Avenue ditch
EPA = US Environmental Protection Agency
VC = vinyl chloride
VOC = volatile organic compound

Table 8
Indicator Hazardous Substances
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Media	Indicator Hazardous Substance	Carcinogen/ Non-Carcinogen
Soil	Trichloroethene	Carcinogen and Non-Carcinogen
	Antimony	Non-Carcinogen
	Cadmium	Non-Carcinogen
	Cyanide	Non-Carcinogen
	Diesel-Range Organics	(a)
	Oil-Range Organics	(a)
	Gasoline-Range Organics	(a)
Groundwater	Trichloroethene	Carcinogen and Non-Carcinogen
	Vinyl Chloride	Carcinogen and Non-Carcinogen
	Cadmium	Non-Carcinogen
	Diesel-Range Organics	(a)
	Oil-Range Organics	(a)
	Gasoline-Range Organics	(a)
Surface Water	Trichloroethene	Carcinogen and Non-Carcinogen
	Vinyl Chloride	Carcinogen and Non-Carcinogen

Note:

(a) Model Toxics Control Act Method A cleanup level is used because insufficient toxicity data is available for evaluation of either carcinogenic or non-carcinogenic effects of petroleum hydrocarbons.

Table 9
Cleanup Technologies Screening
Site-Wide Groundwater Downgradient of Source Areas

Site Physical Conditions: Includes plume areas downgradient of source area including areas off Boeing property. Constituents of concern (COCs) are **trichloroethene (TCE) and vinyl chloride (VC)**. Soils are generally highly permeable sands and gravels with some interbedded silt layers. The groundwater table is present near the ground surface at depths ranging from 0 to 15 feet (ft) below ground surface (bgs). Groundwater hydraulic conductivity averages approximately 300 ft per day, but is higher in some areas. Average seepage velocities were calculated using numerical groundwater modeling at approximately 300 ft per year from the Facility to Mill Creek; however, tracer testing showed seepage velocities in some areas to be much higher (up to 5,000 ft per year in some areas). The aquifer thickness ranges from approximately 60 ft to 90 ft thick. COCs are present throughout the thickness of the aquifer. Groundwater chemistry generally indicates reducing conditions, though some areas are more highly reduced than others are. Presence of VC and ethene indicate that natural reductive dechlorination is occurring.

General Response Actions	Technology Option	Area of Applicability	General Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
				Effectiveness	**Implementability**	**Relative Cost**	
			GROUNDWATER				
In-Situ Biological Treatment	Enhanced Bioremediation	Property boundary, Perimeter Rd	**Benefits**: Treat groundwater at multiple depths; can use injection/extraction to create overlap between wells (overlapping treatment zones form a pseudo barrier). **Limitations:** Limited downgradient treatment zone. Potential to increase VC concentrations downgradient (VC is a more toxic by-product of TCE degradation). Recontamination from upgradient source areas.	**Moderate** Demonstrated effectiveness for reductive dechlorination of COCs at Site. Building 17-05 remediation and Algona pilot study demonstrated bioremediation is effective at reducing COC concentrations. However, VC has been an ongoing issue in the pilot study area, potentially due to recontamination from upgradient sources.	**Moderate** Requirement for repeated injections due to recontamination from upgradient sources. Required length of treatment (>1,000 ft) is excessive. Fast seepage velocities reduce the duration of effective treatment.	**Direct: High** (Includes engineering; well installation; injection fluid, labor, and equipment for multiple injections) **Long Term (operation, monitoring, and maintenance [OMM]): Low** (groundwater monitoring) **Overall: Moderate to High**	Retain
	Enhanced Bioremediation	Downgradient of Property Boundary	**Benefits**: Can be utilized at hot spots or areas of particular concern (i.e. near residential areas). Can inject at multiple depths. **Limitations:** Reductive dechlorination may result in increased VC concentrations downgradient of injection zones. Recontamination from upgradient source areas. Potential for injection fluid to discharge to and adversely impact surface water.	**Moderate** Demonstrated effectiveness for reductive dechlorination of COCs at Site. Building 17-05 remediation and Algona pilot study demonstrated bioremediation is effective at reducing COC concentrations. However, VC has been an ongoing issue in the pilot study area, potentially due to recontamination from upgradient sources.	**Difficult** Buildings, utilities, and other off-property infrastructure limit or prohibit installation of injection wells and equipment in relevant locations, which increases the difficulty of implementation. The presence of nearby surface water may be prohibitive because of the potential to adversely impact surface water quality (the high organic content of injection fluid has a potential to create high biological oxygen demand, which is harmful to aquatic organisms). Would require third party access. Plume is more diffuse both vertically and horizontally in downgradient areas, which would require extensive injection networks and excessive quantities of donor.	**Direct: High** (Includes engineering; well installation; injection fluid, labor, and equipment for multiple injections) **LONG TERM (OMM): Low** (groundwater monitoring) **Overall: Moderate to High**	Retain
	Monitored natural attenuation (MNA)	Property boundary and downgradient areas	**Benefits:** Treats entire plume (both vertical and horizontal); destruction of contaminants. Can be combined with other technologies. Low cost of implementation. **Limitations:** Variable degradation rates; longer restoration timeframe than more active alternatives.	**Moderate to High** Site has demonstrated COC destruction through natural attenuation. Effectiveness is limited by variable natural degradation rates.	**Easy** The existing monitoring network is extensive, so construction costs would be low. Life-span of option is much longer than other technologies.	**Direct: Low** **LONG TERM (OMM): Moderate** **Overall: Low to Moderate**	Retain

Table 9
Cleanup Technologies Screening
Site-Wide Groundwater Downgradient of Source Areas

Site Physical Conditions: Includes plume areas downgradient of source area including areas off Boeing property. Constituents of concern (COCs) are **trichloroethene (TCE) and vinyl chloride (VC)**. Soils are generally highly permeable sands and gravels with some interbedded silt layers. The groundwater table is present near the ground surface at depths ranging from 0 to 15 feet (ft) below ground surface (bgs). Groundwater hydraulic conductivity averages approximately 300 ft per day, but is higher in some areas. Average seepage velocities were calculated using numerical groundwater modeling at approximately 300 ft per year from the Facility to Mill Creek; however, tracer testing showed seepage velocities in some areas to be much higher (up to 5,000 ft per year in some areas). The aquifer thickness ranges from approximately 60 ft to 90 ft thick. COCs are present throughout the thickness of the aquifer. Groundwater chemistry generally indicates reducing conditions, though some areas are more highly reduced than others are. Presence of VC and ethene indicate that natural reductive dechlorination is occurring.

General Response Actions	Technology Option	Area of Applicability	General Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
				Effectiveness	**Implementability**	**Relative Cost**	
In-Situ Physical/Chemical Treatment (passive/reactive treatment wall)	Air Sparge (AS) with overlying soil vapor extraction (SVE) in vadose zone (AS/SVE)	Property boundary and downgradient areas	**Benefits:** Technology is well-documented for treating volatile organic compounds (VOCs). Permanently removes volatile contaminants from soil and groundwater. Removal rates are relatively fast. **Limitations:** May reduce existing potential for natural reductive dechlorination in zones treated. Depth limited by engineering/technology constraints. Preferential flow paths may limit complete cleanup of impacted soil/groundwater in lower permeability zones.	**Low** Treat groundwater before it moves off property. Cannot treat full thickness of contaminated aquifer. Can result in aquifer clogging or plugging due to iron precipitation or biofouling caused by introduction of oxygen into reduced aquifer conditions.	**Difficult** Depth of treatment required at property boundary is not conducive to AS/SVE. May have high operating and maintenance costs due to biofouling and metal precipitation, because of Site's reducing conditions.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
	Chemical treatment permeable reactive barrier (PRB) using emplaced or injected material (reductive; e.g., zero valent iron)	Property boundary and downgradient areas	**Benefits:** Passive treatment requiring little maintenance; can treat groundwater at multiple depths; can target wide range of contaminants. **Limitations:** Temporary treatment – Typically requires refreshing barrier periodically; fast seepage velocities increase the width of required treatment and may reduce the duration of effective treatment; potential for biofouling, clogging of aquifer matrix.	**Moderate** Treat groundwater before it leaves the property; lifespan of a PRB may be reduced by high seepage velocity or may require increased width (increased cost). Does not treat downgradient plume except through dilution/dispersion.	**Difficult** Length of barrier needed would be extensive; thickness of barrier may be excessive to enable sufficient residence time due to high seepage velocity; Likely a requirement to replace or refresh barrier periodically.	**Direct: High** **LONG TERM (OMM): Low** **Overall: Moderate to High**	Retain
	Chemical treatment PRB via injected media (oxidative; e.g., permanganate)	Property boundary and downgradient areas	**Benefits:** Smaller construction footprint for installation than an emplaced PRB; can target multiple depths; ability to vary reageant. **Limitations:** Mass loading may be excessive in reduced aquifers with high seepage velocity and reduce longevity and effectiveness; oxidative potential generally inverse to longevity of treatment; typically requires repeated injections.	**Low** Treat groundwater before it moves off property. Aquifer is naturally reducing and, consequently, treatment would be short-lived and have limited effect. Preferential flow paths in groundwater may inhibit distribution of injected media in total treatment area and oxidation of groundwater would diminish reductive biological dechlorination activity in treatment area and downgradient. Does not treat downgradient plume except through dilution/dispersion.	**Difficult** Mass loading may be excessive due to high seepage velocity and natural oxidant demand making the implementation difficult and costly.	**Direct: High** (Includes engineering; well installation; injection fluid, labor, and equipment for multiple injections) **LONG TERM (OMM): low** (groundwater monitoring) **Overall: High**	Reject

Table 9
Cleanup Technologies Screening
Site-Wide Groundwater Downgradient of Source Areas

Site Physical Conditions: Includes plume areas downgradient of source area including areas off Boeing property. Constituents of concern (COCs) are **trichloroethene (TCE) and vinyl chloride (VC)**. Soils are generally highly permeable sands and gravels with some interbedded silt layers. The groundwater table is present near the ground surface at depths ranging from 0 to 15 feet (ft) below ground surface (bgs). Groundwater hydraulic conductivity averages approximately 300 ft per day, but is higher in some areas. Average seepage velocities were calculated using numerical groundwater modeling at approximately 300 ft per year from the Facility to Mill Creek; however, tracer testing showed seepage velocities in some areas to be much higher (up to 5,000 ft per year in some areas). The aquifer thickness ranges from approximately 60 ft to 90 ft thick. COCs are present throughout the thickness of the aquifer. Groundwater chemistry generally indicates reducing conditions, though some areas are more highly reduced than others are. Presence of VC and ethene indicate that natural reductive dechlorination is occurring.

General Response Actions	Technology Option	Area of Applicability	General Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
				Effectiveness	Implementability	Relative Cost	
	Thermal treatment	Property boundary and downgradient areas	**Benefits:** Removal of contaminants through volatilization; does not directly influence redox conditions. **Limitations:** Energy-intensive, requires extensive above-ground infrastructure, typically most effective in source zones only.	**Low** Effectiveness is dependent on ability to transfer enough heat to groundwater to vaporize COCs. High seepage velocity may limit heat transfer and, therefore, treatment effectiveness.	**Difficult** Depth of treatment required at property boundary and downgradient areas combined with relatively low contaminant concentrations are not conducive to thermal treatment; energy demands would be excessive due to high seepage velocity and aquifer thickness; potential to damage adjacent utilities.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
Enhanced Groundwater Flushing	Dynamic groundwater recirculation	Property boundary and downgradient areas	**Benefits:** Complete treatment of extracted groundwater. Potential to vary groundwater flow paths and remove contaminants from zones of lower hydraulic conductivity. Faster restoration time than pump and treat. **Limitations:** Would require above-ground treatment before reinjection; potential to cause ground settlement and damage to nearby structures buildings, utilities, and other infrastructure in areas with poor soils and high water tables. In reduced aquifers, potential for biofouling increases OMM cost; larger treatment system footprint than in-situ technologies.	**Moderate to Low** Effectiveness has not been thoroughly demonstrated yet, particularly on low concentration plumes, because dynamic groundwater recirculation (DGR) is a relatively new cleanup technology. Theoretically, more effective than pump and treat.	**Difficult** Excessive pumping/discharge rates needed to influence groundwater flow due to high seepage velocity and aquifer thickness; buildings, utilities, and other infrastructure may limit or prohibit extraction and injection in “ideal” locations.	**Direct: High** **LONG TERM (OMM): High** (potentially shorter lifespan than pump and treat [P&T]) **Overall: High**	Retain
Ex-Situ Physical/Chemical Treatment	Pump and treat (various *ex-situ* treatment options)	Property boundary and downgradient area	**Benefits:** Complete treatment of extracted groundwater. **Limitations:** Potential to cause ground settlement and damage to nearby structures buildings, utilities, and other infrastructure in areas with poor soils and high water tables. In reduced aquifers, potential for biofouling; high extraction rates needed in aquifers with hydraulic conductivity; need for discharge permits to discharge large volume of water to sewer or surface water; larger treatment system footprint than in-situ technologies.	**Low** Pump and treat effectiveness decreases as contaminant concentrations decrease. Typically not very effective for low-concentration plumes. Potential for problems with rebound once system is turned off.	**Difficult** Excessive pumping/discharge rates needed to influence groundwater flow due to high seepage velocity, and aquifer thickness; buildings, utilities, and other infrastructure may limit or prohibit extraction in “ideal” locations.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
Containment (physical)	Slurry walls, low-permeability barrier walls, or sheet pile walls	Property boundary	**Benefits:** Contains or slows contaminated groundwater from moving offsite. **Limitations:** Does not provide treatment; not a permanent remedy. Typically has low effectiveness in aquifers with high seepage velocities. Engineering constraints limit depth of barrier.	**Low** Not effective to contain contaminant plume with a physical barrier alone due to high seepage velocities and aquifer thickness.	**Difficult** Not feasible to contain contaminant plume with a physical barrier alone due to high seepage velocities and aquifer thickness.	**Direct: High** **LONG TERM (OMM): Low** **Overall: High**	Reject

Table 9
Cleanup Technologies Screening
Site-Wide Groundwater Downgradient of Source Areas

Site Physical Conditions: Includes plume areas downgradient of source area including areas off Boeing property. Constituents of concern (COCs) are **trichloroethene (TCE) and vinyl chloride (VC)**. Soils are generally highly permeable sands and gravels with some interbedded silt layers. The groundwater table is present near the ground surface at depths ranging from 0 to 15 feet (ft) below ground surface (bgs). Groundwater hydraulic conductivity averages approximately 300 ft per day, but is higher in some areas. Average seepage velocities were calculated using numerical groundwater modeling at approximately 300 ft per year from the Facility to Mill Creek; however, tracer testing showed seepage velocities in some areas to be much higher (up to 5,000 ft per year in some areas). The aquifer thickness ranges from approximately 60 ft to 90 ft thick. COCs are present throughout the thickness of the aquifer. Groundwater chemistry generally indicates reducing conditions, though some areas are more highly reduced than others are. Presence of VC and ethene indicate that natural reductive dechlorination is occurring.

				Site Specific Rankings			
General Response Actions	**Technology Option**	**Area of Applicability**	**General Benefits / Limitations**	**Effectiveness**	**Implementability**	**Relative Cost**	**Screening Result Retain/Reject**
Containment (hydraulic)	Interceptor trench or extraction wells	Property boundary	**Benefits:** Partially capture contaminants. **Limitations:** *Ex-situ* treatment needed; does not treat downgradient plume; potential to cause ground settlement and damage to nearby structures; potential for biofouling. Engineering constraints limit the depth of treatment.	**Low** More effective than physical containment alone, but limited in ability to affect deeper portions of the aquifer.	**Difficult** Depth of treatment needed is not conducive for interceptor trenches. Excessive pumping/discharge rates needed to capture groundwater due to high seepage velocity and aquifer thickness. Buildings, utilities, and other infrastructure may limit or prohibit extraction in “ideal” locations.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
Institutional Controls (off Boeing property)	Restrictive environmental covenant, signage, access agreements	Off Boeing Property	**Benefits:** Restrict use of/exposure to contaminated groundwater. Require engineering controls or signage. Provide access to downgradient properties for monitoring purposes. **Limitations:** Does not provide treatment. Requires agreement from third parties in off-property areas.	**Low to Moderate** Potential to require engineering or institutional controls at some properties. May be useful in limited situations. Not effective as a stand-alone solution for this Site.	**Difficult** Off-site property owners may not agree to environmental covenants. Excessive number of properties not owned by Boeing; access already restricted on Boeing-controlled property.	**Direct: Low** **LONG TERM (OMM): Low** **Overall: Low**	Retain

Table 10
Cleanup Technologies Screening
Area of Concern A-13
Building 17-06 Petroleum Hydrocarbon Release

Site Physical Conditions: Includes petroleum hydrocarbon contamination in soil and groundwater on the east side of Building 17-06 on Boeing property. Non-aqueous phase liquid (NAPL) is also present in a limited area at the water table surface. Constituents of concern (COCs) are **diesel-range organics (DRO) and oil-range organics (ORO).** The hydrocarbon mixture that is present in subsurface is not an exact match to products currently being used in the building, but is a close match to the hydraulic and gear oil products used in the building. These types of oil are engineered for thermal stability and to resist oxidation. Properties of the mixture present in the subsurface were estimated based on the properties from safety data sheets for the similar products being used currently in the building. Analysis of the hydrocarbon mixture in the subsurface by ASTM Method D2887-14 indicates it has a high boiling range from approximately 350 to 530 degrees Celsius. Estimated physical properties based on similar products indicate the hydrocarbon mixture has a density on the order of 7.1 to 7.3pounds [lbs] per gallons, low vapor pressure (<1 millimeter of mercury [mm Hg]), high viscosity (on the order of 30 to 400 centistokes (cSt) @ 40 degrees Celsius), and a high viscosity index (>100, meaning the viscosity is resistant to changes in temperature). Soil contamination is generally present from approximately 12 to 20 feet (ft) below ground surface (bgs). Groundwater contamination is present in the shallow zone (defined as from the water table to 35 ft bgs). Contamination is confined to a limited area beneath the footprint of the building. There is no opportunity for exposure due to soil and groundwater contamination being capped by the concrete slab beneath the building. The plume of groundwater contamination is also limited and does not appear to be migrating. The groundwater table varies seasonally and has been from approximately 9 to 18 ft bgs. Soils are generally highly permeable sands and gravels with some interbedded silt layers. Access to the area for investigation is restricted due to the presence of active mills and an aluminum chip conveyor system and sumps.

			Site Specific Rankings			
General Response Actions	**Technology Option**	**Benefits / Limitations**	**Effectiveness**	**Implementability**	**Relative Cost**	**Screening Result Retain/Reject**
SOIL AND GROUNDWATER						
Institutional Controls	Restrictive environmental covenant	**Benefits:** Prevent exposure. **Limitations:** Requires review indefinitely; restricts future property use and activity.	**Moderate to High** Contamination is limited and is not migrating. Area is already paved and currently there is no complete exposure pathway.	**Easy** Existing infrastructure currently prevents subsurface access.	**Direct: Low** **LONG TERM (operation, monitoring, and maintenance [OMM]): Low** **Overall: Low**	Retain
SOIL						
Physical Removal (Future, at time of Building Closure [more than a decade])	Excavation	**Benefits:** Permanent removal. **Limitations:** Offsite disposal required; depth limited by groundwater.	**High** Permanently removes contamination from Site soil.	**Difficult** Existing infrastructure currently prevents subsurface access.	**Direct: High** **LONG TERM (OMM): Low** **Overall: Moderate**	Retain
GROUNDWATER						
In-Situ Biological Treatment	Enhanced bioremediation (reductive; nitrate/sulfate)	**Benefits:** Normally less expensive than physical treatments; does not require ex-situ treatment infrastructure. Compatible with reduced aquifer conditions. **Limitations:** Only effective for dissolved phase, not effective for NAPL phase.	**Low** Effective with reduced aquifer conditions for dissolved phase, but not effective for NAPL phase. Substantial NAPL phase remains adsorbed to soil particles. Oil has high boiling range, low vapor pressure, and high viscosity that makes it resistant to biological degradation.	**Difficult** Hydraulic oils are difficult to biodegrade and would require an excessive amount of bioremediation fluid and number of injections. Risk associated with introduction of contaminants with groundwater criteria (nitrate maximum contaminant level [MCL] 10 milligrams per liter [mg/L]) could be problematic.	**Direct: High** **LONG TERM (OMM): Low** **Overall: Moderate to High**	Reject
	Enhanced bioremediation (oxidative; e.g., oxygen release compound [ORC])	**Benefits:** Relatively rapid. **Limitations:** Only effective for dissolved phase, not effective for NAPL phase.	**Low** Aquifer is naturally reducing and, consequently, treatment would be short-lived and have limited effect. Not effective for NAPL phase. Substantial NAPL phase remains adsorbed to soil particles. Oil has high boiling range, low vapor pressure, and high viscosity that makes it resistant to biological degradation.	**Difficult** Mass loading would be excessive due to natural oxidant demand. Would require repeated injections and performance monitoring.	**Direct: High** **LONG TERM (OMM): Low** **Overall: Moderate to High**	Reject

Table 10
Cleanup Technologies Screening
Area of Concern A-13
Building 17-06 Petroleum Hydrocarbon Release

Site Physical Conditions: Includes petroleum hydrocarbon contamination in soil and groundwater on the east side of Building 17-06 on Boeing property. Non-aqueous phase liquid (NAPL) is also present in a limited area at the water table surface. Constituents of concern (COCs) are **diesel-range organics (DRO) and oil-range organics (ORO).** The hydrocarbon mixture that is present in subsurface is not an exact match to products currently being used in the building, but is a close match to the hydraulic and gear oil products used in the building. These types of oil are engineered for thermal stability and to resist oxidation. Properties of the mixture present in the subsurface were estimated based on the properties from safety data sheets for the similar products being used currently in the building. Analysis of the hydrocarbon mixture in the subsurface by ASTM Method D2887-14 indicates it has a high boiling range from approximately 350 to 530 degrees Celsius. Estimated physical properties based on similar products indicate the hydrocarbon mixture has a density on the order of 7.1 to 7.3pounds [lbs] per gallons, low vapor pressure (<1 millimeter of mercury [mm Hg]), high viscosity (on the order of 30 to 400 centistokes (cSt) @ 40 degrees Celsius), and a high viscosity index (>100, meaning the viscosity is resistant to changes in temperature). Soil contamination is generally present from approximately 12 to 20 feet (ft) below ground surface (bgs). Groundwater contamination is present in the shallow zone (defined as from the water table to 35 ft bgs). Contamination is confined to a limited area beneath the footprint of the building. There is no opportunity for exposure due to soil and groundwater contamination being capped by the concrete slab beneath the building. The plume of groundwater contamination is also limited and does not appear to be migrating. The groundwater table varies seasonally and has been from approximately 9 to 18 ft bgs. Soils are generally highly permeable sands and gravels with some interbedded silt layers. Access to the area for investigation is restricted due to the presence of active mills and an aluminum chip conveyor system and sumps.

General Response Actions	Technology Option	Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
			Effectiveness	**Implementability**	**Relative Cost**	
	Monitored natural attenuation (MNA)	**Benefits:** Low cost relative to enhanced bioremediation. Natural attenuation may be limiting migration of dissolved-phase plume. **Limitations:** Not viable as a standalone remedy due to long restoration timeframe. Very limited effectiveness for NAPL phase.	**Low** Long restoration timeframe.	**Easy** Existing monitoring well network is sufficient for MNA.	**Direct: Low** **LONG TERM (OMM): Moderate** **Overall: Moderate to low**	Retain
In-Situ Physical/Chemical Treatment	Air sparge or ozone sparge with soil vapor extraction (SVE)	**Benefits:** Permanent removal of volatile contaminants; relatively fast restoration timeframe for contaminants with high volatile fraction. **Limitations:** Potential for aquifer clogging or plugging due to iron precipitation or biofouling caused by introduction of oxygen into reduced aquifer conditions. Not effective for non-volatile fractions; would not destroy non-volatile oil contaminants; not effective for NAPL fraction.	**Low** Would not be effective for the release in this area, because the oil has low volatile fraction and low vapor pressure, which prevents volatilization.	**Difficult** Requires significant in-situ and ex-situ footprint that is incompatible with existing Infrastructure inside the building.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
	Chemical oxidation	**Benefits:** Less expensive than air sparge (AS)/SVE; fast reaction rates. **Limitations:** less effective in naturally reducing aquifer conditions due to natural oxidant demand. Limited effectiveness on NAPL phase.	**Low** Pilot scale bench test results showed no effect on concentrations of DRO and ORO (see Appendix B).	**Difficult** Injection wells could be installed in existing available area; however, mass loading would be excessive due to natural oxidant demand. Would require repeated injection; aquifer is naturally reducing and, consequently, treatment would be short-lived.	**Direct: High** **LONG TERM (OMM): Low** **Overall: Moderate to High**	Reject
	Thermal treatment	**Benefits:** Potential to lower contaminant viscosity. **Limitations:** Typically effective primarily for volatile fraction. Would need to be combined with DPE and treatment of groundwater plume. Low volatile fraction; would not destroy contaminants; potential to increase dissolution and cause expansion of groundwater plume; potential for vapor intrusion.	**Low** Primarily effective for volatile fractions. Would likely decrease the viscosity of light non-aqueous phase liquid (LNAPL), which could lead to plume migration. Amount of recoverable LNAPL, even at higher viscosity, is negligible.	**Difficult** Would require other technologies to control plume migration extract product. Requires significant in-situ and ex-situ footprint that is incompatible with existing Infrastructure at the release location. Existing subsurface infrastructure is incompatible with thermal treatment.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject

Table 10
Cleanup Technologies Screening
Area of Concern A-13
Building 17-06 Petroleum Hydrocarbon Release

Site Physical Conditions: Includes petroleum hydrocarbon contamination in soil and groundwater on the east side of Building 17-06 on Boeing property. Non-aqueous phase liquid (NAPL) is also present in a limited area at the water table surface. Constituents of concern (COCs) are **diesel-range organics (DRO) and oil-range organics (ORO).** The hydrocarbon mixture that is present in subsurface is not an exact match to products currently being used in the building, but is a close match to the hydraulic and gear oil products used in the building. These types of oil are engineered for thermal stability and to resist oxidation. Properties of the mixture present in the subsurface were estimated based on the properties from safety data sheets for the similar products being used currently in the building. Analysis of the hydrocarbon mixture in the subsurface by ASTM Method D2887-14 indicates it has a high boiling range from approximately 350 to 530 degrees Celsius. Estimated physical properties based on similar products indicate the hydrocarbon mixture has a density on the order of 7.1 to 7.3pounds [lbs] per gallons, low vapor pressure (<1 millimeter of mercury [mm Hg]), high viscosity (on the order of 30 to 400 centistokes (cSt) @ 40 degrees Celsius), and a high viscosity index (>100, meaning the viscosity is resistant to changes in temperature). Soil contamination is generally present from approximately 12 to 20 feet (ft) below ground surface (bgs). Groundwater contamination is present in the shallow zone (defined as from the water table to 35 ft bgs). Contamination is confined to a limited area beneath the footprint of the building. There is no opportunity for exposure due to soil and groundwater contamination being capped by the concrete slab beneath the building. The plume of groundwater contamination is also limited and does not appear to be migrating. The groundwater table varies seasonally and has been from approximately 9 to 18 ft bgs. Soils are generally highly permeable sands and gravels with some interbedded silt layers. Access to the area for investigation is restricted due to the presence of active mills and an aluminum chip conveyor system and sumps.

General Response Actions	Technology Option	Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
			Effectiveness	Implementability	Relative Cost	
	Surfactant	**Benefits:** Reduce viscosity of high viscosity petroleum products. Mobilize contaminants for extraction. **Limitations:** Potential to increase dissolved fraction and cause expansion of groundwater plume.	**low** Surfactants would likely be effective in reducing viscosity of in-situ product; does not result in product destruction; increases the potential for expansion of dissolved-phase plume	**Difficult** Would require other technologies to control plume migration (hydraulic control) and recover product (DPE). Hydraulic control and product recovery technologies would require a significant in-situ and ex-situ footprint that is incompatible with existing Infrastructure inside the building.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
Product Recovery	Dual-phase extraction	**Benefits:** Potential to remove NAPL. **Limitations:** Limited effectiveness for high viscosity products with high boiling range and low vapor pressure. Cannot capture all NAPL-phase product.	**Low** High viscosity of the oil would limit effectiveness; free phase (floating) NAPL has only been detected in one location and is only present in the well when the water table is low (spring/summer). Average LNAPL thickness measured over the last 2 years is 1.6 centimeters (cm) in the well. Bail down test indicated LNAPL recovery was only 0.5 cm after 30 minutes.	**Difficult** Would require a significant in-situ and ex-situ footprint that is incompatible with existing Infrastructure inside the building.	**Direct: High** **LONG TERM (OMM): Moderate to High** (depending on duration of operation) **Overall: High**	Reject
	Passive (sorbent sock)	**Benefits:** Removes NAPL; can be easily placed in existing wells. Appropriate when hydraulic control is not necessary. **Limitations:** Limited area of influence, removes NAPL only from well.	**Moderate** Sorbent sock has been demonstrated to sorb and remove product from the well, but removal rates are low and limited by influx of NAPL into the well. Technology can only be used in the one well where NAPL is present.	**Easy** Sorbent material is low-cost compared to other technologies and can be placed in the existing well.	**Direct: Low** **LONG TERM (OMM): Low** **Overall: Low**	Retain
	Active (belt skimmer)	**Benefits:** Removes LNAPL; can be easily placed in existing wells. Appropriate when hydraulic control is not necessary. **Limitations:** Limited area of influence, removes LNAPL only from well. Is not cost-effective for wells with very limited product thickness and slow product recovery. Typically requires aboveground infrastructure.	**Moderate** Sorbent material has been demonstrated to sorb and remove product from the well, but removal rates are low and limited by influx of LNAPL into the well. Technology can only be used in the one well where LNAPL is present.	**Difficult** Would likely require installation of a larger diameter well that may not have LNAPL. Existing infrastructure inside the building limits locations for well installation and adjacent active manufacturing activities limit the ability to install aboveground infrastructure.	**Direct: moderate** **LONG TERM (OMM): Moderate** **Overall: Moderate** (compared to passive removal)	Reject

Table 10
Cleanup Technologies Screening
Area of Concern A-13
Building 17-06 Petroleum Hydrocarbon Release

Site Physical Conditions: Includes petroleum hydrocarbon contamination in soil and groundwater on the east side of Building 17-06 on Boeing property. Non-aqueous phase liquid (NAPL) is also present in a limited area at the water table surface. Constituents of concern (COCs) are **diesel-range organics (DRO) and oil-range organics (ORO).** The hydrocarbon mixture that is present in subsurface is not an exact match to products currently being used in the building, but is a close match to the hydraulic and gear oil products used in the building. These types of oil are engineered for thermal stability and to resist oxidation. Properties of the mixture present in the subsurface were estimated based on the properties from safety data sheets for the similar products being used currently in the building. Analysis of the hydrocarbon mixture in the subsurface by ASTM Method D2887-14 indicates it has a high boiling range from approximately 350 to 530 degrees Celsius. Estimated physical properties based on similar products indicate the hydrocarbon mixture has a density on the order of 7.1 to 7.3pounds [lbs] per gallons, low vapor pressure (<1 millimeter of mercury [mm Hg]), high viscosity (on the order of 30 to 400 centistokes (cSt) @ 40 degrees Celsius), and a high viscosity index (>100, meaning the viscosity is resistant to changes in temperature). Soil contamination is generally present from approximately 12 to 20 feet (ft) below ground surface (bgs). Groundwater contamination is present in the shallow zone (defined as from the water table to 35 ft bgs). Contamination is confined to a limited area beneath the footprint of the building. There is no opportunity for exposure due to soil and groundwater contamination being capped by the concrete slab beneath the building. The plume of groundwater contamination is also limited and does not appear to be migrating. The groundwater table varies seasonally and has been from approximately 9 to 18 ft bgs. Soils are generally highly permeable sands and gravels with some interbedded silt layers. Access to the area for investigation is restricted due to the presence of active mills and an aluminum chip conveyor system and sumps.

General Response Actions	Technology Option	Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
			Effectiveness	**Implementability**	**Relative Cost**	
Ex-Situ Physical/Chemical Treatment	Pump and treat (various *ex-situ* treatment options)	**Benefits:** Removal of hydrocarbons from extracted groundwater. Could be combined with other treatment options to increase effectiveness. **Limitations:** Requires significant infrastructure both above and below ground. Does not remove material sorbed to aquifer matrix.	**Moderate** High viscosity of the oil would limit effectiveness on NAPL fraction and, thus, it would treat primarily dissolved fraction.	**Difficult** High seepage velocities would require excessive groundwater extraction and treatment volumes. Requires a significant in-situ and ex-situ footprint that is incompatible with existing Infrastructure at the release location.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
Containment (vertical barrier)	Slurry walls, low-permeability barrier walls, or sheet pile walls	**Benefits:** Prevents contaminant migration. **Limitations:** Does not provide treatment; not a permanent remedy unless used in conjunction with other remedies. Typically has low effectiveness in aquifers with high seepage velocities. Engineering constraints limit depth of barrier.	**Low** LNAPL and groundwater plume are not expanding so lateral containment provides minimal benefit. High seepage velocities would limit effectiveness.	**Difficult** Requires a significant footprint that is incompatible with existing Infrastructure in the building. Not feasible due to physical constraints of building.	**Direct: High** **LONG TERM (OMM): Low** **Overall: High**	Reject
Containment Cap (without vertical barrier; temporary)	Contain in place with existing Cap (building slab)	**Benefits:** Prevents exposure to contaminants and helps prevent plume spreading. Can be combined with additional remedy in conjunction or in the future. **Limitations:** Does not provide treatment; not a permanent remedy; must be used in conjunction with other remedies.	**Moderate** Hydrocarbons are currently contained under the building slab, which provides a Cap. Downgradient wells indicate that the hydrocarbon plume is limited in extent, is not expanding, and does not extend beyond the building. Existing building slab is effective in preventing exposure. Would need to be combined with additional remedy, such as MNA and future physical removal (excavation) when building is decommissioned.	**Easy** Infrastructure is currently in place. Would not add additional cost to or inhibit future removal actions.	**Direct: Low** **LONG TERM (OMM): Low** **Overall: Low**	Retain

Table 11
Cleanup Technologies Screening
Area of Concern A-01
Former Underground Storage Tanks Northwest of Building 17-06

Site Physical Conditions: Includes petroleum hydrocarbon contamination associated with two former 10,000-gallon underground storage tanks (USTs). Both tanks were removed in 1990 and approximately 500 cubic yards of contaminated soil was excavated from the former tank area. A fuel island was also removed; fuel piping was left in place but is limited in extent and not expected to be an ongoing source of release. Constituents of concern (COCs) are **gasoline-range organics (GRO), diesel-range organics (DRO), benzene, ethylbenzene, and xylenes**. Remaining soil contamination is limited to a small area at depths of approximately 10 to 25 feet (ft) below ground surface (bgs). Groundwater contamination is limited to a small area, is not migrating, and is present in the shallow zone. There is no evidence of non-aqueous phase liquid (NAPL) in groundwater. Soils are generally highly permeable sands and gravels with some interbedded silt layers. Depth to water varies seasonally and is generally observed approximately 10 to 17 ft bgs. Groundwater chemistry indicates generally reducing conditions. The area is located next to a road and in a storage area on Boeing property. The ground surface is covered by asphalt and concrete pavement. Many utilities are present throughout the area including former fuel piping left in place and active piping used for Boeing's current operations.

General Response Actions	Technology Option	Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
			Effectiveness	**Implementability**	**Relative Cost**	
SOIL						
Physical Removal (following approval of Cap)	Excavation	**Benefits:** Removal of residual contaminant source; groundwater expected to attenuate once contaminated soil is removed. **Limitations:** Offsite disposal required; excavation depth limited by groundwater.	**Moderate to High** Permanently removes contamination from Site soil. Contaminated soil appears to be present in the smear zone and the excavation depth may be limited by groundwater.	**Moderate** Requirement to work around existing utility infrastructure; smear zone soils beneath water table may be difficult to remove, conduct work during low water table; removal of overburden soil required to access contaminated soil.	**Direct: Moderate** **LONG TERM (operation, monitoring, and maintenance [OMM]): Low** **Overall: Moderate**	Retain
SOIL AND GROUNDWATER						
In-Situ Physical/Chemical Treatment	Air or ozone sparge with soil vapor extraction	**Benefits:** Permanently removes volatile contaminants from soil and groundwater. Introduction of oxygen is generally beneficial for breakdown of petroleum hydrocarbons. Relatively fast restoration timeframe for contaminants with high volatile fraction. **Limitations:** Potential for aquifer clogging or plugging due to iron precipitation or biofouling caused by introduction of oxygen into reduced aquifer conditions. Preferential flow paths may limit complete cleanup of impacted soil/groundwater. Not effective for non-volatile fractions.	**Moderate to High** Preferential flow paths may limit complete cleanup of impacted soil/groundwater.	**Easy** Relatively easily installed and implemented given limited aboveground infrastructure in the area.	**Direct: Moderate** **LONG TERM (OMM): Moderate** **Overall: Moderate**	Retain
	Chemical oxidation	**Benefits:** Fast reaction rates. May be less costly than removal or sparging systems. **Limitations:** Less effective in naturally reducing aquifer conditions due to natural oxidant demand. Short-lived treatment effect; often requires repeated injections; potential for contaminant rebound. Generally only treats groundwater.	**Moderate to Low** Effectiveness is limited due to high oxidant demand in reducing groundwater conditions.	**Moderate** Mass loading may be excessive due to natural oxidant demand; would likely require repeated injections and/or excessive amounts of substrate.	**Direct: Moderate to High** **LONG TERM (OMM): Low** **Overall: Moderate**	Retain

Table 11
Cleanup Technologies Screening
Area of Concern A-01
Former Underground Storage Tanks Northwest of Building 17-06

Site Physical Conditions: Includes petroleum hydrocarbon contamination associated with two former 10,000-gallon underground storage tanks (USTs). Both tanks were removed in 1990 and approximately 500 cubic yards of contaminated soil was excavated from the former tank area. A fuel island was also removed; fuel piping was left in place but is limited in extent and not expected to be an ongoing source of release. Constituents of concern (COCs) are **gasoline-range organics (GRO), diesel-range organics (DRO), benzene, ethylbenzene, and xylenes**. Remaining soil contamination is limited to a small area at depths of approximately 10 to 25 feet (ft) below ground surface (bgs). Groundwater contamination is limited to a small area, is not migrating, and is present in the shallow zone. There is no evidence of non-aqueous phase liquid (NAPL) in groundwater. Soils are generally highly permeable sands and gravels with some interbedded silt layers. Depth to water varies seasonally and is generally observed approximately 10 to 17 ft bgs. Groundwater chemistry indicates generally reducing conditions. The area is located next to a road and in a storage area on Boeing property. The ground surface is covered by asphalt and concrete pavement. Many utilities are present throughout the area including former fuel piping left in place and active piping used for Boeing's current operations.

			Site Specific Rankings			
General Response Actions	**Technology Option**	**Benefits / Limitations**	**Effectiveness**	**Implementability**	**Relative Cost**	**Screening Result Retain/Reject**
	Thermal treatment	**Benefits:** Relatively rapid; near complete volatilization of contaminants. **Limitations:** High cost/benefit ratio for small areas. Concerns related to high subsurface temperatures and underground infrastructure.	**High** Demonstrated effectiveness for quickly reducing concentrations of contaminants in soil and groundwater.	**Difficult** Energy demands may be excessive due to high seepage velocity; source area is not large enough to make thermal treatment cost effective. Concerns about potential to damage adjacent utilities from high subsurface temperatures.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
Containment (without vertical barrier)	Cap in place	**Benefits:** Reduces potential leaching from contaminated soil overlying groundwater; minimizes potential for direct contact. **Limitations:** Requires periodic inspections and maintenance indefinitely; restricts future property use and activity.	**Moderate to Low** Cap effective in preventing infiltration and direct contact. However, it has longer restoration timeframe for contaminant mass in the smear zone that is already in contact with groundwater. Current asphalt Cap has been effective at helping reduce concentrations and extent of groundwater contamination over time, but rate is slow.	**Easy** Existing asphalt pavement already in place. Would need to be combined with monitored natural attenuation (MNA) or other technologies for groundwater. Low cost and effort for implementation compared to active treatment. Requires ongoing inspection and maintenance until cleanup goals are achieved.	**Direct: Low** **LONG TERM (OMM): Low to Moderate** **Overall: Low**	Retain
Institutional Controls	Restrictive environmental covenant, fencing, signage	**Benefits:** Can be used in conjunction with MNA and containment; minimizes potential for direct contact and groundwater withdrawal. **Limitations:** Requires review indefinitely; restricts future property use and activity.	**Moderate** Prevents exposure, but does not provide treatment as a standalone remedy. Can be combined with other technologies to provide low cost, but protective solution.	**Easy** Would need to be combined with other remedies. Low cost and effort for implementation compared to active treatment. Property is already fenced and access is controlled.	**Direct: Low** **LONG TERM (OMM): Low** **Overall: Low**	Retain
			GROUNDWATER			
In-Situ Biological Treatment	Enhanced bioremediation (reductive; nitrate/sulfate)	**Benefits:** Can use in reduced aquifer conditions; relatively inexpensive; treats smear zone soil. **Limitations:** Slower degradation rates than physical or chemical options, may require repeated injection. Introduction of contaminants with groundwater criteria	**Moderate** Effective with reduced aquifer conditions for dissolved phase contaminants. Slower degradation rate than oxygen release compound (ORC), but more soluble than oxygen in water.	**Easy** Does not require permanent installation of treatment equipment; repeated injections and performance monitoring are relatively easy to implement; nitrate/sulfate is less costly than ORC; high seepage velocity is a design constraint that may increase the restoration timeframe or require repeated injections.	**Direct: Moderate** **LONG TERM (OMM): Low** **Overall: Moderate**	Retain

Table 11
Cleanup Technologies Screening
Area of Concern A-01
Former Underground Storage Tanks Northwest of Building 17-06

Site Physical Conditions: Includes petroleum hydrocarbon contamination associated with two former 10,000-gallon underground storage tanks (USTs). Both tanks were removed in 1990 and approximately 500 cubic yards of contaminated soil was excavated from the former tank area. A fuel island was also removed; fuel piping was left in place but is limited in extent and not expected to be an ongoing source of release. Constituents of concern (COCs) are **gasoline-range organics (GRO), diesel-range organics (DRO), benzene, ethylbenzene, and xylenes**. Remaining soil contamination is limited to a small area at depths of approximately 10 to 25 feet (ft) below ground surface (bgs). Groundwater contamination is limited to a small area, is not migrating, and is present in the shallow zone. There is no evidence of non-aqueous phase liquid (NAPL) in groundwater. Soils are generally highly permeable sands and gravels with some interbedded silt layers. Depth to water varies seasonally and is generally observed approximately 10 to 17 ft bgs. Groundwater chemistry indicates generally reducing conditions. The area is located next to a road and in a storage area on Boeing property. The ground surface is covered by asphalt and concrete pavement. Many utilities are present throughout the area including former fuel piping left in place and active piping used for Boeing's current operations.

			Site Specific Rankings			
General Response Actions	**Technology Option**	**Benefits / Limitations**	**Effectiveness**	**Implementability**	**Relative Cost**	**Screening Result Retain/Reject**
		(nitrate maximum contaminant level [MCL] 10 milligrams per liter [mg/L]).				
	Enhanced bioremediation (oxidative; e.g., oxygen release compound [ORC])	**Benefits:** Relatively rapid. **Limitations:** In reduced aquifer conditions can have excessive oxidant demand making treatment short-lived and requiring repeated injection.	**Low** Aquifer is naturally reducing (and, therefore. contains naturally occurring total organic carbon [TOC]) and, consequently, treatment would be short-lived and have limited effect. Would likely require repeated injections.	**Difficult** Mass loading requirements may be excessive due to natural oxygen demand and high seepage velocities.	**Direct: Moderate to High** **LONG TERM (OMM): Low** **Overall: Moderate to High**	Retain
	Monitored natural attenuation (MNA)	**Benefits:** Low cost; can be combined with other technologies; can be relatively effective for residual contamination; co-metabolic degradation with chlorinated volatile organic compounds (cVOCs). **Limitations:** Longer restoration timeframe than more active alternatives.	**High** Evidence of natural degradation occurring at the site (reductions in extent and magnitude of groundwater contamination).	**Easy** No construction required; existing monitoring well infrastructure is sufficient; long-term monitoring and reporting is easily implementable compared to more active options.	**Direct: Low** **LONG TERM (OMM): Low** **Overall: Low**	Retain
Ex-Situ Physical/Chemical Treatment	Pump and treat (various *ex-situ* treatment options)	**Benefits:** Complete removal of hydrocarbons from extracted groundwater. **Limitations:** Cost/benefits are generally low for small areas. Can leave behind contaminant mass in low-permeability zones.	**Low** Low contaminant concentrations difficult to fully extract from subsurface.	**Difficult** Would require relatively costly long-term operation, monitoring, and maintenance, for relatively low benefit.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
Containment (Vertical physical barrier)	Slurry walls, low-permeability barrier walls, or sheet pile walls	**Benefits:** Reduces downgradient contaminant migration. **Limitations:** Does not provide treatment; costly; limited by utilities and buildings.	**Low** Relatively low contaminant concentrations that are not migrating make containment unnecessary.	**Difficult** High seepage velocities reduce effectiveness of barrier. Cost benefit is low.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject

Table 12
Cleanup Technologies Screening
Area of Concern A-09
Building 17-07 Acid Scrubber Drain Line Lea

Site Physical Conditions: Includes metals and cyanide contamination associated with a leak from the acid scrubber drain line located on the south side of Building 17-07. Contaminated soil was removed to the extent practical in 1996; however, some soil was left in place around foundations due to the risk of undermining and damaging infrastructure. The impacted soil is all capped as it remains underneath the Building 17-07 floor, scrubber pad foundations, and adjacent pavement. Groundwater contamination is limited to a small area mostly underneath Building 17-07, does not appear to be migrating, and is present in the shallow groundwater zone. Constituents of concern (COCs) are **cadmium, nickel, copper, and cyanide**. Analysis of cyanide indicates that it is primarily comprised of strong metal complexes with very little available cyanide (weak metal complexes) or free cyanide. Soils are generally highly permeable sands and gravels with some interbedded silt layers. Depth to water varies seasonally and is generally observed approximately 10 to 16 feet (ft) below ground surface (bgs). Access to the area for investigation is restricted due to the presence of active scrubbers and the Building 17-07 tank line area and associated underground pit.

General Response Actions	Technology Option	Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
			Effectiveness	**Implementability**	**Relative Cost**	
SOIL						
Physical Removal (Future, at time of Building Closure [more than a decade])	Excavation	**Benefits:** Permanent Removal. **Limitations:** Offsite disposal required; depth limited by groundwater.	**Moderate** Groundwater expected to attenuate after soil is removed. Can be combined with other technologies. May not be able to excavate impacted soil below the water table.	**Difficult** Existing infrastructure currently prevents complete physical removal. For the areas that are outside of the building footprint, excavation may potentially damage the building's foundation and structure or associated utilities. Since the chemicals in Building 17-07's process line are hazardous, shutting down activity in the building could result in safety concerns. Can be implemented in the future when building is decommissioned.	**Direct: Moderate** **LONG TERM (operation, monitoring, and maintenance [OMM]): Low** **Overall: Moderate**	Retain
SOIL AND GROUNDWATER						
Containment (vertical barrier)	Slurry walls, low-permeability barrier walls, or sheet pile walls	**Benefits:** Prevents contaminant migration. **Limitations:** Does not provide treatment; not a permanent remedy unless used in conjunction with other remedies. Typically has low effectiveness in aquifers with high seepage velocities. Engineering constraints limit depth of barrier.	**Low** Relatively low contaminant concentrations that are not migrating make containment unnecessary.	**Difficult** Requires significant footprint that is likely incompatible with existing infrastructure (utilities and buildings).	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
Containment (without vertical barrier; temporary)	Contain in place with existing Cap (building slab and asphalt)	**Benefits:** Reduces potential for groundwater leaching from contaminated soil overlying groundwater; minimizes potential for direct contact. **Limitations:** Does not provide treatment; not a permanent remedy; must be used in conjunction with other remedies.	**Moderate** Contamination is currently contained under building slab and asphalt, which provides a ap. Downgradient wells indicate that the metals and cyanide plume is limited in extent and is not expanding. Existing Cap is effective in preventing exposure. Would need to be combined with additional remedy, such as monitored Natural Attenuation (MNA) and future physical removal (excavation) when building is decommissioned.	**Easy** Infrastructure is currently in place. Would not add additional cost to or inhibit future removal actions.	**Direct: Low** **LONG TERM (OMM): Low** **Overall: Low**	Retain

Table 12
Cleanup Technologies Screening
Area of Concern A-09
Building 17-07 Acid Scrubber Drain Line Lea

Site Physical Conditions: Includes metals and cyanide contamination associated with a leak from the acid scrubber drain line located on the south side of Building 17-07. Contaminated soil was removed to the extent practical in 1996; however, some soil was left in place around foundations due to the risk of undermining and damaging infrastructure. The impacted soil is all capped as it remains underneath the Building 17-07 floor, scrubber pad foundations, and adjacent pavement. Groundwater contamination is limited to a small area mostly underneath Building 17-07, does not appear to be migrating, and is present in the shallow groundwater zone. Constituents of concern (COCs) are **cadmium, nickel, copper, and cyanide**. Analysis of cyanide indicates that it is primarily comprised of strong metal complexes with very little available cyanide (weak metal complexes) or free cyanide. Soils are generally highly permeable sands and gravels with some interbedded silt layers. Depth to water varies seasonally and is generally observed approximately 10 to 16 feet (ft) below ground surface (bgs). Access to the area for investigation is restricted due to the presence of active scrubbers and the Building 17-07 tank line area and associated underground pit.

General Response Actions	Technology Option	Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
			Effectiveness	Implementability	Relative Cost	
Institutional Controls	Restrictive environmental covenant	**Benefits:** Prevent exposure. **Limitations:** Requires review indefinitely; restricts future property use and activity.	**Moderate** Contamination is limited and does not appear to be migrating. Area is already paved or covered and currently there is no complete exposure pathway.	**Easy** Existing infrastructure currently prevents subsurface access. Boeing property is already fenced and controlled.	**Direct: Low** **LONG TERM (OMM): Low** **Overall: Low**	Retain
GROUNDWATER						
In-Situ Biological Treatment	Enhanced bioremediation (oxidative; e.g., sucrose, bioaugmentation with pseudomonas pseudoalcaligenes)	**Benefits:** Normally less expensive than physical treatments; does not require ex-situ treatment infrastructure. **Limitations:** Slower degradation rates than physical or chemical technologies; presence of other contaminants/metals may inhibit degradation.	**Low** Requires suitable geochemical conditions (i.e. aerobic, alkaline, higher temperatures) to support biodegradation processes for cyanide; groundwater conditions at the site (anaerobic, neutral pH) may not support cyanide biodegradation.	**Difficult** Implementation would be difficult and costly because of unfavorable aquifer geochemistry.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
	Monitored Natural Attenuation (MNA)	**Benefits:** Low cost; can be combined with other technologies; can be relatively effective for residual contamination. **Limitations:** Longer restoration timeframe than more active alternatives; requires long-term monitoring.	**High** Site data indicates that concentrations are attenuating over time. May have longer restoration time if groundwater chemistry conditions limit precipitation/sorption.	**Easy** No construction required; existing monitoring well infrastructure is sufficient; long-term monitoring and reporting is easily implementable compared to more active options.	**Direct: Low** **LONG TERM (OMM): Moderate** **Overall: Low**	Retain
In-Situ Physical/Chemical Treatment	Chemical oxidation (ozone; Fenton's reagent)	**Benefits:** Relatively inexpensive; small footprint; little waste generated; faster reactions than enhanced bioremediation. **Limitations:** May not treat strongly complexed cyanides.	**Low** Requires suitable geochemical conditions (i.e. aerobic, alkaline) to support chemical degradation processes for cyanide. Groundwater conditions at the site (anaerobic, acidic pH) may not support cyanide degradation. Data indicate cyanide is primarily in the form of strong metal complexes that are not conducive to oxidation reactions.	**Difficult** Implementation would be difficult and costly because of unfavorable aquifer geochemistry.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject

Table 12
Cleanup Technologies Screening
Area of Concern A-09
Building 17-07 Acid Scrubber Drain Line Lea

Site Physical Conditions: Includes metals and cyanide contamination associated with a leak from the acid scrubber drain line located on the south side of Building 17-07. Contaminated soil was removed to the extent practical in 1996; however, some soil was left in place around foundations due to the risk of undermining and damaging infrastructure. The impacted soil is all capped as it remains underneath the Building 17-07 floor, scrubber pad foundations, and adjacent pavement. Groundwater contamination is limited to a small area mostly underneath Building 17-07, does not appear to be migrating, and is present in the shallow groundwater zone. Constituents of concern (COCs) are **cadmium, nickel, copper, and cyanide**. Analysis of cyanide indicates that it is primarily comprised of strong metal complexes with very little available cyanide (weak metal complexes) or free cyanide. Soils are generally highly permeable sands and gravels with some interbedded silt layers. Depth to water varies seasonally and is generally observed approximately 10 to 16 feet (ft) below ground surface (bgs). Access to the area for investigation is restricted due to the presence of active scrubbers and the Building 17-07 tank line area and associated underground pit.

General Response Actions	Technology Option	Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
			Effectiveness	**Implementability**	**Relative Cost**	
	Air/ozone sparging; biosparging	**Benefits:** Creates environment for cyanide volatilization and biodegradation; active treatment, little waste generated. **Limitations:** Strongly complexed cyanide is not degraded by oxidation reactions; limited by gas transfer rates and groundwater flow pathways.	**Moderate to High** Free cyanide has relatively high vapor pressure and naturally degrades with gaseous and aqueous oxygen. However, complexed cyanide does not readily volatilize. Data indicate cyanide is primarily in the form of strong metal complexes that are not conducive to oxidation reactions.	**Difficult** Implementation could involve placement of activated carbon, because it is a catalyst for the degradation reaction. May be difficult to implement due to surface infrastructure (difficult to place infrastructure needed for treatment).	**Direct: High** **LONG TERM (OMM): Moderate** **Overall: Moderate**	Reject
	Sorption/Precipitation (adjustment of pH or addition of substrate to remove metals from solution)	**Benefits:** Targets many dissolved contaminants simultaneously; relatively low maintenance requirements. **Limitations:** Metals and cyanide could be remobilized in the future if changes occur to groundwater chemical conditions.	**Moderate to High** Demonstrated effectiveness in permeable reactive barrier (PRB) applications. Would need additional treatability studies to test effectiveness.	**Moderate** Implementation could be difficult because of high groundwater seepage velocities and surface infrastructure.	**Direct: High** **LONG TERM (OMM): Moderate** **Overall: Moderate**	Retain
Ex-Situ Physical/Chemical Treatment	Pump and Treat (various *ex-situ* treatment options; e.g., ion exchange; activated carbon)	**Benefits:** Complete removal of cyanide and metals from extracted groundwater. **Limitations:** Typically has low effectiveness for low contaminant concentrations.	**Low** Not effective for residual contamination or long-term treatment of low contaminant concentrations.	**Difficult** Would require long-term operation and maintenance; disposal of byproducts (e.g., brine) from certain treatment trains may be difficult or costly. Excessive pumping/discharge rates needed to influence groundwater flow due to high seepage velocity and aquifer thickness. Buildings, utilities, and other infrastructure may limit or prohibit extraction and injection in useful locations.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject

Table 13
Cleanup Technologies Screening
Building 17-07 Source Area; Building 17-07 Former Degreasers and Associated Piping

Site Physical Conditions: Includes groundwater plume at the Building 17-07 source area on Boeing property. Constituents of concern (COCs) are **trichloroethene (TCE) and vinyl chloride (VC)**. Concentrations of TCE in groundwater monitoring wells in the area have typically been below 5 micrograms per liter (µg/L). TCE is also detected in sub-slab soil gas with concentrations of up to 1,800 micrograms per cubic meter (µg/m^3). Soils are generally highly permeable sands and gravels with some interbedded silt layers. The groundwater table is present near the ground surface at approximately 15 feet (ft) below ground surface (bgs). The aquifer thickness in this area is approximately 90 ft thick. COCs are present throughout the thickness of the aquifer. Groundwater chemistry generally indicates reducing conditions. Presence of VC and ethene indicate that natural reductive dechlorination is occurring in the Building 17-07 source area. Access to the area for investigation is restricted due to location inside Building 17-07, the active Building 17-07 tank line area, and associated underground pit.

			Site Specific Rankings			
General Response Actions	**Technology Option**	**Benefits / Limitations**	**Effectiveness**	**Implementability**	**Relative Cost**	**Screening Result Retain/Reject**
SOIL AND GROUNDWATER – SOURCE AREA						
In-Situ Physical/Chemical Treatment	Thermal treatment	**Benefits:** Removal of contaminants through volatilization; does not directly influence redox conditions; can treat both soil and groundwater. **Limitations:** Energy-intensive, requires extensive aboveground infrastructure. Low cost/benefit for low-level contaminant concentrations; safety concerns if used near utilities; requires SVE if used under or near buildings.	**Low to Moderate** Effectiveness is dependent on ability to transfer enough heat to groundwater to vaporize COCs. High seepage velocity may require excessive energy to achieve adequate heat transfer and treatment effectiveness. Effective for soil desorption; however, soil sampling does not indicate significant adsorbed mass in vadose zone soil. Must be used with soil vapor extraction (SVE) to remove vapors after volatilization.	**Difficult, Dangerous** Targeted treatment area is below a chemical tank line with critical infrastructure and is not compatible with thermal treatment below ground. Energy demands may be excessive due to high seepage velocity and aquifer thickness; infrastructure in building may not allow installation of equipment needed to access all source zones; potential to damage adjacent utilities. Would also require SVE system.	**Direct: High** **LONG TERM (operation, monitoring, and maintenance [OMM]): High** **Overall: High**	Reject
SOIL – SOURCE AREA						
In-Situ Physical/Chemical Treatment	Soil Vapor Extraction (SVE)	**Benefits:** Effective treatment of vadose zone soil; protective of vapor intrusion pathway. **Limitations:** Does not treat impacted groundwater. Preferential flow paths may limit or slow extraction of contaminants from low-permeability zones.	**Moderate** Technology is well-documented for treating volatile organic compounds (VOCs) in the vadose zone. However, soil sampling has not indicated significant mass in the vadose zone. Protects groundwater from recontamination via the vapor pathway.	**Moderate** Requires significant surface and subsurface infrastructure and construction will be limited by existing building, which had significant existing below grade infrastructure and piping associated with the chemical tank line. More practicable than soil removal given the infrastructure constraints.	**Direct: Moderate** **LONG TERM (OMM): High** **Overall: Moderate**	Retain
GROUNDWATER – SOURCE AREA						
In-Situ Biological Treatment	Enhanced bioremediation (source area)	**Benefits:** Small infrastructure footprint; can target multiple depths. Effective for reducing aquifer conditions. **Limitations:** Well spacing is determined by aquifer characteristics. Low cost/benefit for low VOC concentrations.	**High** Effective with reduced aquifer conditions. Groundwater conditions are favorable for biodegradation as evidenced by TCE breakdown products. Can target multiple depths. Likely to require multiple rounds of injection.	**Moderate to Difficult** Does not require installation of permanent aboveground treatment equipment. Existing infrastructure and subgrade vaults limit placement of injection wells, desired spacing may not be achievable. High seepage velocity is a design constraint that may require more frequent injections.	**Direct: Moderate to High** **LONG TERM (OMM): Low** **Overall: Moderate**	Retain

Table 13
Cleanup Technologies Screening
Building 17-07 Source Area; Building 17-07 Former Degreasers and Associated Piping

Site Physical Conditions: Includes groundwater plume at the Building 17-07 source area on Boeing property. Constituents of concern (COCs) are **trichloroethene (TCE) and vinyl chloride (VC)**. Concentrations of TCE in groundwater monitoring wells in the area have typically been below 5 micrograms per liter (µg/L). TCE is also detected in sub-slab soil gas with concentrations of up to 1,800 micrograms per cubic meter (µg/m^3). Soils are generally highly permeable sands and gravels with some interbedded silt layers. The groundwater table is present near the ground surface at approximately 15 feet (ft) below ground surface (bgs). The aquifer thickness in this area is approximately 90 ft thick. COCs are present throughout the thickness of the aquifer. Groundwater chemistry generally indicates reducing conditions. Presence of VC and ethene indicate that natural reductive dechlorination is occurring in the Building 17-07 source area. Access to the area for investigation is restricted due to location inside Building 17-07, the active Building 17-07 tank line area, and associated underground pit.

General Response Actions	Technology Option	Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
			Effectiveness	Implementability	Relative Cost	
	Monitored natural attenuation (MNA)	**Benefits:** Low cost; can be combined with other technologies; can be relatively effective for residual contamination. **Limitations:** Variable degradation rates; longer restoration timeframe than more active alternatives.	**Moderate** Site data indicates that natural attenuation is occurring and concentrations are declining over time, but restoration timeframe is expected to be longer than for active remedies.	**Easy** No construction required; existing monitoring well infrastructure is sufficient; long-term monitoring and reporting is easily implementable compared to more active options.	**Direct: Low** **LONG TERM (OMM): Low** **Overall: Low**	Retain
In-Situ Physical/Chemical Treatment	Air Sparge	**Benefits:** Permanently removes volatile contaminants from soil and groundwater. Removal rates are relatively fast. **Limitations:** May reduce existing potential for natural reductive dechlorination in zones treated due to introduction of oxygen. Depth limited by engineering/technology constraints. Preferential flow paths may limit complete cleanup of impacted groundwater; potential for vapor intrusion if not combined with SVE.	**Low** TCE and other chlorinated volatile organic compounds (cVOCs) have relatively high vapor pressure, which is favorable for volatilization. However, the aquifer thickness and high seepage velocity greatly limits the effectiveness of this treatment beyond the shallow aquifer zone. May reduce existing biodegradation rates in zones treated.	**Difficult** Would need to be combined with SVE. Implementability would be difficult and costly, because of required treatment depth and high groundwater seepage velocity. Requires significant surface and subsurface infrastructure and construction will be limited by existing building, which had significant existing below grade infrastructure and piping associated with the chemical tank line. May result in aquifer clogging or plugging due to iron precipitation or biofouling caused by introduction of oxygen into reduced aquifer conditions.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
	Chemical treatment (reductive; e.g., zero valent iron)	**Benefits:** *In situ* destruction; rapid contaminant destruction. Can inject at multiple depths. **Limitations:** Treatment limited by distribution of chemical; longevity may be shortened in aquifers with high seepage velocities; repeated injections likely required. Aquifer characteristics determine well spacing.	**Low to Moderate** Effectiveness is not as well documented, relative to other technologies. Preferential flow paths for injected material may not reach low-permeability zones. Reagents must come in direct contact with contaminated media, which reduces effectiveness in source areas of late stage plumes dominated by back diffusion because reagent typically does not reach low-permeability zones.	**Moderate** High seepage velocity and preferential pathways would increase the difficulty and cost of this technology. Placement of injection wells limited by building infrastructure.	**Direct: High** **LONG TERM (OMM): Low** **Overall: Moderate to High**	Reject

Table 13
Cleanup Technologies Screening
Building 17-07 Source Area; Building 17-07 Former Degreasers and Associated Piping

Site Physical Conditions: Includes groundwater plume at the Building 17-07 source area on Boeing property. Constituents of concern (COCs) are **trichloroethene (TCE) and vinyl chloride (VC)**. Concentrations of TCE in groundwater monitoring wells in the area have typically been below 5 micrograms per liter (µg/L). TCE is also detected in sub-slab soil gas with concentrations of up to 1,800 micrograms per cubic meter (µg/m^3). Soils are generally highly permeable sands and gravels with some interbedded silt layers. The groundwater table is present near the ground surface at approximately 15 feet (ft) below ground surface (bgs). The aquifer thickness in this area is approximately 90 ft thick. COCs are present throughout the thickness of the aquifer. Groundwater chemistry generally indicates reducing conditions. Presence of VC and ethene indicate that natural reductive dechlorination is occurring in the Building 17-07 source area. Access to the area for investigation is restricted due to location inside Building 17-07, the active Building 17-07 tank line area, and associated underground pit.

General Response Actions	Technology Option	Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
			Effectiveness	**Implementability**	**Relative Cost**	
	Chemical treatment (oxidative; e.g., permanganate)	**Benefits:** *In situ* destruction; can inject at multiple depths; rapid contaminant destruction. **Limitations:** Treatment limited by distribution of chemical; oxidative potential generally inverse to longevity of treatment and longevity may be shortened in aquifers with high seepage velocities; not as effective in reducing conditions. Aquifer characteristics determine well spacing.	**Low** Aquifer is naturally reducing and, consequently, treatment would be short-lived and have lower effectiveness. Preferential flow paths for injected material may not reach low-permeability zones. Reagents must come in direct contact with contaminated media, which reduces effectiveness in source areas of late stage plumes dominated by back diffusion because reagent typically does not reach low-permeability zones. Oxidation of groundwater would diminish reductive biological dechlorination activity in treatment area and downgradient.	**Difficult** Mass loading may be excessive due to high seepage velocity, aquifer thickness, and natural oxidant demand making the implementation difficult and costly.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
Enhanced Groundwater Flushing	Dynamic groundwater recirculation	**Benefits:** Complete treatment of extracted groundwater. Potential to vary groundwater flow paths and remove contaminants from zones of lower hydraulic conductivity. Faster restoration time than pump and treat. **Limitations:** Would require aboveground treatment before reinjection. In reduced aquifers, potential for biofouling increases OMM cost; larger treatment system footprint than in-situ technologies.	**Low to Moderate** Effectiveness has not been thoroughly demonstrated yet, particularly on low-concentration plumes, because DGR is a relatively new cleanup technology. Theoretically, more effective than pump and treat.	**Difficult** Excessive pumping/discharge rates needed to influence groundwater flow due to high seepage velocity and aquifer thickness; buildings, utilities, and other infrastructure may limit or prohibit extraction and injection in useful locations.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject

Table 13
Cleanup Technologies Screening
Building 17-07 Source Area; Building 17-07 Former Degreasers and Associated Piping

Site Physical Conditions: Includes groundwater plume at the Building 17-07 source area on Boeing property. Constituents of concern (COCs) are **trichloroethene (TCE) and vinyl chloride (VC)**. Concentrations of TCE in groundwater monitoring wells in the area have typically been below 5 micrograms per liter (µg/L). TCE is also detected in sub-slab soil gas with concentrations of up to 1,800 micrograms per cubic meter (µg/m^3). Soils are generally highly permeable sands and gravels with some interbedded silt layers. The groundwater table is present near the ground surface at approximately 15 feet (ft) below ground surface (bgs). The aquifer thickness in this area is approximately 90 ft thick. COCs are present throughout the thickness of the aquifer. Groundwater chemistry generally indicates reducing conditions. Presence of VC and ethene indicate that natural reductive dechlorination is occurring in the Building 17-07 source area. Access to the area for investigation is restricted due to location inside Building 17-07, the active Building 17-07 tank line area, and associated underground pit.

			Site Specific Rankings			
General Response Actions	**Technology Option**	**Benefits / Limitations**	**Effectiveness**	**Implementability**	**Relative Cost**	**Screening Result Retain/Reject**
Ex-Situ Physical/Chemical Treatment	Pump and treat (various *ex-situ* treatment options)	**Benefits:** Complete treatment of extracted groundwater. **Limitations:** Potential for biofouling in reduced aquifers increases OMM cost; high extraction rates needed in aquifers with hydraulic conductivity; need for discharge permits to discharge large volume of water to sewer or surface water; larger treatment system footprint than in-situ technologies.	**Low** Pump and treat effectiveness decreases as contaminant concentrations decrease. Typically not very effective for low concentration plumes. Potential for problems with rebound once system is turned off.	**Difficult** Excessive pumping/discharge rates needed to capture groundwater due to high seepage velocity and aquifer thickness; potential for biofouling; limitations on pumping well placement.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
Containment (physical)	Slurry walls, low-permeability barrier walls, or sheet pile walls	**Benefits:** Contains or slows contaminated groundwater movement. Can limit migration. **Limitations:** Does not provide treatment; not a permanent remedy. Typically has low effectiveness in aquifers with high seepage velocities. Engineering constraints limit depth of barrier.	**Low** Not effective to contain contaminant plume with a physical barrier alone due to high seepage velocities and aquifer thickness.	**Difficult** Not feasible to contain contaminant plume with a physical barrier alone due to high seepage velocities and aquifer thickness. Building infrastructure severely limits placement of significant subsurface infrastructure.	**Direct: High** **LONG TERM (OMM): Low** **Overall: High**	Reject
Containment (hydraulic)	Interceptor trench or extraction wells	**Benefits:** Partially captures contaminants and limits migration. **Limitations:** *Ex-situ* treatment needed; potential for biofouling in reduced aquifers increases OMM cost; need for discharge permits; larger treatment system footprint than in-situ technologies. Engineering constraints limit the depth of treatment.	**Low** More effective than physical containment alone, but limited in ability to affect deeper portions of the aquifer.	**Difficult** Depth of treatment needed is not conducive for interceptor trenches. Excessive pumping/discharge rates needed to capture groundwater due to high seepage velocity and aquifer thickness. Buildings, utilities, and other infrastructure may limit or prohibit extraction in useful locations.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
Institutional Controls	Restrictive environmental covenant, fencing, signage	**Benefits:** Restrict use of/exposure to contaminated groundwater; can be combined with other technologies. **Limitations:** Restricts future property use and activity; does not provide treatment; requires indefinite periodic review.	**Low to Moderate** May be useful in limited situations. Not effective as a standalone solution for this Site, but can be combined with other technologies.	**Easy** Target source area is owned by Boeing and area is already access controlled.	**Direct: Low** **LONG TERM (OMM): Low** **Overall: Low**	Retain

Table 14
Cleanup Technologies Screening
Building 17-03 Source Area; Building 17-03 Former Degreasers, Tank Line, and Waste Piping

Site Physical Conditions: Includes groundwater plume at the Building 17-03 source area on Prologis property. Constituents of concern (COCs) are **trichloroethene (TCE) and vinyl chloride (VC)**. Concentrations of TCE in groundwater monitoring wells in the area have typically been below 5 micrograms per liter (μg/L); however, groundwater grab samples in the area have detections of up 11 μg/L. TCE is also present in soil gas near the Building 17-03 source area with concentrations of up to 1,700 micrograms per cubic meter (μg/m^3). 2017 investigation activities indicated limited detections of TCE in soil that were generally at or below the depth of the high water table. Soils are generally highly permeable sands and gravels with some interbedded silt layers. The groundwater table is present near the ground surface at approximately 10 to 18 feet (ft) below ground surface (bgs). The aquifer thickness in this area is approximately 90 ft thick. COCs are present in the shallow and intermediate aquifer zones. Breakdown products cis-1,2-dichloroethene (cDCE) and VC are generally not detected in this area, indicating conditions for reductive dechlorination are limited; however concentrations have been declining naturally at AGW001 in the source area from a high around 5 μg/L in 2008 to around 1 μg/L in 2018. Access to the area for investigation is currently restricted due to trucking operations occurring on this property. An access agreement that makes changes to timing, location, and scheduling of cleanup or business operations will be required to permit cleanup. In 2005, an enhanced bioremediation injection cleanup was completed in adjacent former Building 17-05. The cleanup was successful and reducing conditions have persisted in the treatment zone since the completion of the cleanup.

General Response Actions	Technology Option	Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
			Effectiveness	**Implementability**	**Relative Cost**	
SOIL AND GROUNDWATER – SOURCE AREA						
In-Situ Physical/Chemical Treatment	Thermal treatment	**Benefits:** Removal of contaminants through volatilization; does not directly influence redox conditions; can treat both soil and groundwater. **Limitations:** Energy-intensive, requires extensive aboveground infrastructure. Low cost/benefit for low-level contaminant concentrations; safety concerns if used near utilities; requires soil vapor extraction (SVE) if used under or near buildings.	**Low to Moderate** Effectiveness is dependent on ability to transfer enough heat to groundwater to vaporize COCs. High seepage velocity may require excessive energy to achieve adequate heat transfer and treatment effectiveness. Effective for soil desorption; however, soil sampling does not indicate significant adsorbed mass in vadose zone soil. Must be used with SVE to remove vapors after volatilization.	**Difficult** Energy demands will likely be excessive due to high seepage velocity and aquifer thickness; potential to damage adjacent utilities, will require SVE due to proximity to adjacent building and asphalt surface.	**Direct: High** **LONG TERM (operation, monitoring, and maintenance [OMM]): High** **Overall: High**	Reject
SOIL – SOURCE AREA						
In-Situ Physical/Chemical Treatment	Soil Vapor Extraction (SVE)	**Benefits:** Effective treatment of vadose zone soil and soil gas; protective of vapor intrusion pathway. **Limitations:** Preferential flow paths may limit complete cleanup of impacted soil.	**Moderate to High** Technology is well-documented for treating volatile organic compounds (VOCs). Effective for soil and soil gas; however, soil sampling does not indicate significant mass in vadose zone soil. Potential to protect groundwater from vapor pathway.	**Moderate** Requires aboveground infrastructure. Construction and placement of infrastructure may be limited by existing site use and site needs (area is now a trucking corridor).	**Direct: Moderate** **LONG TERM (OMM): Moderate** **Overall: Moderate**	Retain

Table 14
Cleanup Technologies Screening
Building 17-03 Source Area; Building 17-03 Former Degreasers, Tank Line, and Waste Piping

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General Response Actions	Technology Option	Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
			Effectiveness	**Implementability**	**Relative Cost**	
GROUNDWATER – SOURCE AREA						
In-Situ Biological Treatment	Enhanced bioremediation (source area)	**Benefits:** Small infrastructure footprint; can target multiple depths. Effective for reducing aquifer conditions. **Limitations:** Well spacing is determined by aquifer characteristics. Low cost/benefit for low VOC concentrations.	**High** Effective with reduced aquifer conditions. Can target multiple depths. Likely to require multiple rounds of injection.	**Easy to Moderate** Does not require permanent installation of aboveground treatment equipment; however, significant equipment is needed during injection. Site use is somewhat restricted due to trucking and warehouse operations. Repeated injections and performance monitoring are relatively easy to implement; high seepage velocity is a design constraint that may require more frequent injections.	**Direct: Moderate** **LONG TERM (OMM): Low** **Overall: Moderate**	Retain
	Monitored natural attenuation (MNA)	**Benefits:** Low cost; can be combined with other technologies; can be relatively effective for residual contamination. **Limitations:** Variable degradation rates; longer restoration timeframe than more active alternatives.	**Moderate** Concentrations in the source area well have declined from around 5 µg/L to around 1 µg/L in 10 years. Other areas are expected to experience similar declines in concentration.	**Easy** Would require limited additional monitoring wells; long-term monitoring incurs less disturbance to property operations and is easily implementable compared to more active options.	**Direct: Low** **LONG TERM (OMM): Low** **Overall: Low**	Retain
In-Situ Physical/Chemical Treatment	Air Sparge	**Benefits:** Permanently removes volatile contaminants. Removal rates are relatively fast. **Limitations:** Preferential flow paths may limit complete cleanup of impacted groundwater.	**Low** TCE and other chlorinated volatile organic compounds (cVOCs) have relatively high vapor pressure, which is favorable for volatilization. However, the aquifer thickness and high seepage velocity greatly limits the effectiveness of this treatment beyond the shallow aquifer zone.	**Moderate to Difficult** Would need to be combined with SVE. Implementability would be difficult and costly because of required treatment depth and high groundwater seepage velocity. Requires aboveground infrastructure. Construction and placement of infrastructure may be limited by existing site use and site needs (area is now a trucking corridor).	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject

Table 14
Cleanup Technologies Screening
Building 17-03 Source Area; Building 17-03 Former Degreasers, Tank Line, and Waste Piping

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			Site Specific Rankings			
General Response Actions	**Technology Option**	**Benefits / Limitations**	**Effectiveness**	**Implementability**	**Relative Cost**	**Screening Result Retain/Reject**
	Chemical treatment (reductive; e.g., zero valent iron	**Benefits:** *In situ* destruction; can inject at multiple depths; rapid contaminant destruction. Ability to use various reagents. **Limitations:** Treatment limited by distribution of chemical; longevity may be shortened in aquifers with high seepage velocities; repeated injections likely required. Aquifer characteristics determine well spacing.	**Low to Moderate** Effectiveness is not as well documented, relative to other technologies. Preferential flow paths for injected material may not reach low-permeability zones. Reagents must come in direct contact with contaminated media, which reduces effectiveness in source areas of late-stage plumes dominated by back diffusion because reagent typically does not reach low-permeability zones.	**Moderate** Does not require installation of permanent aboveground treatment equipment; however, significant equipment is needed during injection. Site use is somewhat restricted due to trucking and warehouse operations. High seepage velocity is a design constraint that may require more frequent injections. Repeated injections and performance monitoring are relatively easy to implement. Sufficient chemical distribution to provide adequate treatment would be difficult given the heterogeneity and high seepage velocity.	**Direct: High** **LONG TERM (OMM): Low** **Overall: Moderate to High**	Reject
	Chemical treatment (oxidative; e.g., permanganate)	**Benefits:** *In situ* destruction; can inject at multiple depths; rapid contaminant destruction. **Limitations:** Treatment limited by distribution of chemical; longevity may be shortened in aquifers with high seepage velocities; repeated injections likely required. Aquifer characteristics determine well spacing.	**Low to Moderate** Oxidation is a well-documented treatment method, but oxidative chemicals must come in direct contact with contaminants to be effective. Preferential flow paths for injected material may not reach low-permeability zones, which reduces effectiveness in source areas of late-stage plumes dominated by back diffusion from low-permeability zones.	**Difficult** Does not require installation of permanent aboveground treatment equipment; however, significant equipment is needed during injection. Site use is somewhat restricted due to trucking and warehouse operations. High seepage velocity is a design constraint that may require more frequent injections. Repeated injections and performance monitoring are relatively easy to implement. Sufficient chemical distribution to provide adequate treatment would be difficult given the heterogeneity and high seepage velocity.	**Direct: High** **LONG TERM (OMM): Low** **Overall: Moderate to High**	Reject

Table 14
Cleanup Technologies Screening
Building 17-03 Source Area; Building 17-03 Former Degreasers, Tank Line, and Waste Piping

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			Site Specific Rankings			
General Response Actions	**Technology Option**	**Benefits / Limitations**	**Effectiveness**	**Implementability**	**Relative Cost**	**Screening Result Retain/Reject**
Enhanced Groundwater Flushing	Dynamic groundwater recirculation	**Benefits:** Complete treatment of extracted groundwater. Potential to vary groundwater flow paths and remove contaminants from zones of lower hydraulic conductivity. Does not remove material adsorbed to aquifer matrix. Faster restoration time than pump and treat. **Limitations:** Would require aboveground treatment before reinjection. In reduced aquifers, potential for biofouling increases OMM cost; larger treatment system footprint than in-situ technologies.	**Low to Moderate** Effectiveness has not been thoroughly demonstrated yet, particularly on low-concentration plumes, because dynamic groundwater recirculation (DGR) is a relatively new cleanup technology. Theoretically more effective than pump and treat.	**Difficult** Excessive pumping/discharge rates needed to influence groundwater flow due to high seepage velocity and aquifer thickness. Requires aboveground infrastructure. Construction and placement of infrastructure may be limited by existing site use and site needs (area is now a trucking corridor).	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Retain
Ex-Situ Physical/Chemical Treatment	Pump and treat (various *ex-situ* treatment options)	**Benefits:** Complete treatment of extracted groundwater. **Limitations:** High extraction rates needed in aquifers with hydraulic conductivity; need for discharge permits to discharge large volume of water to sewer or surface water; larger treatment system footprint than in-situ technologies. Does not remove material adsorbed to aquifer matrix.	**Low** Pump and treat effectiveness decreases as contaminant concentrations decrease. Typically not very effective for low-concentration plumes. Potential for problems with rebound once system is turned off.	**Difficult** Excessive pumping/discharge rates needed to capture groundwater due to high seepage velocity and aquifer thickness. Construction and placement of infrastructure may be limited by existing site use and site needs (area is now a trucking corridor).	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
Containment (physical)	Slurry walls, low-permeability barrier walls, or sheet pile walls	**Benefits:** Contains or slows contaminated groundwater movement. Can limit migration. **Limitations:** Does not provide treatment; not a permanent remedy. Typically has low effectiveness in aquifers with high seepage velocities. Engineering constraints limit depth of barrier.	**Low** Not effective to contain contaminant plume with a physical barrier alone due to high seepage velocities and aquifer thickness.	**Difficult** Not feasible to contain contaminant plume with a physical barrier alone due to high seepage velocities and aquifer thickness.	**Direct: High** **LONG TERM (OMM): Low** **Overall: High**	Reject

Table 14
Cleanup Technologies Screening
Building 17-03 Source Area; Building 17-03 Former Degreasers, Tank Line, and Waste Piping

Site Physical Conditions: Includes groundwater plume at the Building 17-03 source area on Prologis property. Constituents of concern (COCs) are **trichloroethene (TCE) and vinyl chloride (VC)**. Concentrations of TCE in groundwater monitoring wells in the area have typically been below 5 micrograms per liter (µg/L); however, groundwater grab samples in the area have detections of up 11 µg/L. TCE is also present in soil gas near the Building 17-03 source area with concentrations of up to 1,700 micrograms per cubic meter (µg/m^3). 2017 investigation activities indicated limited detections of TCE in soil that were generally at or below the depth of the high water table. Soils are generally highly permeable sands and gravels with some interbedded silt layers. The groundwater table is present near the ground surface at approximately 10 to 18 feet (ft) below ground surface (bgs). The aquifer thickness in this area is approximately 90 ft thick. COCs are present in the shallow and intermediate aquifer zones. Breakdown products cis-1,2-dichloroethene (cDCE) and VC are generally not detected in this area, indicating conditions for reductive dechlorination are limited; however concentrations have been declining naturally at AGW001 in the source area from a high around 5 µg/L in 2008 to around 1 µg/L in 2018. Access to the area for investigation is currently restricted due to trucking operations occurring on this property. An access agreement that makes changes to timing, location, and scheduling of cleanup or business operations will be required to permit cleanup. In 2005, an enhanced bioremediation injection cleanup was completed in adjacent former Building 17-05. The cleanup was successful and reducing conditions have persisted in the treatment zone since the completion of the cleanup.

General Response Actions	Technology Option	Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
			Effectiveness	**Implementability**	**Relative Cost**	
Containment (hydraulic)	Interceptor trench or extraction wells	**Benefits:** Partially captures contaminants and limits migration. **Limitations:** *Ex-situ* treatment needed; does not treat downgradient plume; Engineering constraints limit the depth of treatment. Need for discharge permits.	**Low** More effective than physical containment alone, but limited in ability to affect deeper portions of the aquifer.	**Difficult** Depth of treatment needed is not conducive for interceptor trenches. Excessive pumping/discharge rates needed to capture groundwater due to high seepage velocity and aquifer thickness. Construction and placement of infrastructure may be limited by existing site use and site needs (area is now a trucking corridor).	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
Institutional Controls	Restrictive environmental covenant, fencing, signage	**Benefits:** Restrict use of/exposure to contaminated groundwater; can be combined with other technologies to make more protective. **Limitations:** Restricts future property use and activity; does not provide treatment; requires review indefinitely.	**Low to Moderate** May be useful in limited situations. Not effective as a standalone solution for this Site, but can be combined with other technologies to make more protective.	**Moderate** Offsite property owners may not agree to environmental covenants.	**Direct: Low** **LONG TERM (OMM): Low** **Overall: Low**	Retain

Table 15
Cleanup Technologies Screening
Surface Water

Site Physical Conditions: Includes surface water in Mill Creek. Currently, there are no detections of contaminants in Mill Creek. Constituents of concern (COCs) are **trichloroethene (TCE) and vinyl chloride (VC)**. Access concerns include deep surface water features surrounded by wetland and bordered by major roadways and highways.

General Response Actions	Technology Option	Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
			Effectiveness	Implementability	Relative Cost	
			GROUNDWATER (upgradient of surface water)			
In-Situ Biological Treatment	Enhanced bioremediation	**Benefits**: Treat groundwater at multiple depths; can use injection/extraction to create overlap between wells (overlapping treatment zones form a pseudo barrier). **Limitations:** Potential to increase VC concentrations downgradient (VC is a more toxic by-product of TCE degradation). Recontamination from upgradient source areas. Substrate can adversely affect surface water geochemical conditions (e.g., total organic carbon and biological oxygen demand).	**Moderate** Demonstrated effectiveness for reductive dechlorination of COCs at Site. Building 17-05 remediation and Algona pilot study demonstrated bioremediation is effective at reducing COC concentrations. However, VC has been an ongoing issue in the pilot study area, potentially due to recontamination from upgradient sources.	**Difficult** Requirement for repeated injections due to recontamination from upgradient sources. Required length of treatment (>1,000 feet) is excessive. Fast seepage velocities reduce the duration of effective treatment and the potential for discharge of injection substrate to adjacent surface water. Infrastructure, highways, and wetlands limit access for well installation. Injection near surface water is problematic because high seepage velocities and preferential flow pathways create a high likelihood of substrate discharging to surface water. If wells need to be placed in critical areas, permitting is difficult.	**Direct: High** (Includes engineering; well installation; injection fluid, labor, and equipment for multiple injections) **Long Term (operation, monitoring, and maintenance [OMM]): Low** (groundwater monitoring) **Overall: Moderate to High**	Reject
Natural Attenuation	Monitored natural attenuation (MNA)	**Benefits:** Treats entire plume (both vertical and horizontal); destruction of contaminants. Can be combined with other technologies. Low cost of implementation. **Limitations:** Variable degradation rates; longer restoration timeframe than more active alternatives.	**Moderate to High** Site has demonstrated COC destruction through natural biodegradation processes. Effectiveness is limited by variable natural degradation rates.	**Easy** The existing monitoring network is extensive, so construction costs would be low. Life-span of option is much longer than other technologies.	**Direct: Low** **LONG TERM (OMM): Moderate** **Overall: Low to Moderate**	Retain
Phyto-remediation	Planting vegetation around surface water features (e.g., poplar trees, willow trees)	**Benefits:** Can provide a polishing phase to other cleanup technologies **Limitations:** Permitting constraints, depth is limited to root zone, mass removal mechanisms are not well understood.	**Low to Moderate** Limited depth of treatment; may be difficult to plant sufficient amounts for complete treatment due to high seepage velocity	**Moderate** Highways and infrastructure nearby limit access for planting; large amounts of surface water in winter may limit area available for planting. Relatively easy to plant trees. Requires maintenance and weed control until plants become established. Area has high populations of invasive species that may require chemical control.	**Direct: Moderate** **LONG TERM (OMM): Moderate** **Overall: Low**	Retain
In-Situ Physical/Chemical Treatment (passive/reactive treatment barrier upgradient of surface water)	Air Sparge	**Benefits:** Permanently removes volatile contaminants. Removal rates are relatively fast. **Limitations:** Preferential flow paths may limit complete cleanup of impacted groundwater.	**Low** TCE and other chlorinated volatile organic compounds (cVOCs) have relatively high vapor pressure, which is favorable for volatilization. However, the aquifer thickness and high seepage velocity greatly limits the effectiveness of this treatment beyond the shallow aquifer zone.	**Difficult** Costly because of required treatment depth and high groundwater seepage velocity. Requires significant aboveground infrastructure and electricity. Construction and placement of infrastructure extremely difficult due to nearby roadways, wetland critical areas, and access limitations near surface water features. Potential electrocution hazards related to placement of electrical equipment in wet areas.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject

Table 15
Cleanup Technologies Screening
Surface Water

Site Physical Conditions: Includes surface water in Mill Creek. Currently, there are no detections of contaminants in Mill Creek. Constituents of concern (COCs) are **trichloroethene (TCE) and vinyl chloride (VC)**. Access concerns include deep surface water features surrounded by wetland and bordered by major roadways and highways.

			Site Specific Rankings			
General Response Actions	**Technology Option**	**Benefits / Limitations**	**Effectiveness**	**Implementability**	**Relative Cost**	**Screening Result Retain/Reject**
	Chemical treatment permeable reactive barrier (reductive; e.g., zero valent iron, activated carbon)	**Benefits:** Passive treatment requiring little maintenance; can treat groundwater at multiple depths; can target wide range of contaminants. **Limitations:** Temporary treatment – Typically requires refreshing barrier periodically; fast seepage velocities increase the width of required treatment and may reduce the duration of effective treatment; potential for biofouling, clogging of aquifer matrix. Substrate can adversely affect surface water geochemical conditions (e.g., total organic carbon and biological oxygen demand).	**Low** Aquifer is naturally reducing and, consequently, treatment would be short-lived and have limited effect. Preferential flow paths in groundwater may inhibit distribution of injected media in total treatment area and oxidation of groundwater would diminish reductive biological dechlorination activity in treatment area and downgradient.	**Difficult** Mass loading may be excessive due to high seepage velocity and natural oxidant demand making the implementation difficult and costly. Requirement for repeated injections due to recontamination from upgradient sources. Required length of treatment (>1,000 feet) is excessive. Construction and placement of infrastructure extremely difficult due to nearby roadways and access near surface water features. Fast seepage velocities reduce the duration of effective treatment and the potential for discharge of injection substrate to adjacent surface water. If wells need to be placed in critical areas, permitting is difficult.	**Direct: High** (Includes engineering; well installation; injection fluid, labor, and equipment for multiple injections) **LONG TERM (OMM): Low** (groundwater monitoring) **Overall: High**	Reject
	Chemical treatment (oxidative; e.g., permanganate)	**Benefits:** *In situ* destruction; can inject at multiple depths; rapid contaminant destruction. **Limitations:** Treatment limited by distribution of chemical; longevity may be shortened in aquifers with high seepage velocities; repeated injections likely required. Aquifer characteristics determine well spacing. Oxidants may discharge to surface water.	**Low to Moderate** Oxidation is a well-documented treatment method, but oxidative chemicals must come in direct contact with contaminants to be effective.	**Difficult** Does not require installation of permanent aboveground treatment equipment; however, significant equipment is needed during injection. Construction and placement of infrastructure extremely difficult due to nearby roadways, wetlands, and access constraints near surface water features. High seepage velocity is a design constraint that may require more frequent injections. Repeated injections and performance monitoring are relatively easy to implement. Sufficient chemical distribution to provide adequate treatment would be difficult given the heterogeneity and high seepage velocity.	**Direct: High** (Includes engineering; well installation; injection fluid, labor, and equipment for multiple injections) **LONG TERM (OMM): Low** (groundwater monitoring) **Overall: High**	Reject
	Thermal Treatment	**Benefits:** Removal of contaminants through volatilization; does not directly influence redox conditions. **Limitations:** Energy-intensive, requires extensive aboveground infrastructure, typically most effective in source zones only.	**Low** Effectiveness is dependent on ability to transfer enough heat to groundwater to vaporize COCs. High seepage velocity may limit heat transfer and, therefore, treatment effectiveness.	**Difficult** Depth of treatment required at near-surface water features combined with relatively low-contaminant concentrations are not conducive to thermal treatment; energy demands would be excessive due to high seepage velocity and aquifer thickness; potential to damage adjacent utilities. May be infeasible to install due to presence of wetlands and infrastructure; vapor extraction component infeasible due to saturation to ground surface; increase temperature of groundwater discharging to creek, which negatively affects biota and plant life. Requires electricity to operate; potential electrocution hazards related to placement of electrical equipment in wet areas.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject

Table 15
Cleanup Technologies Screening
Surface Water

Site Physical Conditions: Includes surface water in Mill Creek. Currently, there are no detections of contaminants in Mill Creek. Constituents of concern (COCs) are **trichloroethene (TCE) and vinyl chloride (VC)**. Access concerns include deep surface water features surrounded by wetland and bordered by major roadways and highways.

General Response Actions	Technology Option	Benefits / Limitations	Site Specific Rankings			Screening Result Retain/Reject
			Effectiveness	**Implementability**	**Relative Cost**	
Ex-Situ Physical/Chemical Treatment	Pump and treat (various *ex-situ* treatment options)	**Benefits:** Complete treatment of extracted groundwater. **Limitations:** High extraction rates needed in aquifers with hydraulic conductivity; need for discharge permits to discharge large volume of water to sewer or surface water; larger treatment system footprint than in-situ technologies. Does not remove material adsorbed to aquifer matrix.	**Low** Pump and treat effectiveness decreases as contaminant concentrations decrease. Typically not very effective for low-concentration plumes. Potential for problems with rebound once system is turned off.	**Difficult** Excessive pumping/discharge rates needed to capture groundwater due to high seepage velocity and aquifer thickness. Construction and placement of infrastructure limited by nearby roadways and presence of wetlands. Requires electricity to operate; potential electrocution hazards related to placement of electrical equipment in wet areas.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
Containment (hydraulic)	Interceptor trench or extraction wells	**Benefits:** Partially captures contaminants and limits migration. **Limitations:** *Ex-situ* treatment needed. Engineering constraints limit the depth of treatment. Need for discharge permits.	**Low** Limited in ability to affect deeper portions of the aquifer.	**Difficult** Excessive pumping/discharge rates needed to capture groundwater due to high seepage velocity and aquifer thickness. Construction and placement of infrastructure may be limited by nearby roadways and presence of wetlands. Requires electricity to operate; potential electrocution hazards related to placement of electrical equipment in wet areas.	**Direct: High** **LONG TERM (OMM): High** **Overall: High**	Reject
SURFACE WATER						
Containment (physical)	Piping of surface water features	**Benefits:** Prevents contaminated groundwater from discharging to surface water features. **Limitations:** Feasibility dependent on size/flow of surface water features. Potential to alter groundwater flow and nearby groundwater elevations if discharge sink is removed.	**Low to Moderate** High groundwater discharge rates may not allow for physical containment of surface water features.	**Moderate to Difficult** Only implementable where amount of groundwater discharging to surface water is limited and where volume of surface water needed to be piped would be feasible. Would require extensive permitting and agreement from municipalities.	**Direct: High** **LONG TERM (OMM): Low** **Overall: High**	Retain
Institutional Controls	Restrictive environmental covenant, fencing, signage	**Benefits:** Restricts use of/exposure to contaminated groundwater. Requires engineering controls or signage. **Limitations:** Does not provide treatment. Requires agreement from third parties.	**Low to Moderate** May be useful in limited situations. Not effective as a standalone solution for this Site, but can be combined with other technologies to make more protective.	**Easy** Covenants may not be applicable or legally enforceable due to public use of waters of the state. However, signage is relatively easy to install and would provide warning to the public.	**Direct: Low** **LONG TERM (OMM): Low** **Overall: Low**	Retain

Table 16
Summary of Retained Technologies

	Technologies					
	Site-wide Groundwater Downgradient of Source Areas		Area of Concern A-13 (Building 17-06 Hydrocarbon Release)		Area of Concern A-01	
Treatment Category	Retained	Screened Out	Retained	Screened Out	Retained	Screened Out
Containment (Physical/Hydraulic)	None	Slurry walls, low-permeability barrier walls, or sheet pile walls Interceptor trench or extraction wells	Cap (Contain in place)	Vertical barrier (Slurry walls, low-permeability barrier walls, or sheet pile walls)	Cap (Contain in place)	Vertical barrier (Slurry walls, low permeability barrier walls, or sheet pile walls)
Ex-Situ Physical/Chemical Treatment	None	Pump and treat (various ex-situ treatment options)	None	Pump and treat (various ex-situ treatment options)	None	Pump and treat (various ex-situ treatment options)
Enhanced Groundwater Flushing	Dynamic groundwater recirculation	None	Not Applicable (NA)	NA	NA	NA
In Situ Biological Treatment	Enhanced bioremediation (property boundary and downgradient) Monitored Natural Attenuation (MNA)	None	Monitored Natural Attenuation (MNA)	Enhanced bioremediation (reductive) Enhanced bioremediation (oxidative)	Enhanced bioremediation (reductive) Enhanced bioremediation (oxidative) Monitored natural attenuation (MNA)	None
In Situ Chemical/Physical Treatment	Chemical treatment (reductive; e.g., zero valent iron)	Air sparge Chemical treatment (oxidative; e.g., permanganate) Thermal treatment	None	Air sparge Surfactant Chemical Oxidation Thermal treatment	Air/ozone sparge Chemical Oxidation	Thermal treatment
Physical Removal (Soil)	NA	NA	Excavation	None	Excavation	None
Phytoremediation	NA	NA	NA	NA	NA	NA
Product Recovery	NA	NA	Passive (sorbent sock)	Dual-phase extraction Active (belt skimmer)	NA	NA
Institutional Controls	Restrictive environmental covenant, fencing, signage	None	Restrictive environmental covenant, fencing, signage	None	Restrictive environmental covenant, fencing, signage	None

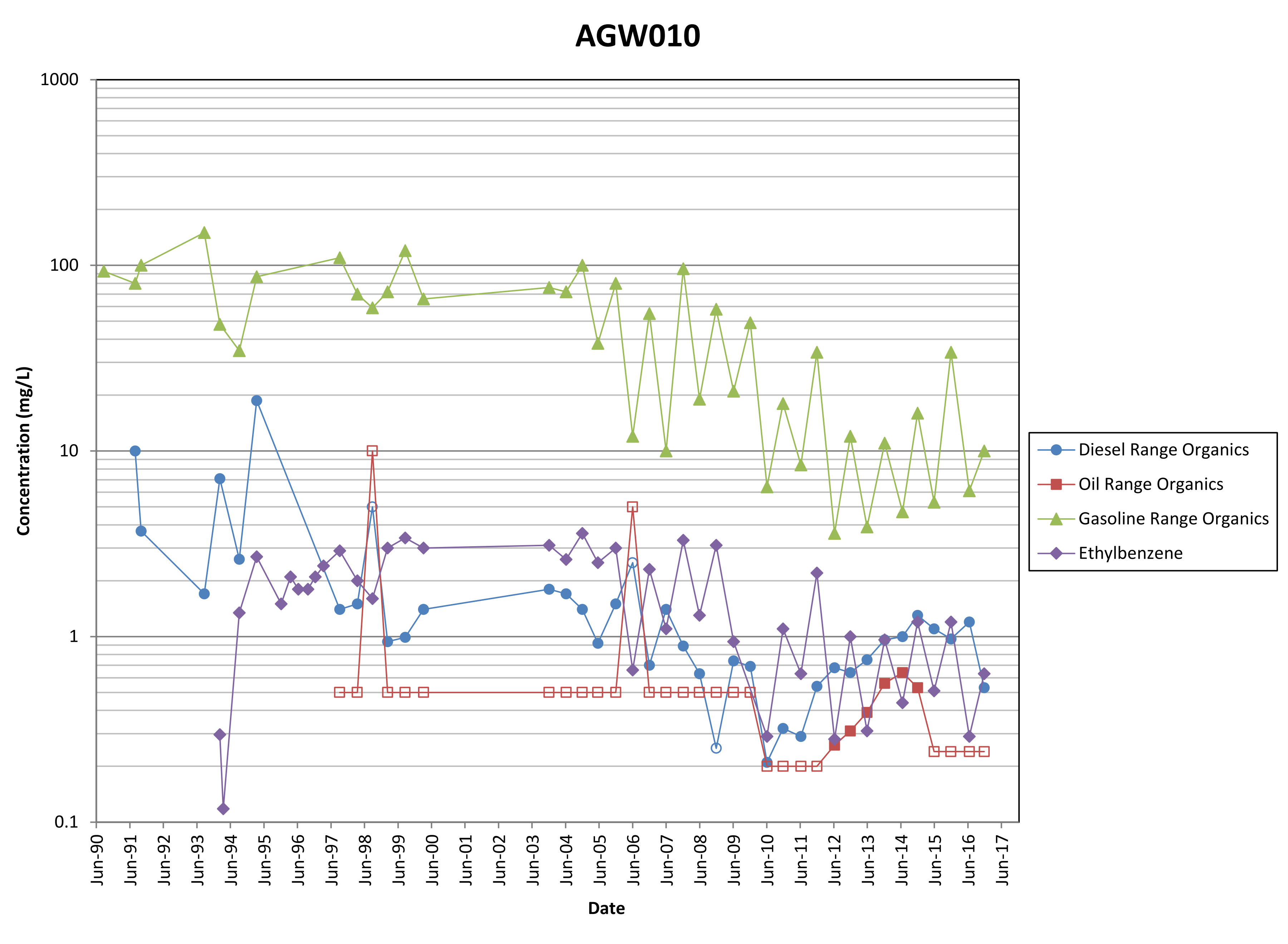
Table 16
Summary of Retained Technologies

	Technologies							
	Area of Concern A-09		Building 17-07 Former Degreaser Source Area		Building 17-03 Former Degreaser Source Area		Surface Water	
Treatment Category	Retained	Screened Out	Retained	Screened Out	Retained	Screened Out	Retained	Screened Out
Containment (Physical/Hydraulic)	Cap (Contain in place)	Vertical barrier (Slurry walls, low-permeability barrier walls, or sheet pile walls)	None	Slurry walls, low-permeability barrier walls, or sheet pile walls Interceptor trench or extraction wells	None	Slurry walls, low-permeability barrier walls, or sheet pile walls Interceptor trench or extraction wells	Piping of Surface Water Features	Interceptor trench or extraction wells
Ex-Situ Physical/Chemical Treatment	None	Pump and treat (various ex-situ treatment options)	None	Pump and treat (various ex-situ treatment options)	None	Pump and treat (various *ex-situ* treatment options)	None	Pump and treat (various *ex-situ* treatment options)
Enhanced Groundwater Flushing	NA	NA	None	Dynamic groundwater recirculation	Dynamic groundwater recirculation	None	NA	NA
In Situ Biological Treatment	None	Enhanced bioremediation (oxidative)	Enhanced bioremediation (reductive) Monitored natural attenuation (MNA)	None	Enhanced bioremediation (reductive) Monitored natural attenuation (MNA)	None	Monitored natural attenuation (MNA)	Enhanced bioremediation
In Situ Chemical/Physical Treatment	Sorption/Precipitation	Chemical oxidation Air/ozone sparging; biosparging	SVE (soil only)	Air sparge Chemical treatment (reductive) Chemical treatment (oxidative) Thermal treatment	SVE (soil only)	Air sparge Chemical treatment (reductive) Chemical treatment (oxidative) Thermal treatment	None	Air sparge Chemical treatment (reductive) Chemical treatment (oxidative) Thermal treatment
Physical Removal (Soil)	Excavation	None	NA	NA	NA	NA	NA	NA
Phytoremediation	NA	NA	NA	NA	NA	NA	Planting vegetation	None
Product Recovery	NA	NA	NA	NA	NA	NA	NA	NA
Institutional Controls	Restrictive environmental covenant, fencing, signage	None	Restrictive environmental covenant, fencing, signage	None	Restrictive environmental covenant, fencing, signage	None	Restrictive environmental covenant, fencing, signage	None

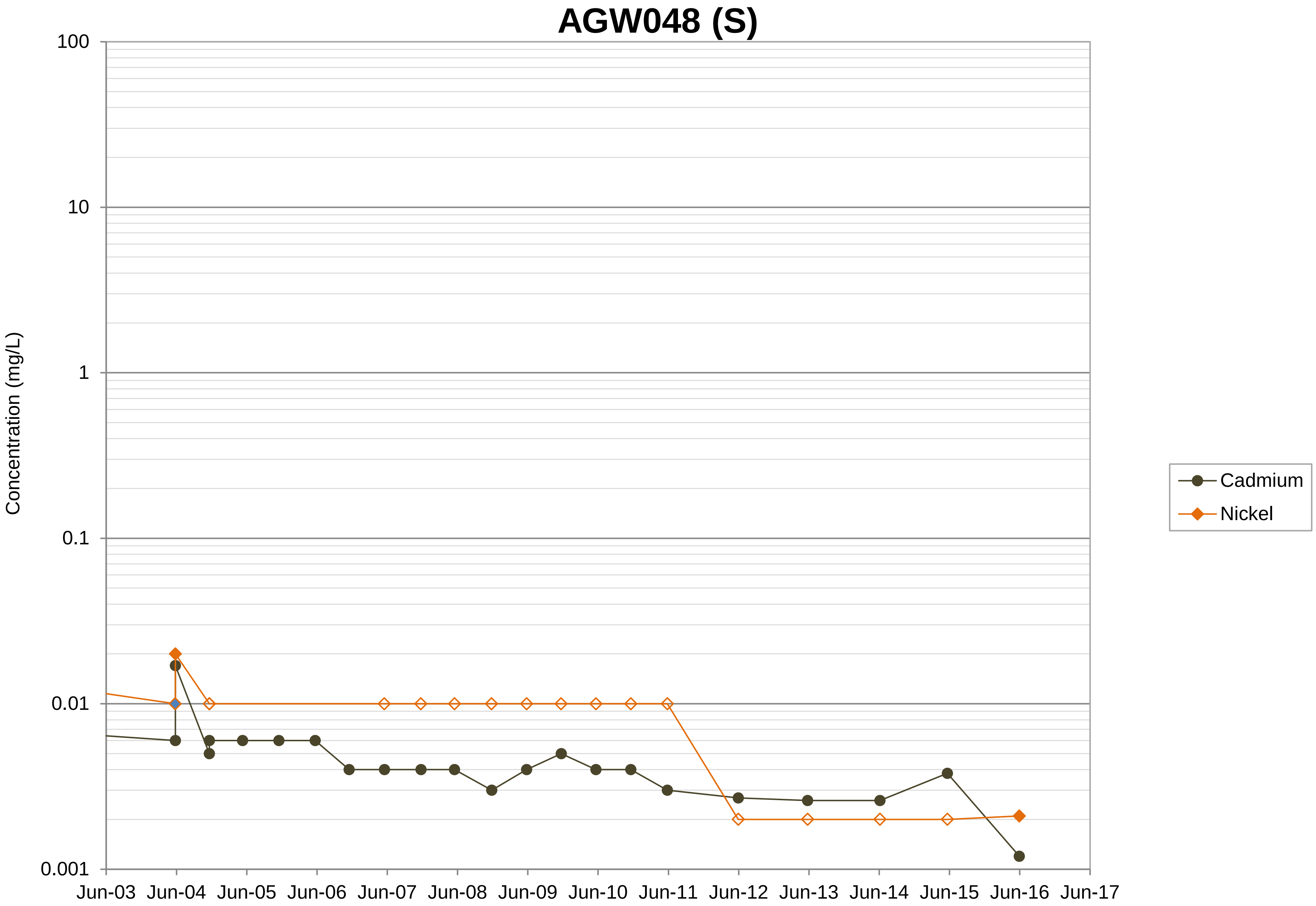
APPENDIX A

Time Series Plots

AOC A-01 TPH


AGW010
Concentration (mg/L)
1000
100
10
1
0.1
Jun-90
Jun-91
Jun-92
Jun-93
Jun-94
Jun-95
Jun-96
Jun-97
Jun-98
Jun-99
Jun-00
Jun-01
Jun-02
Jun-03
Jun-04
Jun-05
Jun-06
Jun-07
Jun-08
Jun-09
Jun-10
Jun-11
Jun-12
Jun-13
Jun-14
Jun-15
Jun-16
Jun-17
Date
Diesel Range Organics
Oil Range Organics
Gasoline Range Organics
Ethylbenzene

AOC A-09 Metals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Concentration (mg/L)
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0.001
Jun-03
Jun-04
Jun-05
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Jun-07
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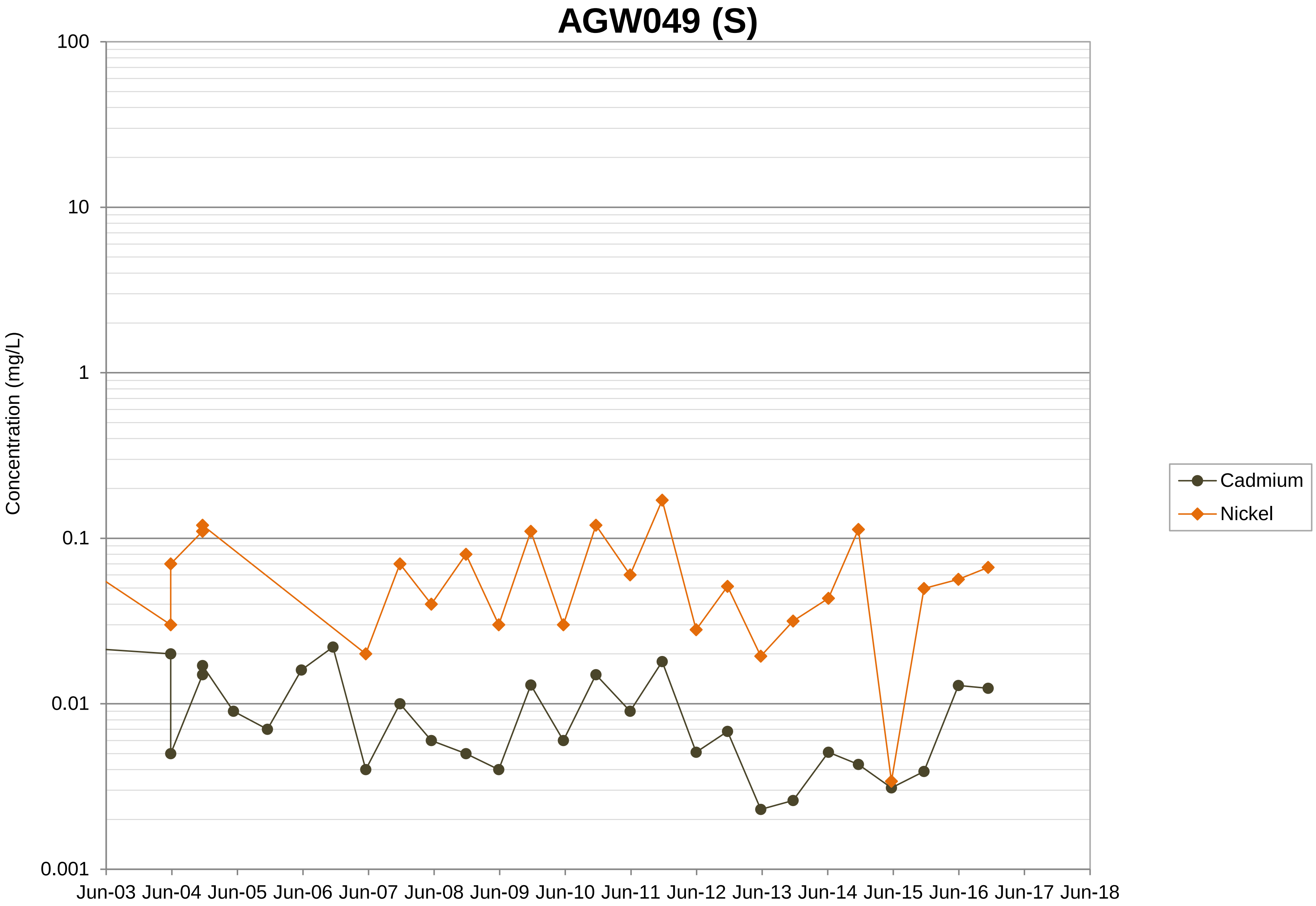
Jun-12
Jun-13
Jun-14
Jun-15
Jun-16
Jun-17
Cadmium
Nickel



AGW049 (S)
Concentration (mg/L)
100
10
1
0.1
0.01
0.001
Jun-03
Jun-04
Jun-05
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Jun-07
Jun-08
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Jun-14
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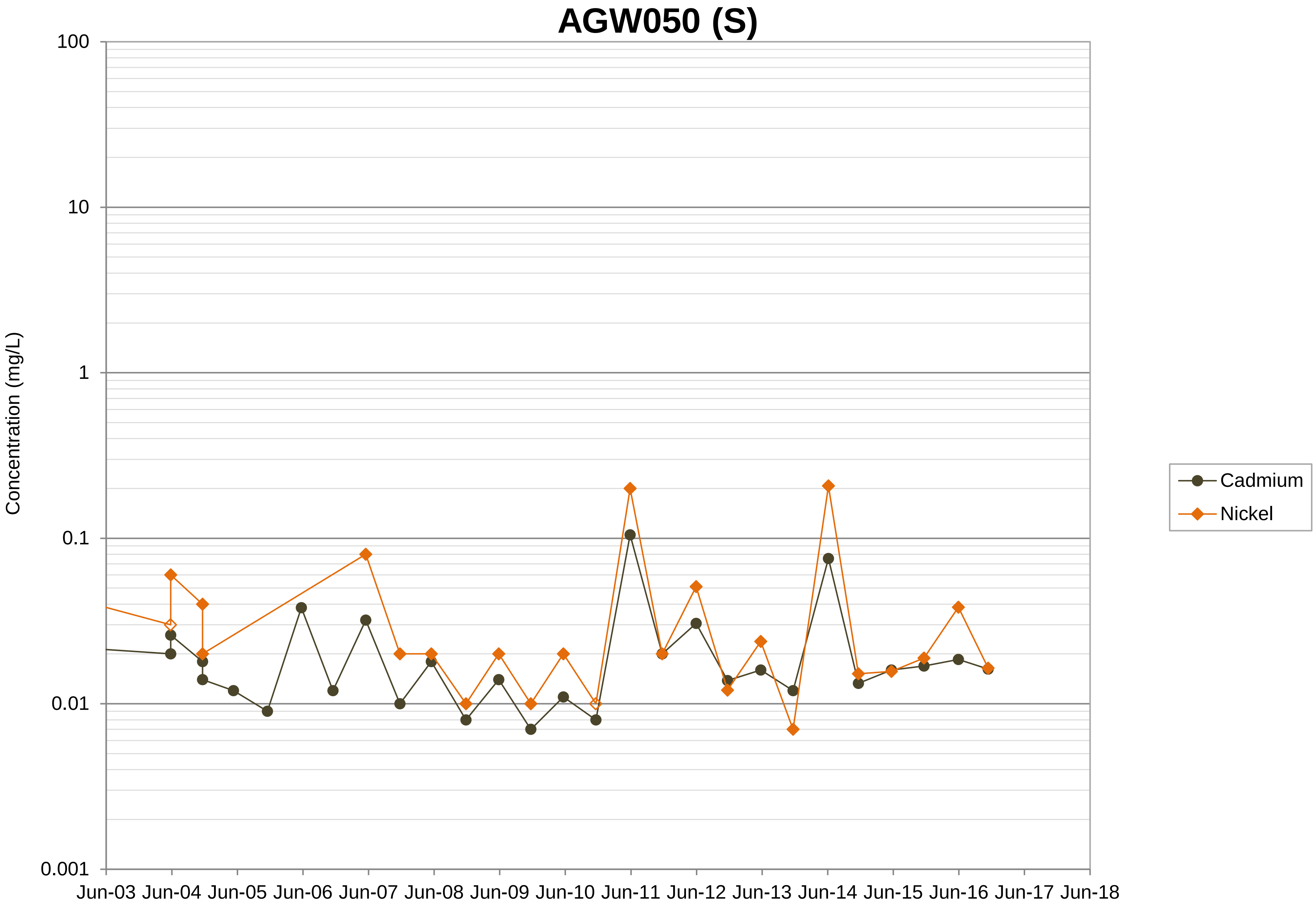
Jun-16
Jun-17
Jun-18
Cadmium
Nickel


AGW050 (S)
Concentration (mg/L)
100
10
1
0.1
0.01
0.001
Jun-03
Jun-04
Jun-05
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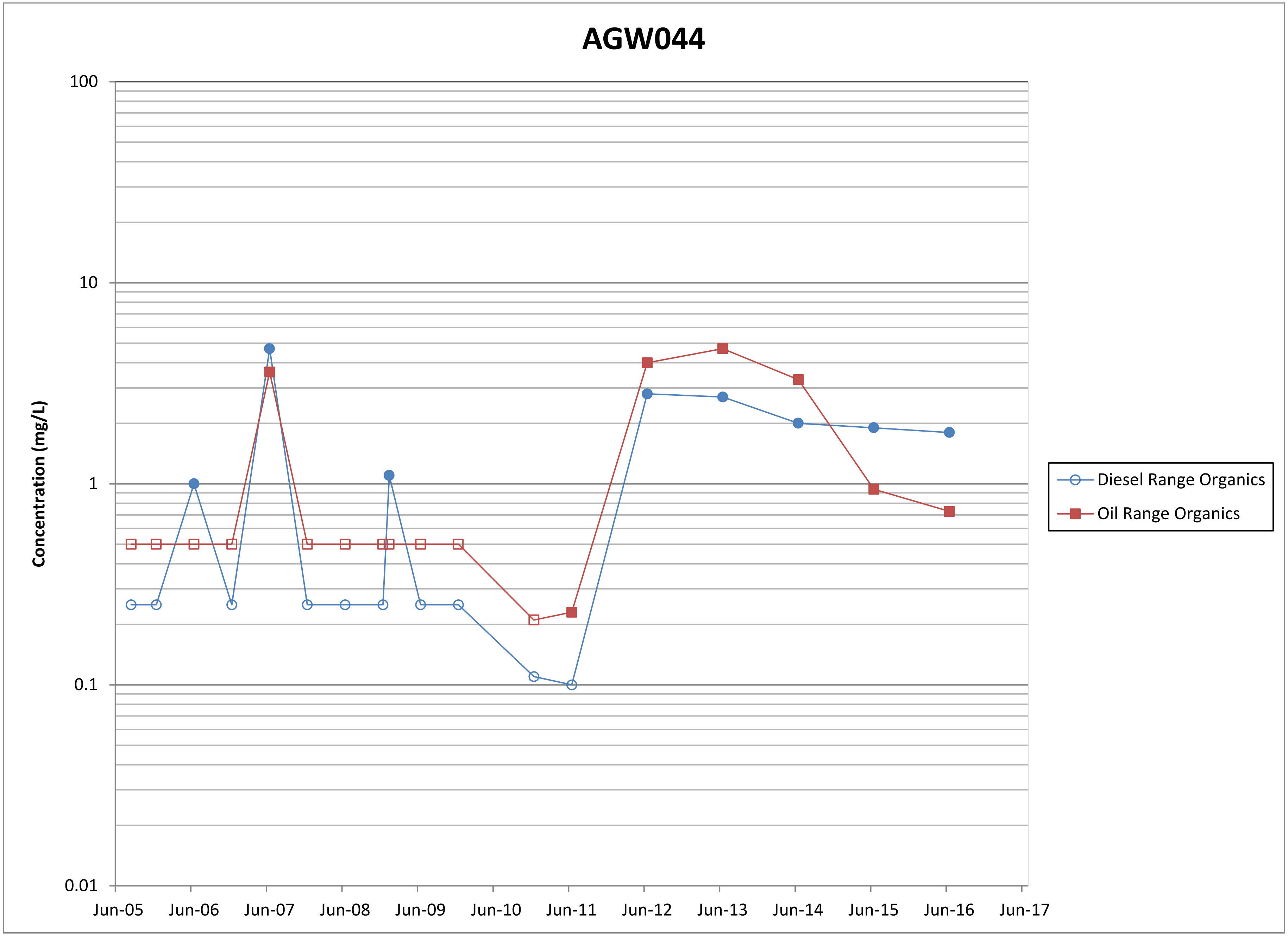
Jun-07
Jun-08
Jun-09
Jun-10
Jun-11
Jun-12
Jun-13
Jun-14
Jun-15
Jun-16
Jun-17
Jun-18
Cadmium
Nickel

AOC A-13 TPH

AGW044
Concentration (mg/L)
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10
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0.1
0.01
Jun-05
Jun-06
Jun-07
Jun-08
Jun-09
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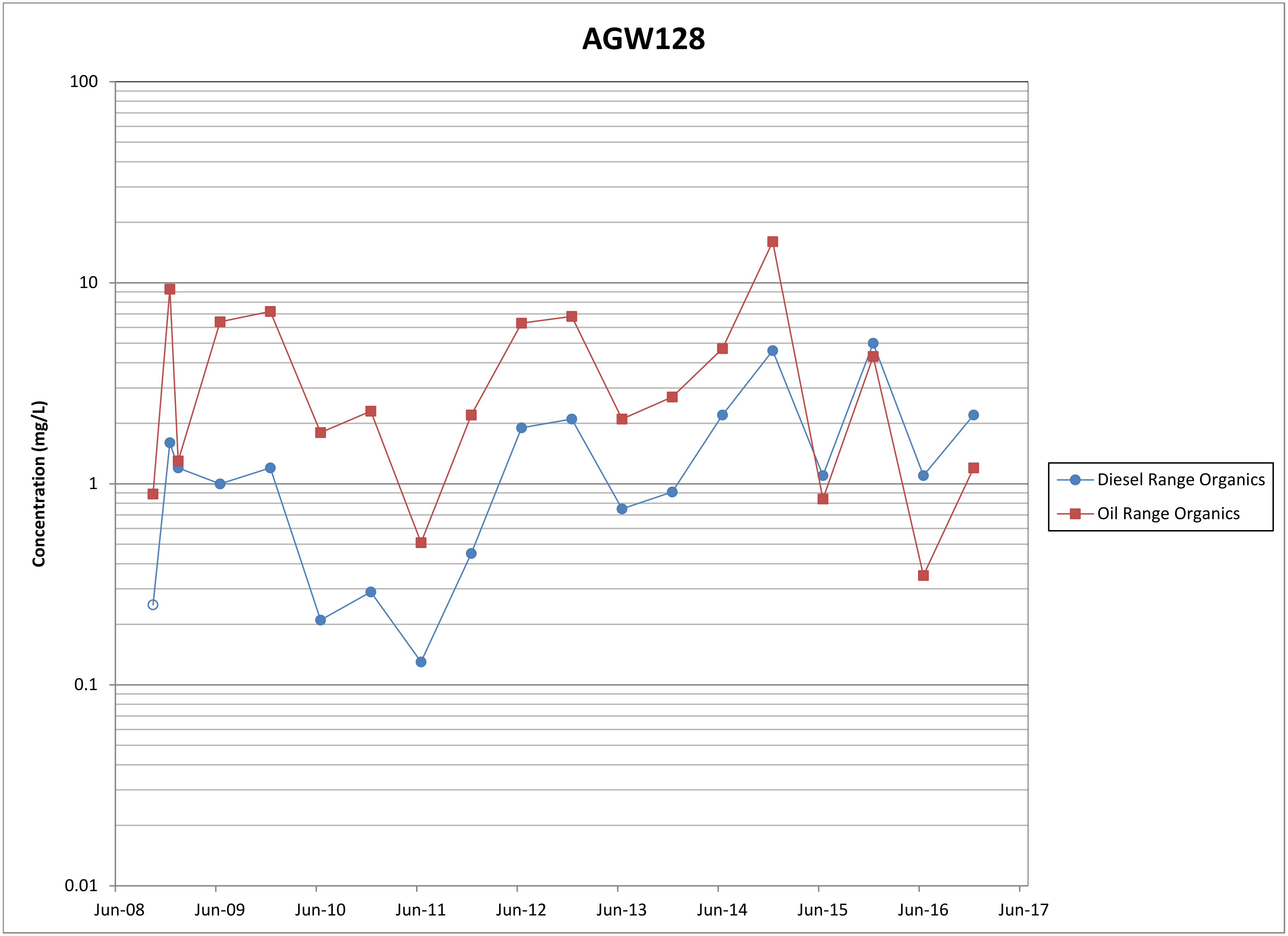
Jun-13
Jun-14
Jun-15
Jun-16
Jun-17
Diesel Range Organics
Oil Range Organics


AGW128
Concentration (mg/L)
100
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1
0.1
0.01
Jun-08
Jun-09
Jun-10
Jun-11
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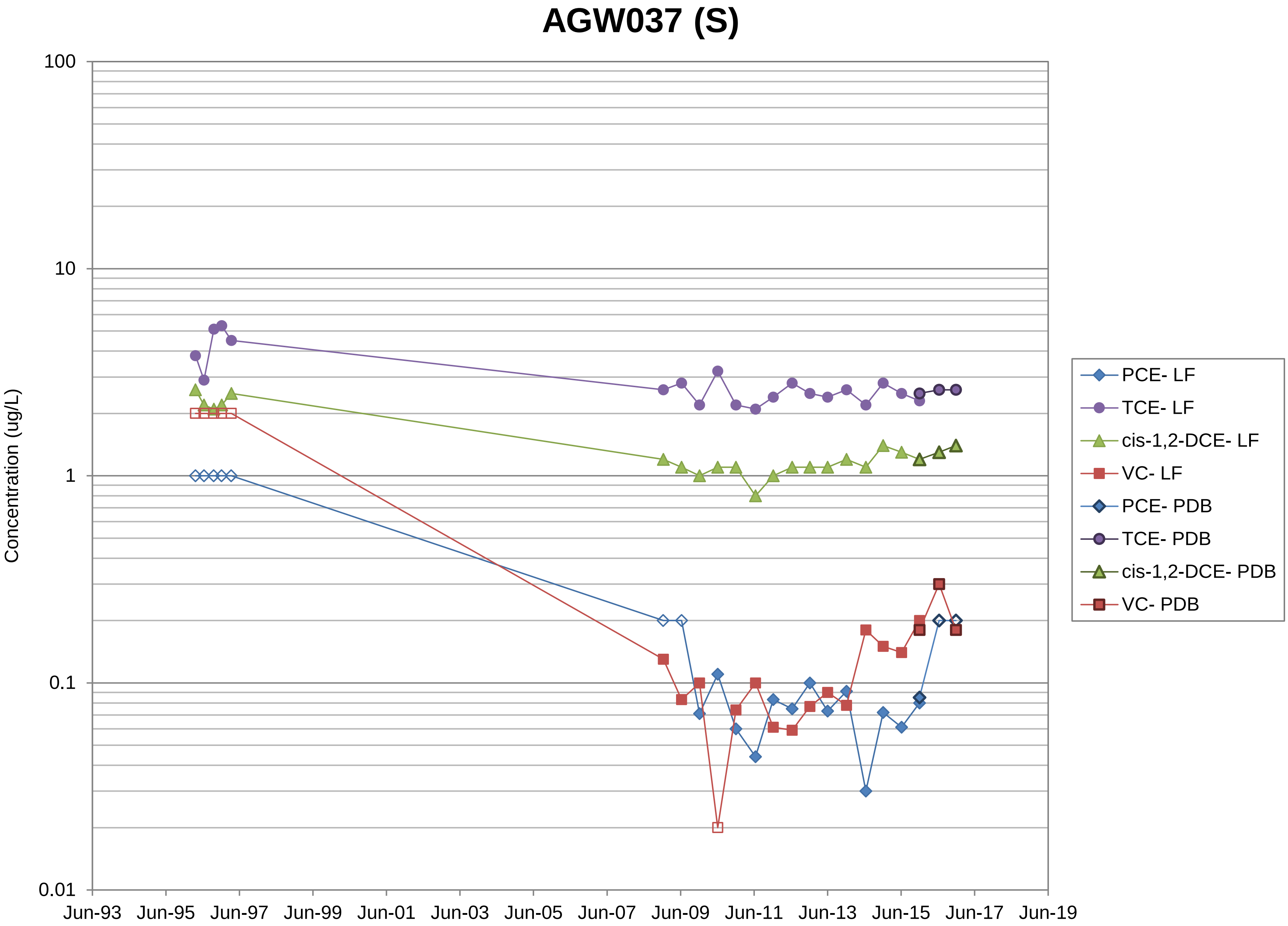
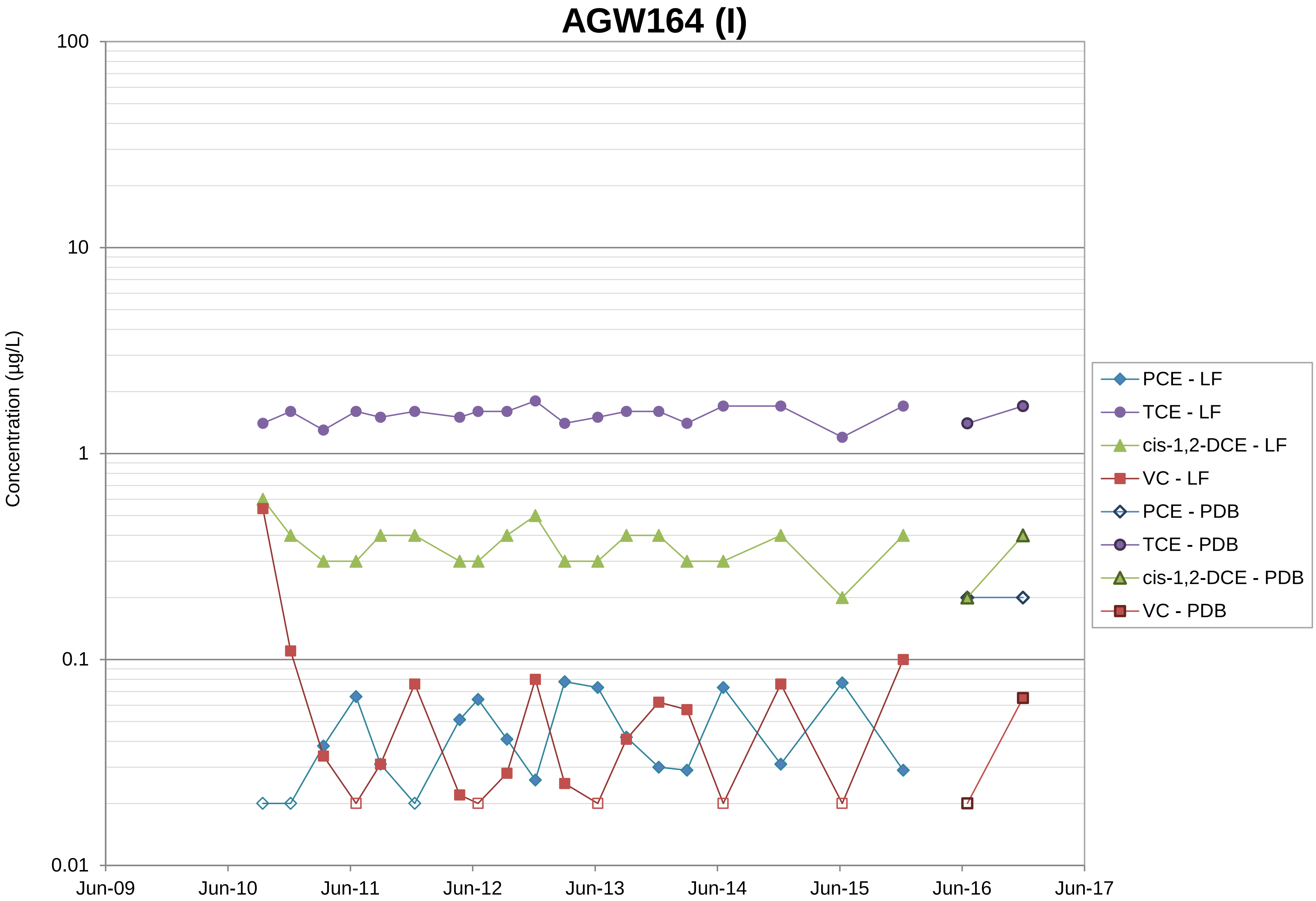
Jun-16
Jun-17
Diesel Range Organics
Oil Range Organics

Building 17-07 VOC


AGW037 (S)
100
10
1
0.1
0.01
Concentration (ug/L)
Jun-93
Jun-95
Jun-97
Jun-99
Jun-01
Jun-03
Jun-05
Jun-07
Jun-09
Jun-11
Jun-13
Jun-15
Jun-17
Jun-19
PCE- LF
TCE- LF
cis-1,2-DCE- LF
VC- LF
PCE- PDB
TCE- PDB
cis-1,2-DCE- PDB
VC- PDB


AGW164 (I)
Concentration (µg/L)
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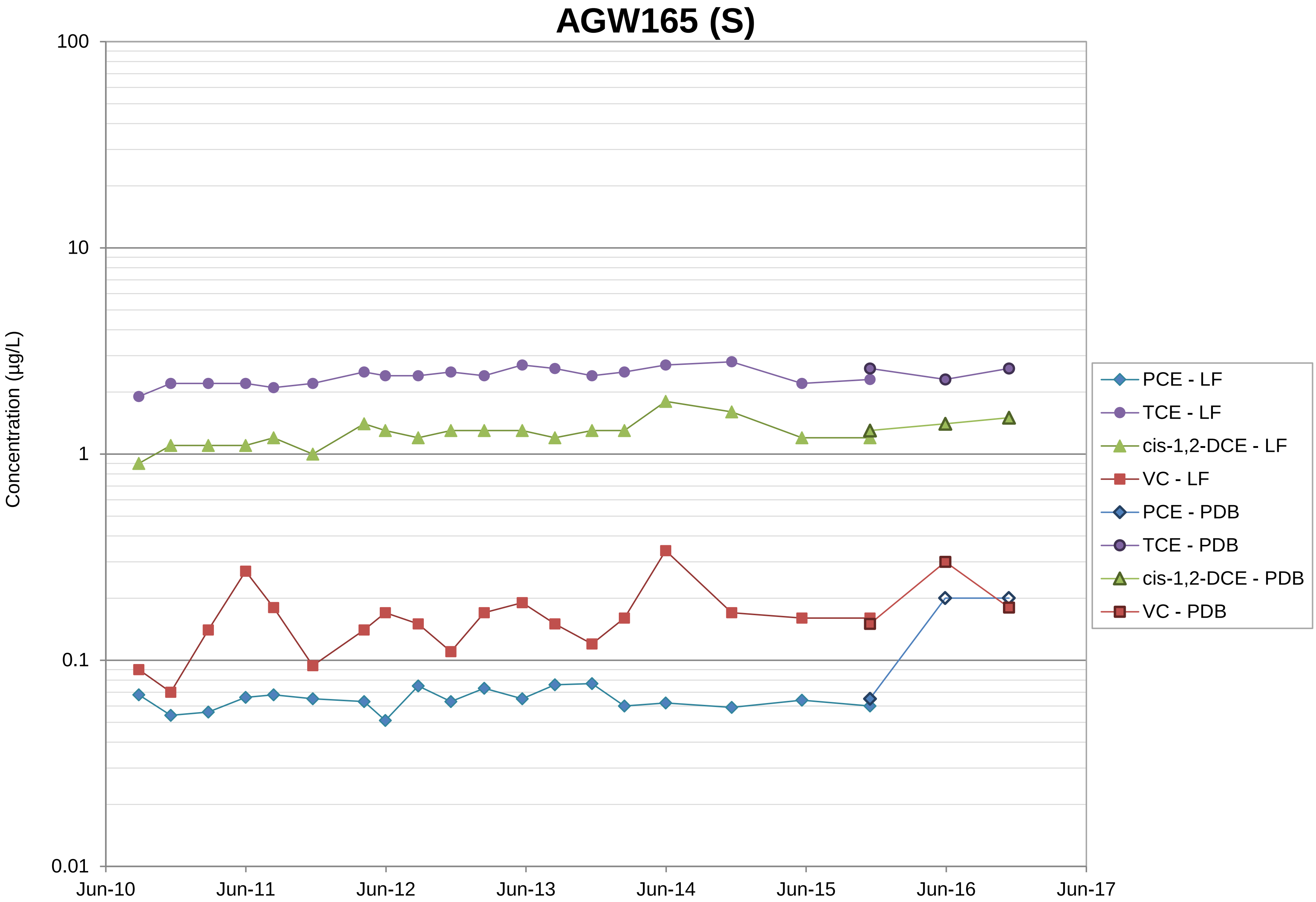
10
1
0.1
0.01
Jun-09
Jun-10
Jun-11
Jun-12
Jun-13
Jun-14
Jun-15
Jun-16
Jun-17
PCE - LF
TCE - LF
cis-1,2-DCE - LF
VC - LF
PCE - PDB
TCE - PDB
cis-1,2-DCE - PDB
VC - PDB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Concentration (µg/L)
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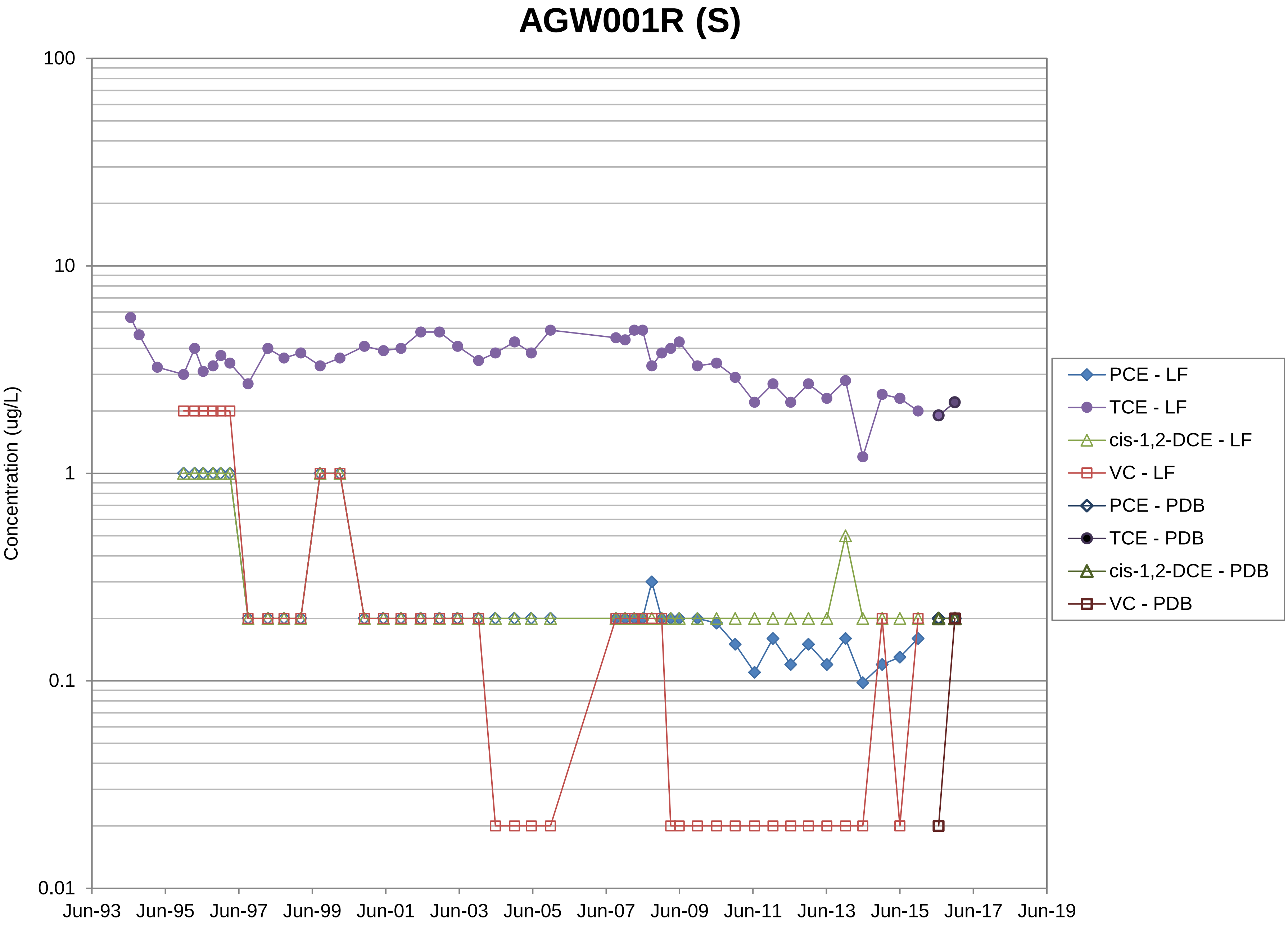
0.01
Jun-10
Jun-11
Jun-12
Jun-13
Jun-14
Jun-15
Jun-16
Jun-17
PCE - LF
TCE - LF
cis-1,2-DCE - LF
VC - LF
PCE - PDB
TCE - PDB
cis-1,2-DCE - PDB
VC - PDB

Former Building 17-03 VOC


AGW001R (S)
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0.01
Jun-93
Jun-95
Jun-97
Jun-99
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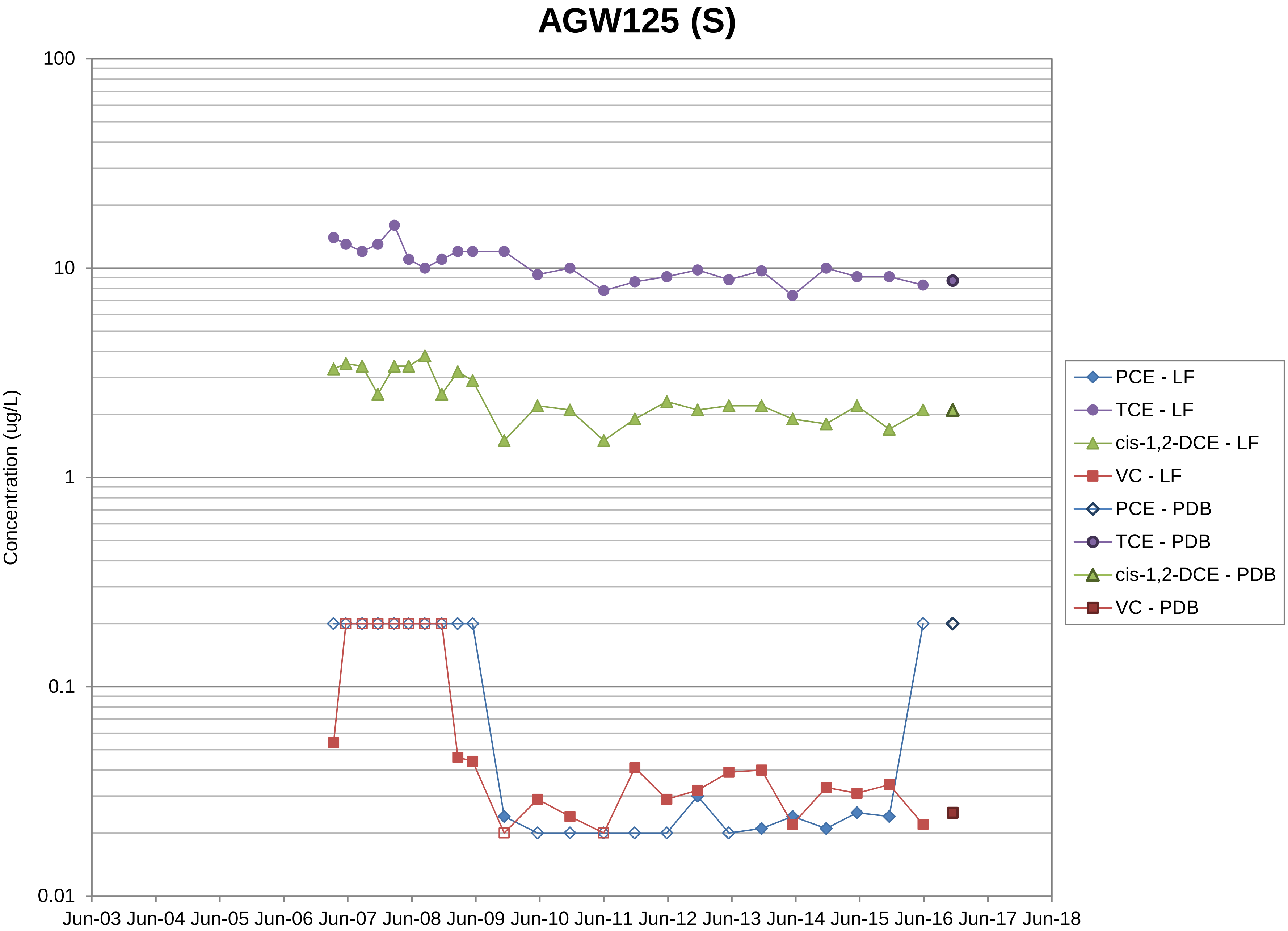
Jun-05
Jun-07
Jun-09
Jun-11
Jun-13
Jun-15
Jun-17
Jun-19
PCE - LF
TCE - LF
cis-1,2-DCE - LF
VC - LF
PCE - PDB
TCE - PDB
cis-1,2-DCE - PDB
VC - PDB


AGW125 (S)
Concentration (ug/L)
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10
1
0.1
0.01
Jun-03
Jun-04
Jun-05
Jun-06
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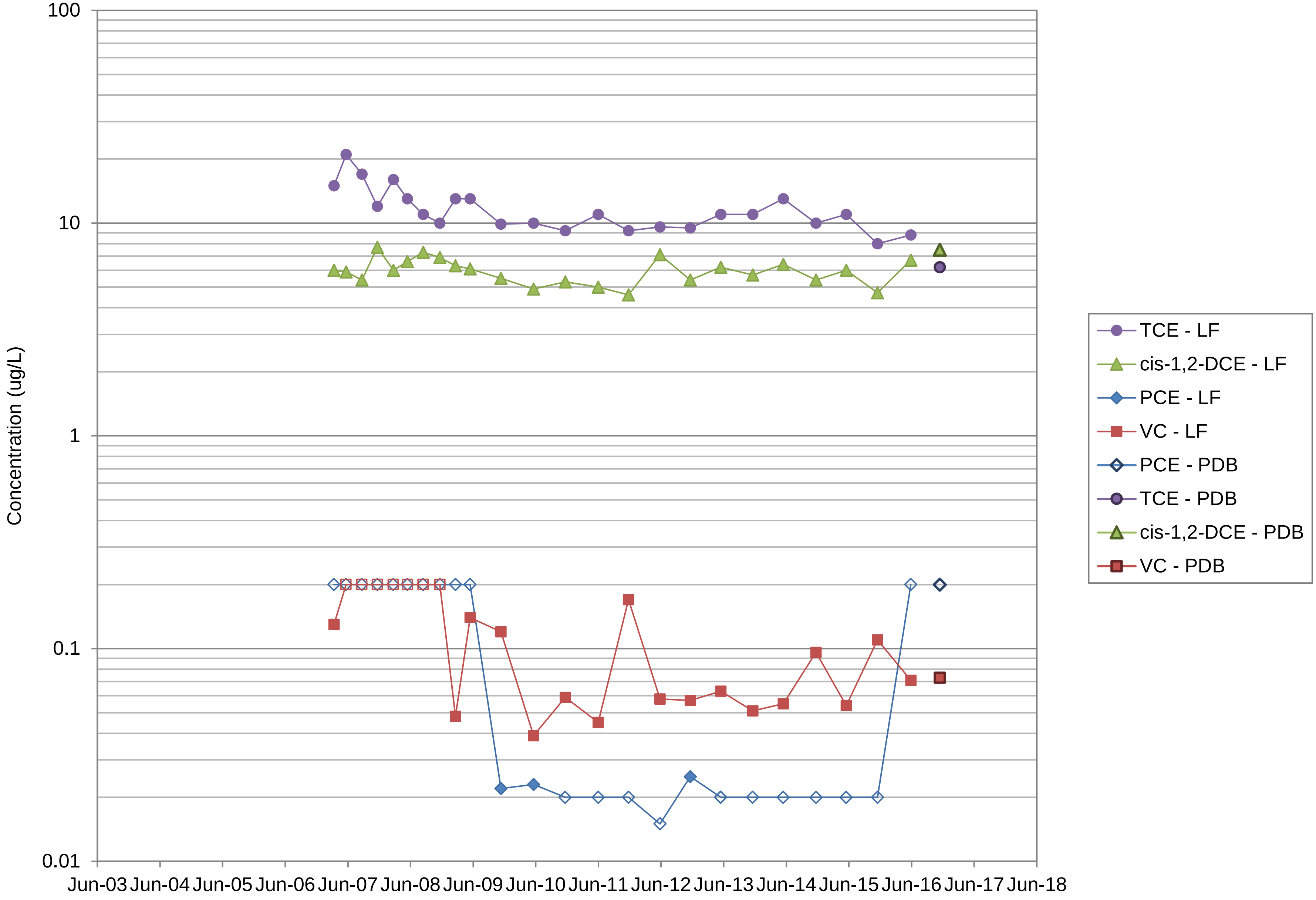
Jun-08
Jun-09
Jun-10
Jun-11
Jun-12
Jun-13
Jun-14
Jun-15
Jun-16
Jun-17
Jun-18
PCE - LF
TCE - LF
cis-1,2-DCE - LF
VC - LF
PCE - PDB
TCE - PDB
cis-1,2-DCE - PDB
VC - PDB

AGW126 (I)



100
10
1
0.1
0.01
Concentration (ug/L)
Jun-03
Jun-04
Jun-05
Jun-06
Jun-07
Jun-08
Jun-09
Jun-10
Jun-11
Jun-12
Jun-13
Jun-14
Jun-15
Jun-16
Jun-17
Jun-18
TCE - LF
cis-1,2-DCE - LF
PCE - LF
VC - LF
PCE - PDB
TCE - PDB
cis-1,2-DCE - PDB
VC - PDB

APPENDIX B

17-06 TPH Treatability Study

Technical Memorandum

TO: Robin Harrover, Washington State Department of Ecology

FROM: Sarah Fees and Jennifer Wynkoop

DATE: October 23, 2018

RE: **17-06 Persulfate Treatability Study**
Boeing Auburn Facility
Auburn, Washington
Project No. 0025164.160.112

The Boeing Company (Boeing) completed a treatability study to determine if chemical oxidation was a feasible cleanup methodology for the petroleum hydrocarbon contamination in soil and groundwater at Area of Concern (AOC) A-13 in Building 17-06. A bench test was conducted using two different forms of persulfate and from soil and groundwater collected from the site. Soil and groundwater samples were sent to the PeroxyChem soil and groundwater laboratory located in Tonawanda, New York. Laboratory analysis of diesel-range organic (DRO) and oil-range organic (ORO) by NWTPH-Dx was completed by TestAmerica Laboratories in Fife, Washington. The intent of the bench test was to complete a screening level study to determine overall mass reduction of DRO and ORO for both alkaline and iron-activated persulfate.

Sample Collection and Bench Testing Procedure

Soil and groundwater samples were collected from the site during feasibility study (FS) investigation activities that were completed on August 12 and 13, 2017. Soil samples were collected from the borings with the highest evidence of petroleum hydrocarbon contamination based on field screening. Soil samples were collected from boring AGW281 at depths of 18.5 and 21 feet (ft) below ground surface (bgs) and from boring ASB0288 at 18 and 22.5 ft bgs. After collection, each soil sample was homogenized and divided into three sample containers for the bench test, one each for alkaline-activated persulfate, iron-activated persulfate, and a control.

Because persulfate reactions require an aqueous medium, groundwater grab samples were also collected for the persulfate bench testing from the temporary boring ASB0288 at time of drilling and from permanent well AGW281 on January 5, 2018 following well development. Soil and groundwater samples were shipped on ice to PeroxyChem under chain-of-custody. A figure showing the boring locations within Building 17-06 is provided on Figure 1.

Upon receipt of the soil and groundwater samples, PeroxyChem completed bench test procedures for control (no persulfate), alkaline-activated persulfate, and iron-activated persulfate samples. Persulfate and the activator were first mixed with groundwater from the corresponding boring for each sample. The amount of activator used was calculated as follows:

- A ratio of 1:2.25 moles of Klozur to moles of sodium hydroxide was used for the setup of alkaline-activated conditions.
- For the iron-activated samples, the amount of Fe-EDTA to be added was calculated using a target of 600 milligrams per liter (mg/L) iron in groundwater. This was converted to grams per kilogram (g/kg) of soil assuming an average soil density value of 1500 g/mL and 35 percent pore space.

After the persulfate and activator were mixed with the groundwater, the mixture was added to each soil sample in the 4-oz collection jars at a ratio of 30 g of persulfate per 1 kg of soil. The remaining pore space in the jar was filled with site groundwater so the top of the soil was barely submerged. The jar was mixed by hand and then samples were allowed to sit for 20 days. After 20 days, the samples were shipped to TestAmerica for analytical testing of the soil by NWTPH-Dx. Groundwater from the samples was not tested due to insufficient volume. The complete persulfate bench testing procedure is provided in Attachment 1.

Results and Discussion

The persulfate bench testing results are provided in Table 1. Neither the alkaline or iron persulfate mixtures appeared to decrease the DRO or ORO mass in any of the samples when compared to the control sample. In fact, in many instances, the concentrations in the control samples were lower than in the persulfate-treated samples. For one sample location, AGW281-18.5, the soil samples treated with both the alkaline and iron persulfate mixtures had significantly higher concentrations of both DRO and ORO compared to the control sample. The results of the persulfate bench test indicate that two different forms of persulfate were not effective in reducing residual hydrocarbon concentrations in soil, and chemical oxidation is unlikely to be successful remediation technology.

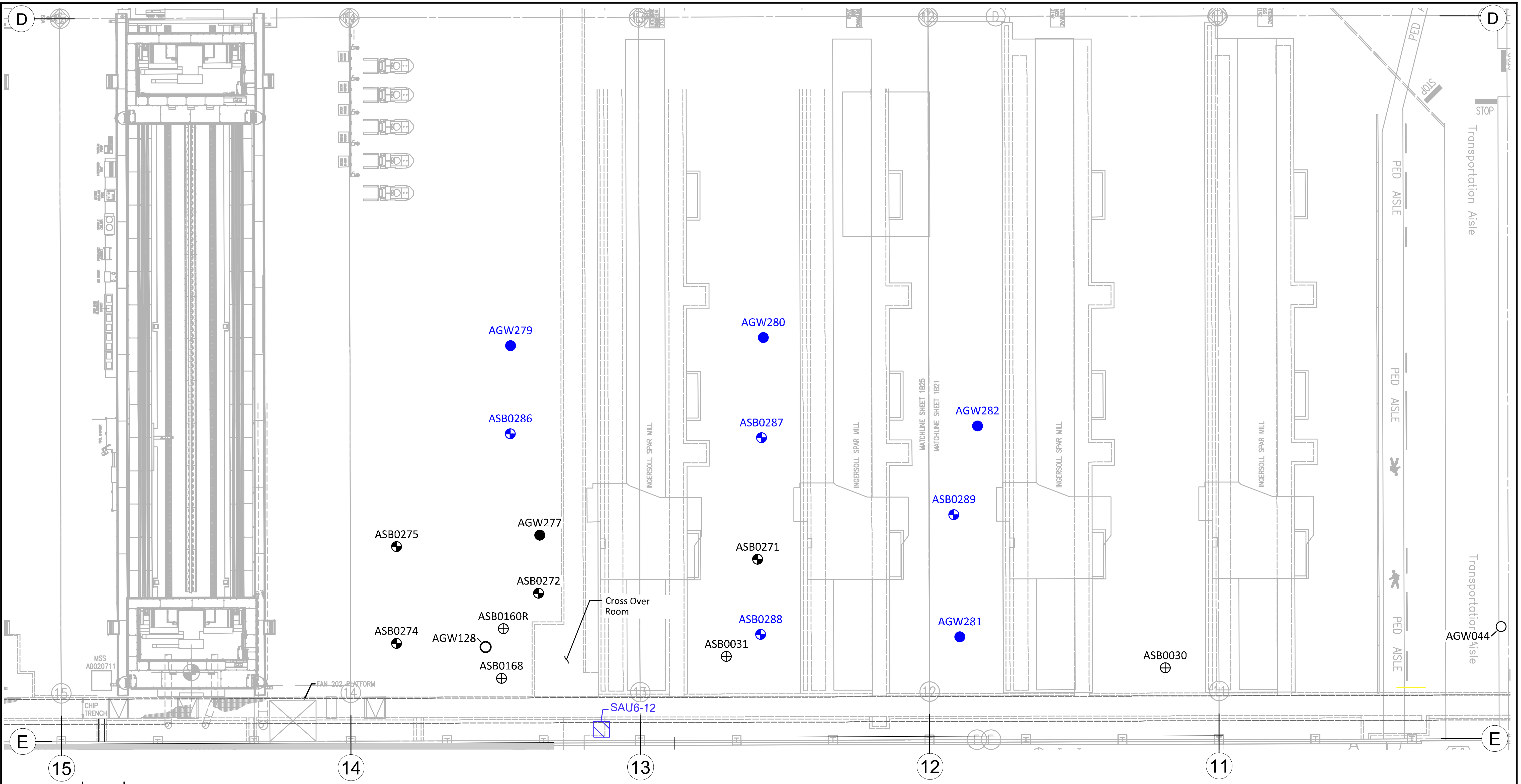
LANDAU ASSOCIATES, INC.

Jennifer Wynkoop
Principal

SEF/JWW/tam
Y:\025\164\R\FS Workplan\FS Workplan\Appendices\App B_TPH Treatability Study\Treatability Study_TM.docx

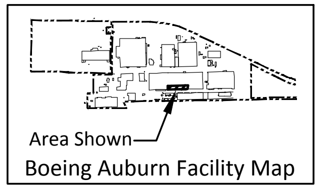
Attachments:

Figure 1	Boring and Well Locations AOC A-13: Petroleum Hydrocarbon Contamination on East Side of Building 17-06
Table 1	Persulfate Bench Test Results
Attachment 1	Persulfate Bench Test Results – Peroxychem Memo



Legend

AGW277	●	FS Monitoring Well Location and Designation (August 2017)
ASB0274	◕	FS Boring Location and Designation (August 2017)
AGW279	●	FS Monitoring Well Location and Designation (December 2017)
ASB0286	◕	FS Boring Location and Designation (December 2017)
AGW128	○	Pre-FS Monitoring Well and Location and Designation
ASB0031	⊕	Pre-FS Boring Location and Designation
SAU6-34	▨	Chip runoff Sump Location and Designation
	Ⓔ ⑪	Building 17 06 Column Designations



Boeing Auburn Facility Map

Base map source: Geomatrix 2003a

Landau Associates | G:\Projects\025\164\150\112\17-06\AdditionalWorkDataSubmittal\F01 AOC A-13 BoringWellLocations.dwg | 4/10/2018

LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

**Boring and Well Locations AOC A-13:
Petroleum Hydrocarbon Contamination
on East Side of Building 17-06**

Figure
1

Table 1
Persulfate Bench Test Results
Boeing Auburn Facility
Auburn, Washington

Analyte	Screening Levels (a)	Sample ID, Laboratory SDG, and Sample Date		
		AGW281-18.5-C Control 580-75055-1 2/12/2018	AGW281-18.5-AP Alkaline Persulfate 580-75055-1 2/12/2018	AGW281-18.5-IP Iron Persulfate 580-75055-1 2/12/2018
Petroleum Hydrocarbons (mg/kg; NWTPH-Dx)				
Diesel Range Organics (C12-C24)	2,000	**1,100 J**	**2,600**	**2,100**
Oil Range Organics (C24-C40)	2,000	**4,600 J**	**10,000**	**9,400**

Analyte	Screening Levels (a)	Sample ID, Laboratory SDG, and Sample Date		
		AGW281-21-C Control 580-75055-1 2/12/2018	AGW281-21-AP Alkaline Persulfate 580-75055-1 2/12/2018	AGW281-21-IP Iron Persulfate 580-75055-1 2/12/2018
Petroleum Hydrocarbons (mg/kg; NWTPH-Dx)				
Diesel-Range Organics (C12-C24)	2,000	**110**	**140**	**140**
Oil-Range Organics (C24-C40)	2,000	**430**	**500**	**490**

Analyte	Screening Levels (a)	Sample ID, Laboratory SDG, and Sample Date		
		ASB0288-18-C Control 580-75055-1 2/12/2018	ASB0288-18-AP Alkaline Persulfate 580-75055-1 2/12/2018	ASB0288-18-IP Iron Persulfate 580-75055-1 2/12/2018
Petroleum Hydrocarbons (mg/kg; NWTPH-Dx)				
Diesel-Range Organics (C12-C24)	2,000	**2,000**	**2,000**	**2,000**
Oil-Range Organics (C24-C40)	2,000	**8,400**	**8,300**	**8,700**

Analyte	Screening Levels (a)	Sample ID, Laboratory SDG, and Sample Date		
		ASB0288-22.5-C Control 580-75055-1 2/12/2018	ASB0288-22.5-AP Alkaline Persulfate 580-75055-1 2/12/2018	ASB0288-22.5-IP Iron Persulfate 580-75055-1 2/12/2018
Petroleum Hydrocarbons (mg/kg; NWTPH-Dx)				
Diesel-Range Organics (C12-C24)	2,000	**240**	**230**	**220**
Oil-Range Organics (C24-C40)	2,000	**850**	**920**	**970**

Notes:

(a) MTCA Method A soil cleanup levels for unrestricted land uses are used for petroleum hydrocarbons.
Bold text indicates detected analyte.
Green Box = detected concentration is greater than the screening level

Abbreviations/Acronyms:

ID = identification
mg/kg = milligrams per kilogram
MTCA = Model Toxics Control Act
NWTPH = Northwest Total Petroleum Hydrocarbon
SDG = sample delivery group

ATTACHMENT 1

Persulfate Bench Test Results – Peroxychem Memo

Activated Klozur® Persulfate Bench Study

Client:
Ken Reid, LEG
Landau Associates
130 2nd Avenue South
Edmonds, WA 98020
Direct: (425) 329-0266

Performing Lab:
PeroxyChem Environmental Solutions USA
Tonawanda, New York, 14150

Date
March 29, 2018

I. Procedure

The intent of the bench test is a screening level study to determine overall mass reduction of DRO and ORO for both alkaline and iron activated persulfate. The persulfate test was conducted on soil collected from the site. The soil and groundwater was collected by Landau Associates and sent to PeroxyChem for bench testing. Below is an outline of the procedure completed by PeroxyChem.

<u>Bench Test Procedure</u>: completed by PeroxyChem

1. Weigh the full soil sample jars to determine the weight of the soil in each jar (total weight – jar weight).
2. Determine which jars for each sample will be the control (no persulfate), iron activated persulfate, and alkaline activated persulfate according to the code in the sample ID (C = control; IP = iron activated persulfate; AP = alkaline activated persulfate).
3. Measure out required amount of persulfate based on the weight of soil in each jar. A ratio of 30 g of persulfate per 1 kg of soil should be used.
4. Determine the appropriate amount of activator to be used for each sample per the:
    a. Klozur Persulfate Activation Guide
    b. Klozur SP Activation Guide

5. Mix the persulfate and activator with site groundwater from the same boring location that the soil was collected from.
    a. Both the groundwater and soil sample ID's should start with the same six or seven digit code
6. Add the groundwater/persulfate mixture to the appropriate soil jar, fill the remaining pore space in the jar with site groundwater (so top of soil is just barely submerged, approximately 1 pore volume) and screw the lid on tightly; for control samples do not add persulfate, just fill the pore space with the appropriate site groundwater. Tip the jar a few times to mix the water/persulfate mixture into the soil column. Shake gently to ensure all soil is settled back into the bottom of the jar and submerged.
7. Let sit for 20 days.
8. On day 20, submit all three jars for each test to the TestAmerica for analytical testing (1 week TAT).

Some of the jars submitted had large stones or some soils removed to allow for addition of treatments and groundwater, a target of ¾" headspace in each jar was targeted.

A ratio of 1:2.25 moles of Klozur to moles of sodium hydroxide was used for the setup of alkaline activated conditions.

The amount of Fe-EDTA to be added was calculated using a target of 600mg/L Fe in groundwater. This was converted to g/kg of soil assuming an average soil density value of 1500g/cc and 35% pore space.

Below is an outline of the additions of persulfate, activator and groundwater added to each jar.

		Mass (g)									
Soil Sample ID		**Empty Jar**	**Filled Jar**	**Soil**	**g Klozur to Add**	**g 25% NaOH**	**mL 25% NaOH**	**g of Fe-EDTA**	**GW to use**	**Dissolve Fe-EDTA in mL GW**	**Additional mL GW added**
Loc: 580 73990 # 1A	AGW281-18.5-C	123.7	317.75	194.1	-		-	-	AGW 281	-	16.13
Loc: 580 73990 # 2A	AGW281-18.5-IP	123.2	297.42	174.2	**5.227**		-	**0.188**		6.13	10.00
Loc: 580 73990 # 3A	AGW281-18.5-AP	123.9	295.41	171.5	**5.145**	7.78222	**6.128**	-		-	10.00
Loc: 580 73990 # 6A	AGW281-21-C	123.0	309.65	186.7	-		-	-		-	11.79
Loc: 580 73990 # 7A	AGW281-21-IP	123.0	317.36	194.4	**5.831**		-	**0.210**		6.79	5.00
Loc: 580 73990 # 8A	AGW281-21-AP	124.0	313.99	190.0	**5.700**	8.62075	**6.788**	-		-	5.00
Loc: 580 73990 # 11A	ASBO288-22.5-C	123.1	338.06	215.0	**-**		-	-	ASBO 288	-	16.00
Loc: 580 73990 # 12A	ASBO288-22.5-IP	123.3	332.43	209.1	**6.274**		-	**0.226**		7.50	8.50
Loc: 580 73990 # 13A	ASBO288-22.5-AP	124.0	333.92	209.9	**6.298**	9.52507	**7.500**	-		-	8.50
Loc: 580 73990 # 17A	ASBO288-18-C	123.2	347.51	224.3	-		-	-		-	13.07
Loc: 580 73990 # 18A	ASBO288-18-IP	123.6	344.34	220.7	**6.622**		-	**0.238**		8.07	5.00
Loc: 580 73990 # 19A	ASBO288-18-AP	124.1	350.01	225.9	**6.777**	10.25061	**8.071**	-		-	5.00

VI. Conclusions

The Klozur® Persulfate treatments did not appear to destroy the contaminants of concern of the site.

APPENDIX C

Health and Safety Plan

Health and Safety Plan
Boeing Auburn Facility
Auburn, Washington

Revised October 23, 2018

Prepared for

The Boeing Company
Seattle, Washington

LANDAU ASSOCIATES

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Tacoma, WA 98402
(253) 926-2493

Health and Safety Plan
Boeing Auburn Facility
Auburn, Washington

This document was prepared by, or under the direct supervision of, the technical professionals noted below.

Document prepared by: Katie M. Gauglitz Katie Gauglitz

Author; Staff GIT

Document reviewed by:

Kenneth J. Reid Ken Reid

Quality Reviewer

Date:	RevisedOctober 23, 2018
Project No.:	0025164.160.112
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Project Coordinator:	Juliann Cooley

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APPENDIX

LIST OF ABBREVIATIONS AND ACRONYMS

Boeing	The Boeing Company
CFR	Code of Federal Regulations
COC	contaminant of concern
°F	degrees Fahrenheit
EPA	US Environmental Protection Agency
FS	feasibility study
HASP	health and safety plan
HHCA	high hazard chemical access
LAI	Landau Associates, Inc.
OSHA	Occupational Safety and Health Administration
PID	photoionization detector
PPE	personal protective equipment
ppm	parts per million
SCBA	self-containing breathing apparatus
TPH	total petroleum hydrocarbon
VC	vinyl chloride
VOC	volatile organic compound

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1.0 INTRODUCTION

The Boeing Company (Boeing) hired Landau Associates, Inc. (LAI) to conduct field and sampling activities at the Boeing Auburn Site (Site) in Auburn, Washington. This Site-specific Health and Safety Plan (HASP) presents procedures and protocols that will be followed to provide worker safety during the field and sampling activities to be conducted during implementation of the Feasibility Study (FS) work plan. The FS sampling activities include installation of groundwater monitoring wells; advancement of soil borings; installation of permanent sub-slab soil gas monitoring points; installation of pore water monitoring piezometers; and sampling of groundwater, surface water, pore water, soil, and soil vapor. This HASP presents project health and safety organization, safety rules and procedures, potential Site hazards, description of personal protection and required equipment, emergency response information, training requirements, and requirements for routine health care and health monitoring. This HASP is based on the most current knowledge of Site conditions.

1.1 Applicability and Adherence

This HASP will apply to all individuals involved with intrusive field activities for this project, and is focused on activities typically performed by LAI personnel, including sampling potentially contaminated media, and observation of groundwater monitoring well installation and soil boring advancement activities. Individuals performing these activities at the Site must read, understand, and comply with this HASP prior to participating in these activities. If any information presented in this HASP is unclear, the reader should contact the LAI Corporate Health and Safety Officer or the designated LAI Site Health and Safety Manager for clarification prior to participating in any Site activity. After the information has been read and understood, the individual must sign the Acknowledgement Form (Form 1; Appendix A), and the Boeing Safety Promise (Form 2; Appendix A). These forms will then be saved in the project file.

Activities conducted as part of the FS fieldwork will be conducted in a manner to minimize health and safety risks for nearby workers and the public. All on-Site personnel will be attentive to the potential for release of contaminated materials associated with Site activities and will immediately bring all such matters to the attention of the LAI Health and Safety Manager. Decontamination procedures and other elements of the planned monitoring well installation, soil boring advancement, and sampling activities (e.g., access to/from work areas by heavy equipment) have been developed to be protective of the worker and public health and safety.

Health and safety procedures associated with the Contractor’s work and operation of heavy equipment are not specifically addressed herein. The Contractor will be required to prepare and implement their own Site-specific HASP to address the work under the contract to be performed by its workers and by its subcontractors, and to promote the health and protection of all on-Site personnel and the environment. LAI will provide health and safety Site monitoring for contaminants and will inform the Contractor on contaminant levels and subsequent upgrades to required personal protective equipment (PPE).

1.2 Purpose and Regulatory Compliance

This HASP addresses procedures to be followed to minimize the risk of chemical exposures and physical accidents to on-Site workers and the public, and to minimize the risk of environmental contamination. This HASP complies with, but does not replace, Washington State Health and Safety Regulations as set forth in Washington Administrative Code 296-62 Part P. Requirements outlined in this HASP are considered the minimum health and safety requirements for metals, total petroleum hydrocarbon (TPH), cyanide, and volatile organic compound (VOC) sampling activities. All monitoring well installation, soil boring advancement, and sampling activities will be performed in accordance with this HASP and the Occupational Safety and Health Administration (OSHA) Standard 29 Code of Federal Register (CFR) 1910.120, which regulates hazardous waste site operations.

This HASP is flexible and allows unanticipated Site-specific problems to be addressed, while providing adequate and suitable worker protection. This HASP may be modified at any time, based on the judgment of the LAI Corporate Health and Safety Officer, as appropriate. Minor modifications to this HASP regarding day-to-day activities may be made by the designated LAI Site Health and Safety Manager. Substantive changes to procedures (e.g., changes in action levels) must receive the concurrence of Boeing Project Managers and the LAI Corporate Health and Safety Officer. Modifications will be discussed with on-Site personnel during a safety briefing, and posted in a designated area using the attached HASP Modification Form (Form 3; Appendix A).

1.3 Responsible Individuals

Safety monitoring during well installation, soil boring advancement, and sampling activities will be the responsibility of Boeing Project Managers and the designated LAI Site Health and Safety Manager. The LAI Site Health and Safety Manager, or equivalent designee, will be present at the Site at all times during intrusive Site activities related to the monitoring well installation, soil boring advancement, and sampling activities. Boeing Project Managers are identified in Table 1. The LAI Site Health and Safety Manager will be identified prior to the initiation of Site activities and can include Sierra Mott, Project Scientist or Katie Gauglitz, Staff GIT.

1.4 Site Security

Monitoring well installation, soil boring advancement, and sampling activities will be occurring in a restricted-access industrial area. All personnel will need to be in possession of the appropriate access badge issued by Boeing while performing work at the Site. Work areas will be partitioned with traffic safety cones to prevent non-trained personnel from entering the immediate vicinity where work is taking place.

1.4.1 High Hazard Chemical Access

Some work will take place in the High Hazard Chemical Access area (HHCA) in Building 17-07. LAI personnel will have completed the required training and have an HHCA badge, and will act as escort for any contractors needing access to this area.

1.4.2 Basement Area Access

LAI personnel may need to access the basement area beneath the tank line for sub-slab soil gas sampling. At least two people are required during basement access. Additional PPE required in the basement includes a hard hat for each person and a flashlight for each group. LAI personnel who will work in the basement area will have completed the appropriate training before participating in any work in this area. Personnel who have completed the training will be allowed to act as an escort for contractors or additional personnel needing access to the basement area.

1.4.3 Offsite Security Concerns

Some sampling activities will take place offsite in publicly accessible areas. At least two people are required during all sampling and related activities at the wells and surrounding areas where it has been determined that there is an increased safety risk. These wells are outlined in Figure B-1.

2.0 SAFETY RULES AND PROCEDURES

Safety is the responsibility of every individual involved in project activities. Whether in the office or on the Site, properly followed procedures are essential for personal safety and to minimize injuries or accidents involving equipment. Potential hazards while working at the Site include, but are not limited to:

- Exposure to toxic and/or hazardous chemicals.
- Physical hazards associated with drilling machinery.
- Physical hazards associated with working conditions (e.g., heat stress, hypothermia, or working at night).
- General hazards associated with working in public areas offsite including but not limited to hazards associated with vagrancy, solid or biological waste, persons carrying weapons, or persons generally behaving in an unexpected manner.

2.1 Safety Rules

All personnel working at the Site will follow the rules and procedures listed below:

- All personnel will conduct themselves in a professional manner at all times.
- At least two people are required for work in areas with safety concerns. These areas are shown on Figure B-1. If personnel feel unsafe at any time, stop work, leave the area, and inform the designated LAI Site Health and Safety Manager. If there is a perceived immediate safety threat, call 911.
- No personnel will be admitted into an operational exclusion zone without safety equipment in proper working condition and requisite training.
- All personnel must comply with the established safety procedures. Anyone working on-Site for or under contract with Boeing and who does not comply with this HASP or other approved HASP may be immediately dismissed from the Site.
- Working while under the influence of intoxicants, narcotics, or controlled substances is prohibited and will result in immediate dismissal from the Site. Personnel should not take prescription drugs if the potential for contact with toxic substances exists, unless approved in writing by a physician.
- Firearms, ammunition, fireworks, and explosives are prohibited.
- Climbing or standing on machinery (other than service trucks) or equipment is prohibited unless authorized by the LAI Site Health and Safety Manager or their designee.
- Long hair must be contained inside a hard hat or tied back and tucked under clothing. Facial hair that interferes with proper operation and fit of respiratory protection gear is not allowed.
- Eating, drinking, chewing gum, or any practice that increases the probability of hand-to-mouth transfer and ingestion of material is prohibited in an exclusion zone. Facilities are considered tobacco free areas, no tobacco smoking or chewing is allowed on the premises.

- Electronic devices, including phones and laptops, will be operated only in designated Site-specific Safety Zones that will be identified prior to the start of field activities. All non-moving vehicles not in gear have been universally identified as a Safety Zone. Temporary Safety Zones may be established where there are no Safety Zones in the vicinity of the work area; temporary Safety Zones will be clearly marked and signage will be removed at the end of each work day.
- Disposable clothing will be used whenever necessary and appropriate to minimize the risk of cross-contamination.
- The number of personnel and the amount of equipment in contaminated areas will be minimized to allow for efficient Site operations.
- Only trained and authorized personnel will perform well installation, soil boring advancement, and sampling activities.
- Contact with contaminated or potentially contaminated material should be avoided. Efforts will be made to stage Site activity upwind of equipment, activities, and materials if dust is present.
- Proper decontamination procedures must be followed before leaving the sampling area and the Site, unless medical emergencies dictate otherwise (Section 2.2.1.1). All decontamination residual materials, and any other potentially contaminated materials, will be handled properly and kept on-Site or at a designated secure area.
- Only approved work clothes or equipment will be allowed within the sampling areas.

2.2 Safety Procedures

Site personnel are required to follow certain safety procedures when performing well installation, soil boring advancement, and sampling activities. These safety procedures are described below:

- All activities performed in the exclusion zone will be conducted at a minimum of Level D (modified; see Section 4.0).
- Whenever possible, personnel will be stationed upwind of Site activities capable of creating airborne contamination.
- If any physical discomfort is experienced (e.g., abnormalities, nausea, lightheadedness), immediately stop work, tell the other team members, leave the area, and inform the designated LAI Site Health and Safety Manager.
- If any PPE fails, immediately leave the area, procure functional PPE, and inform the designated Site Health and Safety Manager.

2.2.1 Decontamination

Decontamination procedures to be used in emergencies for injuries and for equipment are described in the following sections.

2.2.1.1 Emergency Decontamination

In case of an emergency, decontamination procedures will be quickly implemented, if possible. If a life-threatening injury occurs and the injured person cannot undergo decontamination procedures without incurring additional injuries or risk, he or she will be wrapped in plastic sheeting, if time allows and, if appropriate, for the given injury and then be transported to the nearest medical facility. The medical facility staff will be: 1) informed that the injured person has not been decontaminated, and 2) given information regarding the most probable contaminants.

2.2.1.2 Equipment Decontamination

Decontaminating drilling equipment or other sampling equipment will occur in the immediate work area or another area designated for equipment decontamination. Procedures described in Section 6.0 of this HASP will be followed while decontaminating equipment.

2.2.2 Management of Work-Derived Wastes

Equipment and materials used for decontamination or personal protection will be cleaned or collected for appropriate disposal. Non-disposable equipment will be decontaminated on-Site. Disposables will be containerized. Investigation-derived wastewater will be collected and stored in accordance with this HASP.

2.2.3 Housekeeping

Work areas will be kept as clean and orderly as possible at all times. Ordinary refuse and lightly soiled disposable protective clothing will be placed in suitable rubbish bins or trash containers at the Site. The storage or introduction of extraneous materials will be minimized in the work areas to minimize the decontamination load and reduce possibilities for cross-contamination.

2.2.4 Visitors

Authorized visitors will only be allowed under escort by Boeing and must obey all instructions of the LAI Site Health and Safety Manager and/or Boeing’s Project Managers or designated representative.

3.0 POTENTIAL SITE HAZARDS, RISKS, AND PROTECTIVE MEASURES

There are two types of hazard categories for well installation, soil boring advancement, and sampling activities. These categories are chemical and physical. The risks associated with each type of hazard and implementing the protective measures to minimize the risks are discussed below.

3.1 Chemical

Several contaminants of concern (COCs) are identified at the Site including metals, cyanide, TPH, and VOCs. The COCs to be analyzed are summarized by sample media in the table below.

Target Chemical Class for Analysis by Media

Chemical Class	Soil	Groundwater	Surface Water and Pore Water	Soil Vapor	Air
Metals		X			
Cyanide		X			
TPH	X	X			
VOCs	X	X	X	X	X

3.1.1 Risks

Based on previous information and knowledge of the types of activities conducted at the Site, the following chemicals may be present: metals, cyanide, TPH, and VOCs. Human health hazards of these chemicals are summarized in Table 2. The information provided in this table covers potential toxic effects that might occur if relatively significant acute and/or chronic exposure occurred. However, this information does not indicate that such effects are likely to occur from the planned Site activities. The chemicals that may be encountered at this Site are not expected to be present at concentrations that could cause significant health hazards from short-term exposures. The types of planned work activities and use of monitoring procedures and protective measures will further limit potential exposures at this Site.

3.1.2 Protective Measures

Measures that will be implemented to avoid the risks associated with the chemical hazards include:

- Don appropriate PPE (described in Section 4.0).
- Wash hands and face before eating or drinking.
- Avoid contact with potentially contaminated substances.
- Work from clean areas to more contaminated areas (if known) to prevent cross contamination.
- Prevent splashing of contaminated liquids.

3.2 Physical

The planned activities will involve potential physical hazards inherent with working outside, inside Boeing Facility buildings, and in the presence of heavy equipment. Each potential hazard, the associated risk, and protective measures to be implemented to minimize each risk are as described below:

- **Drilling Machinery:** Drilling machinery may be equipped with various winches, motors, booms, and other machines. These present a general physical hazard from moving parts. Personnel will stand clear of machinery at all times unless specific instructions are given by the rig operator or other person in authority. Personnel will stand clear of the swing ratios and avoid pinch points between equipment. Personnel will stand in areas where the rig operator can make eye contact, whenever possible. Hard hats, safety glasses, steel-toed shoes/boots, and a yellow high-visibility safety vest will be worn at all times in the exclusion zone. When possible, appropriate guards will be in place during equipment use. Lifting equipment used to raise and lower sampling equipment may also present a physical hazard. Field personnel should be careful to keep loose clothing, hands, and feet away from winches and capstones.
- **Rotary Hammer:** A subcontractor will be employed to operate the rotary hammer. LAI personnel will stand clear of the subcontractor and equipment while in operation. Hard hats, safety glasses, steel-toed shoes/boots, and a yellow high-visibility safety vest will be worn at all times.
- **Vehicular Traffic:** The presence of vehicular traffic associated with Boeing's daily work activities at the Site is considered a potential hazard. Yellow high-visibility safety vests worn by each worker and the attentiveness of each worker will be used as protective measures to minimize the risks associated with vehicular traffic. Safety devices (e.g., safety cones, caution tape, barrier) will be installed to separate the work area from the flow of traffic. If it is necessary for vehicles to back up, a spotter will be used.
- **Falls:** Caution will be exercised to prevent slips on wet surfaces, stepping on sharp objects, etc. Work should not be performed on elevated platforms without fall protection. Recognize and avoid areas with low traction (e.g., muddy areas or slick metal surfaces), ground surface obstructions, or unguarded areas elevated above ground surface.
- **Noise:** Appropriate hearing protection (i.e., ear muffs or ear plugs with a noise reduction rating of at least 20 A-weighted decibels [dBA]) will be used if individuals work near high-noise generating equipment (>85 dBA).
- **Working at Night:** Some of the work in this HASP will take place at night. All work to be completed at night will be located inside a Boeing Facility building; therefore, a light plan will not be required. Workers will stay well rested and communicate throughout shifts as to everyone's ability to complete the job in a safe manner. If a team member appears fatigued or verbally expresses extreme tiredness, work will be stopped immediately.
- **Heat Stress:** See Section 8.2.2.
- **Cold Stress:** See Section 8.2.3.

4.0 PERSONAL SAFETY EQUIPMENT

PPE is required within work areas where there is a potential for exposure to hazardous substances and physical hazards. Descriptions of the levels of protection and the required safety equipment for each level are provided in the following sections.

4.1 Levels of Protection

Levels of protection have been defined by the U.S. Environmental Protection Agency (EPA) in the EPA Standard Operating Guide (1984)[1]:

- Level A requires a fully encapsulating suit and full-face self-contained breathing apparatus (SCBA) with a 5-minute supplied air escape pack for the highest level of respiratory, skin, and eye protection. Level A is not anticipated at the Site; therefore, it is not discussed further.
- Level B requires maximum respiratory protection by the use of supplied air or a positive pressure SCBA. A 5-minute supplied air escape pack is required while in Level B. Dermal protection is selected on the basis of anticipated hazards. Level B is not anticipated at the Site; therefore, it is not discussed further.
- Level C requires an air-purifying respirator that is specific to the COCs. The degree of dermal protection depends on anticipated hazards.
- Level D is the basic work uniform, modified for FS fieldwork activities at the Site, as described in Section 4.2.

4.2 Required Equipment

The level of protection designated Level D is recommended for all FS fieldwork activities. Required upgrades to PPE due to elevated concentrations of compounds in the air are discussed in Section 4.4. The minimum PPE to be worn during all FS fieldwork activities includes:

- Hard hat when working in the vicinity of heavy machinery or drilling equipment and in the basement of the tankline.
- Safety glasses with side shields.
- Steel-toed boots.
- Ear protection in the vicinity of noisy equipment.
- Work gloves and/or chemical-resistant gloves.
- Yellow high-visibility safety vest.

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[1] EPA. 1984. Field Standard Operating Procedures Manuals: FSOP #7 – Decontamination of Response Personnel. OSWER Directive No. 9285.2-02. U.S. Environmental Protection Agency. January 1.

4.3 Safety Equipment

The following safety equipment must be available on-Site during FS fieldwork activities:

- First aid kit.
- Eye wash kit.
- Fire extinguisher.
- Mobile telephone.

4.4 Air Monitoring

Direct-reading instruments give immediate, real-time readings of contaminant levels. Reliable direct-reading instruments such as the combustible gas indicator, photoionization detector (PID), flame ionization detector, dust meter, and colorimetric tubes are available for situations commonly encountered at hazardous and contaminated substance sites. The appropriate type of monitoring equipment depends on the suspected type and concentration of chemical contaminants. The primary limitation of direct-reading instruments is that most do not quantify specific chemical compounds.

Air monitoring for COCs will be conducted during drilling and sub-slab soil gas sampling or other intrusive activities. A multi-gas monitor or VOC monitor down to parts per billion level (e.g., PPBRae) will be used to monitor for VOCs and TPH. The instruments will be calibrated prior to each day's activity according to manufacturer's instructions. Calibration will be recorded in the health and safety logbook or field notes. Monitoring of the worker's breathing zone will be conducted before beginning work and periodically thereafter. Monitoring of the breathing zone will consists of collecting air monitoring readings for the approximate elevation and position of the most exposed workers' faces. Readings will be entered into the logbook at a minimum of 30-minute intervals.

VOC readings above background are not expected at the Site. However, action levels and safety steps are presented in the event that VOCs are detected in the workers breathing zone. Due to a low permissible exposure limit for vinyl chloride (VC; 1 part per million [ppm]), if PID readings for VOCs in the breathing zone are more than 1 ppm above background VOC concentrations (e.g., upwind, rig exhaust, ambient levels) for 1 minute, workers will be required to leave the area until the situation is adequately characterized using chemical-specific colorimetric gas detector tubes for VC. [Note: The lower detection limit of the colorimetric gas detection tube to be used for VC must be below the VC action level of 1 ppm]. Table 3 identifies the air monitoring strategy to be used during field activities.

5.0 TRAINING REQUIREMENTS

Site personnel conducting intrusive field activities during well installation, soil boring advancement, and sampling events will maintain appropriate training and approval for environmental fieldwork. Records describing their training will be stored in the LAI project file. Training will include, as appropriate, the following:

- Current medical approval to conduct environmental fieldwork and wear a respirator.
- Current fit test approval for respirator use; fit test must be conducted every 12 months.
- Completion of training as required by OSHA Title 29 CFR 1910.120.
- 40 hours of health and safety at hazardous waste site training.
- Subsequent to the 40-hour training, a yearly 8-hour hazardous waste site refresher training.
- CPR training refreshed yearly and First Aid training refreshed every 3 years.
- Completion of Boeing building or Site-specific training, which may include HHCA training or training to access basement areas.

6.0 DECONTAMINATION

Decontamination is necessary to limit the migration of contaminants from sampling areas into the surrounding environment. Equipment and personnel decontamination are discussed below:

- Personnel Decontamination
    - Avoid hand to mouth contact
    - Wash hands and face, and change out gloves frequently.
- Decontamination Procedures for Sampling Equipment
    - Disposable sampling equipment will be deposited in a labeled container for disposal at a municipal waste facility.
    - Non-disposable sampling equipment will be decontaminated between sampling intervals by a tap water and Alconox® or Liquinox® soap mixture wash, followed by a tap water rinse and a final distilled water rinse.
    - If necessary, hexane will be used to remove gross contamination. Heavy 15 mil gloves will be used during hexane handling. Hexane will be contained on rags, and placed into a labeled bag. At the end of each work period, the bag will be sealed and disposed of in an orange paint waste bin on Site.
    - If contamination is still observed, the process will be repeated.
    - All generated decontamination water will be stored in a labeled container for disposal or treatment processing.
    - Drill rig tooling will be decontaminated between borings by steam cleaning methods. All drill rig tooling will be decontaminated before arriving to or leaving the job Site.

7.0 SPILL CONTAINMENT

It is not anticipated that bulk chemicals subject to spillage will be used by LAI on this project. In addition, contractors completing drilling projects will adhere to Boeing's documentation on mobile refueling and spill containment for small construction projects. Contractors are responsible for providing spill containment procedures. Accordingly, spill containment provisions are not included as part of this HASP.

8.0 EMERGENCY RESPONSE PLAN

This emergency response plan outlines the steps necessary for appropriate response to emergencies. The following summarizes the key emergency response plan procedures for this project. Each Contractor vehicle associated with well installation and soil boring activities will be provided with a Boeing-supplied Dash-Board Safety Card (Table 1), which will summarize the emergency procedures described below.

8.1 Notification and Reporting

The LAI Site Health and Safety Manager is to be notified immediately of any emergency. If the situation is life threatening and notification of the LAI Site Health and Safety Manager would delay emergency response, Site personnel may initiate the appropriate emergency contacts as noted below prior to notifying the LAI Site Health and Safety Manager. The LAI Site Health and Safety Manager will initiate contacts as follows:

- Step 1: Call Boeing Emergency Dispatch (Table 1) and provide the following information:
    - Name and location of person reporting
    - Location of accident/incident
    - Name and affiliation of injured party
    - Description of injuries
    - Status of medical aid effort
    - Details of any chemicals involved
    - Summary of the accident, including the suspected cause and the time it occurred
    - Temporary control measures taken to minimize further risk
    - Note: This information is not to be released to parties other than the LAI Health and Safety Manager, Boeing personnel, Contractor personnel, and bona fide emergency response team members.
- Step 2: Call the Boeing Project Manager and provide information noted in Item 1 above.
- Step 3: Call the LAI Corporate Health and Safety Manager and the LAI Project Manager with information in Item 1 above.
- Step 4: The LAI Site Health and Safety Manager will complete a written accident/incident report, using the Incident Form (Form 4; Appendix A), within 24 hours, sending copies to the Boeing Project Manager.

Resources to be used in cases of emergency include:

- List of Emergency Contacts: Table 1 includes both the appropriate emergency services and the appropriate project contacts.
- Nearest Phone: Telephones are located inside buildings. Boeing and LAI Site personnel also carry mobile phones.

- On-Site Emergency Equipment: An industrial first-aid kit, a 20-pound, type ABC portable fire extinguisher, and an eyewash kit accompany each Site vehicle operated by LAI.
- Offsite Emergency Services: Phone numbers for offsite emergency services are listed in Table 1. Copies of this table must be located in each vehicle.
- Hospital Route: Auburn Regional Medical Center, 202 N Division Street Auburn, WA 98001
  - Go 0.2 miles, then turn right onto Industry Dr N
  - Go 0.1 miles, then turn right onto Industry Dr SW
  - Go 0.2 miles, then turn right onto 15th St SW
  - Go 0.4 miles, then turn left onto C St SW
  - Go 1.0 mile, then turn right onto 3rd St NW
  - Go 0.2 miles, then turn right onto A St NE
  - Go 387 ft and arrive at Auburn Regional Medical Center.

8.2 Emergencies and Procedures

Emergency procedures to be used in emergencies for injuries and heat and cold stress are described in the following sections.

8.2.1 Injuries

In emergencies for injuries that are not life threatening (e.g., a broken leg), normal decontamination procedures should be followed when possible. However, decontamination procedures may be modified according to the specific circumstances and injury. Outer protective clothing should be removed if doing so would not cause delays or aggravate the injury.

Bodily injuries that occur as a result of an accident during operations at the Site will be handled in the following manner:

- The victim will be administered to by an individual who holds current first aid and/or CPR certification, as necessary.
- The local first-aid squad/rescue unit and the local hospital will be notified, as appropriate, depending on the nature of the emergency.

8.2.2 Heat Stress

Heat stress can occur at any time when impermeable or excessively thick and insulating protective clothing is worn. The degree of risk associated with working in these garments is directly related to numerous factors: ambient temperature, length of time in the impermeable suits (i.e., Tyvek®), availability of shade, acclimatization of personnel, adequate fluids intake by workers, and length of rest periods. Workers wearing semi-permeable or impermeable encapsulating clothing should have their heart rate (pulse rate) monitored prior to and throughout any work period that includes sustained moderate to heavy work in protective clothing when the temperature in the work area is above approximately 70 degrees Fahrenheit (°F). If such conditions exist, the following procedures will be carried out to reduce heat stress:

- Acclimatization.
- Work/rest cycles.
- Heat stress monitoring.
- Liquids that replace electrolytes/salty foods available during rest.
- Use of buddy system.

Each employee should check his/her pulse rate at the beginning of each break period. The pulse rate should be taken at the wrist for 30 seconds and multiplied by 2. If the pulse rate exceeds 110 beats per minute, the length of the next work period should be reduced by one-third (the rest period need not be lengthened). A pulse rate in excess of 150 beats per minute may indicate heat exhaustion, although this rate will vary among workers. All personnel will know what their baseline pulse rate is before working in elevated temperatures, to monitor themselves. Personnel should follow appropriate guidelines if any personnel exhibit these symptoms:

- Heat Rash: Redness of skin. Frequent rest and change of clothing.
- Heat Cramps: Painful muscle spasms in hands, feet, and/or abdomen. Administer lightly salted water by mouth, unless there are medical restrictions.
- Heat Exhaustion: Clammy, moist, pale skin, along with dizziness, nausea, rapid pulse, fainting. Remove to cooler area and administer fluids.
- Heat Stroke: Hot dry skin; red, spotted, or bluish; high body temperature of 104 °F; mental confusion; loss of consciousness; convulsions; or coma. Immediately cool victim by immersion in cool water. Wrap with wet sheet while fanning; sponge with cool liquid while fanning; treat for shock. DO NOT DELAY TREATMENT. COOL BODY WHILE AWAITING AMBULANCE.

The LAI Site Health and Safety Manager will be trained in monitoring, treating, and recognizing the signs of heat stress. If heat stress occurs, decontamination should be minimized and treatment should begin immediately.

8.2.3 Cold Stress

Some FS fieldwork activities may occur in the winter months when Site personnel may be subject to low temperatures, rain, and winds; therefore, proper protective clothing must be worn.

Cold stress can be manifested as both hypothermia and frostbite:

- Hypothermia is a cold-induced decrease in the core body temperature that can increase the safety hazards associated with field work activities that require maximum attentiveness and manual dexterity. Hypothermia produces shivering, numbness, drowsiness, muscular weakness, and, if severe enough, death.
- Frostbite results from the constriction of blood vessels in the extremities, and decreasing the supply of warming blood to these areas. This drop in blood supply may result in the formation

of ice crystals in the tissues, causing tissue damage. The symptoms of frostbite are white or grayish skin, blisters, or numbness.

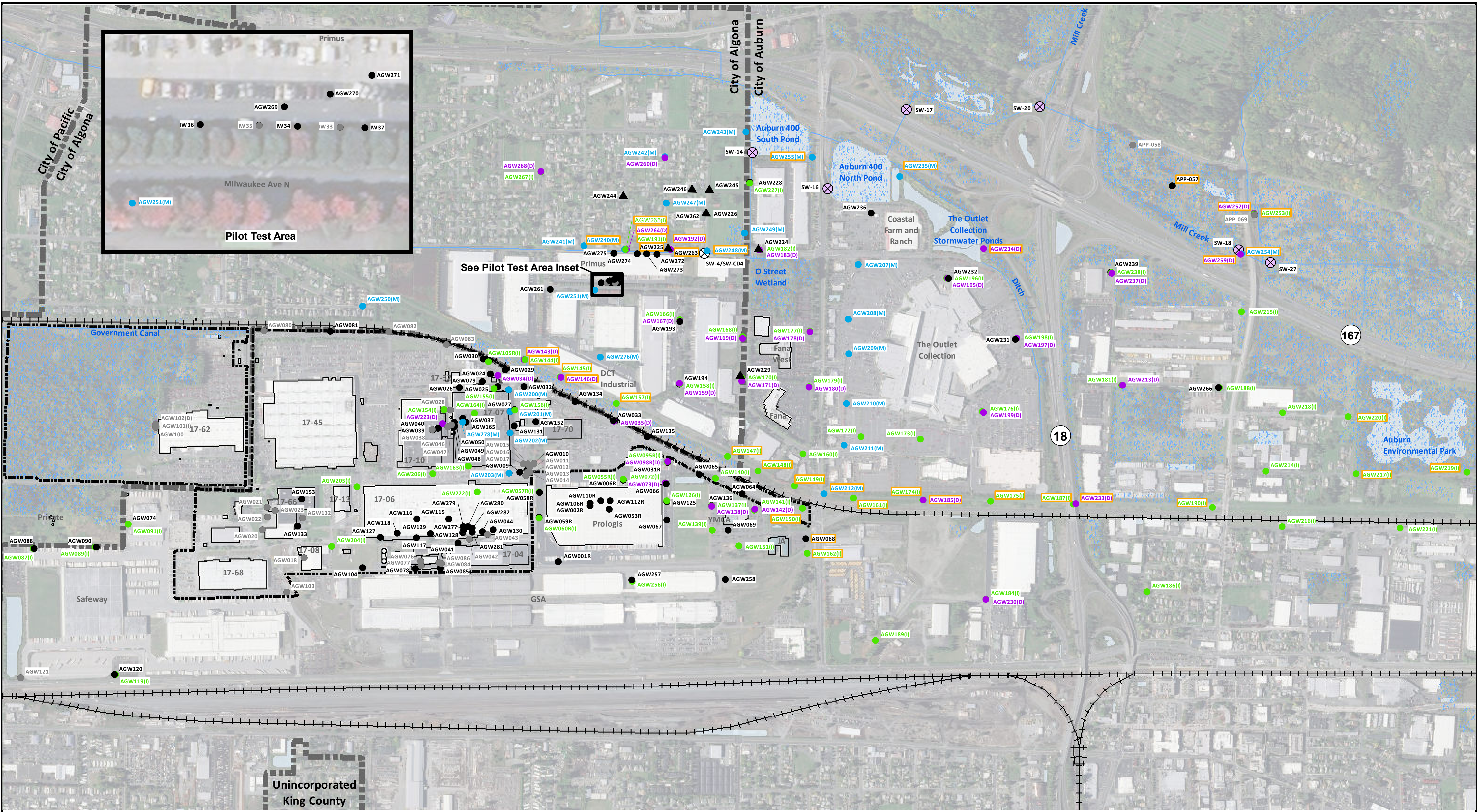
Site personnel should review the information provided in their first-aid training for response to cold-stress problems.

8.3 Fire

Fire extinguishers (ABC-type) will be kept in each Site vehicle. In the event of major fires, explosions, or fire/explosion hazard conditions, all personnel will immediately evacuate the area. The LAI Site Health and Safety Manager will evaluate the need for further evacuation and/or emergency services.

8.4 Site Evaluation and Evacuation

The LAI Site Health and Safety Manager will be responsible for determining if circumstances exist that require further evaluation and/or evacuation. The LAI Site Health and Safety Manager should always assume worst-case conditions until proven otherwise.



Notes

1. Groundwater wells are identified by the AGW prefix. The designations behind the identifications indicate the zone. If there is no designation, the well is screened in the shallow zone. (I) = intermediate zone, (D) = deep zone, (M) = multi-level well; screens in multiple groundwater zones.
2. Well designations beginning with APP are installed and owned by WSDOT.
3. Wells with security concerns and surrounding areas will be accessed by two people at all times.
4. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

- ▲ Offsite Water Table Well
- ● Shallow Monitoring Well (2 to 30 ft bgs)
- (I) ● Intermediate Monitoring Well (40 to 60 ft bgs)
- (D) ● Deep Monitoring Well (80 to 100 ft bgs)
- (M) ● Multi-Level Well
- ● Wells Not Currently Sampled
- ⊗ Annual Surface Water Sample Location
- ⊗ Semiannual Surface Water Sampling Location
- ▨ Wetland Areas
- ▢ Water Bodies
- — Waterways
- AGW240(M) Wells with Security Concerns

N

0 1,000 2,000

Scale in Feet

Base Map Source: Geometrix 2003; Parcel Data Source: King County 2015; Aerial Photo Source: Esri World Imagery.

Boeing Auburn
Auburn, Washington

Current Monitoring Well Network

Figure
1

LANDAU ASSOCIATES

G:\Projects\025\164\150\110\Phase 8 GWMP\B01MWNetwork_Security.mxd 6/25/2018

Table 1

BOEING AUBURN
700 15th Street SW, Auburn, WA 98001

STANDARD WORK PRACTICES

Health and Safety is **EVERYONE'S** responsibility and **NUMBER ONE PRIORITY**

- Regulatory compliance is **MANDATORY** – No work will begin and/or work will immediately stop unless the answer to the following question is a positive **"YES"** – AM I IN COMPLIANCE WITH ALL REGULATORY, FACILITY, PROJECT, AND HEALTH AND SAFETY REQUIREMENTS?

- All incidents and regulatory inspections must be reported immediately

    - **Incident definition**: Any event condition, or action (including near misses) that affects the safety of personnel, does not follow rules and guidelines for work implementation and regulatory compliance onsite
- Incident examples:
    - Spilled liquid in an uncontrolled environment
    - Working without correct/complete permit in place
    - Performing hot works without a "Hot Works Permit"

Before starting work, **HAVE YOU?** :

1. Reviewed the Health and Safety Plan prior to performing work?
2. Performed a Health and Safety "Tail Gate Meeting" and filled out the sign-in form prior to starting work?
3. Reviewed scope of work documents, permits, and other related items prior to performing work?
4. Provided correct Personal Protective Equipment (PPE) for the work to be performed?
5. Followed Lock Out/Tag Out Procedures for equipment?

IF YOU ARE UNSURE OF SAFETY PRACTICES FOR THE PARTICULAR WORK INVOLVED – GET CLARIFICATION PRIOR TO STARTING WORK

Working with subcontractors:

- Review Health and Safety Plan with subcontractor
- Review site "Incident Reporting Procedures"
- Perform "Tail Gate Safety Meeting" with subcontractor

SAFETY AND REGULATORY COMPLIANCE IS MY PRIORITY AND I MUST TAKE THE NECESSARY STEPS TO PROVIDE THIS SERVICE

I AM RESPONSIBLE AND I HAVE THE AUTHORITY TO STOP WORK IF THE TASK DOES NOT MEET THE SAFETY AND REGULATORY REQUIREMENTS

SAFETY DASHBOARD CARD

EMERGENCY AND INCIDENT REPORTING PROCEDURES

EMERGENCY PHONE NUMBER:
Offsite – 911; onsite - (206) 655-2222 Fire, Ambulance, Police, Spill Reporting

If using a cell phone to call be prepared to supply the site and work location address

SITE ADDRESS:
700 15th Street SW, Auburn, WA 98001
WORK LOCATION:
700 15th Street SW, Auburn, WA 98001

A WORKER SHOULD BE STATIONED SO THAT EMERGENCY RESPONSE PERSONNEL CAN BE DIRECTED TO THE WORK SITE

AN EMERGENCY IS AN UNCONTROLLED SITUATION, AN INJURY THAT IS MAJOR OR LIFE THREATENING, FIRE, OR ANYTHING THAT REQUIRES IMMEDIATE ASSISTANCE.

EMERGENCY REPORTING:

1. Contact Emergency Response (fire, ambulance, police) at: off - 911; on **(206) 655-2222**
2. Follow Incident Reporting procedures listed below

INCIDENT REPORTING:
Respond to the incident and get it under control. Contact the following by e-mail and brief phone message (**MUST DO BOTH**):

Name	Email Address	Phone Number	Position
Jennifer Parsons	**jennifer.a.parsons@boeing.com**	**(206) 715-7981 cell**	**Boeing Field Engineer**
Carl Bach	**carl.m.bach@boeing.com**	**(206) 898-0438 cell**	**Boeing Project Manager**
Jim Swortz	**james.p.swortz@boeing.com**	**(360) 790-1767 cell**	**Boeing Site Focal**
Jennifer Wynkoop	**jwynkoop@landauinc.com**	**(206) 617-3117 cell**	**Consultant Contact**
Chris Kimmel	**ckimmel@landauinc.com**	**(206) 786-3801 cell**	**Consultant Contact**
Sarah Fees	**sfees@landauinc.com**	**(801) 694-7635 cell**	**Consultant Contact**

When leaving the voice message or email state the following:

1. **Date:** The date the incident occurred
2. **Time:** The approximate time the incident occurred
3. **Location:** Where the incident occurred, i.e.; Admin Compound…

After the incident is under control, the sequence of events will be recorded, including probable cause, people who responded to the incident, the extents of the incident, and relevant dates and times

Emergency Facilities and Numbers

Hospital :

Auburn Regional Medical Center
202 N Division Street
Auburn, WA 98001

Telephone: 253-833-7711

Emergency Transport Systems (Fire, Police, Ambulance) – 911

Emergency Route:

Head North toward 15th St SW
Turn right onto 15th St SW
Use the left 2 lanes to turn left onto C St SW
Turn right onto West Main St
Turn left onto N Division St
Go 436 ft and arrive at Auburn Regional Medical Center, on the right

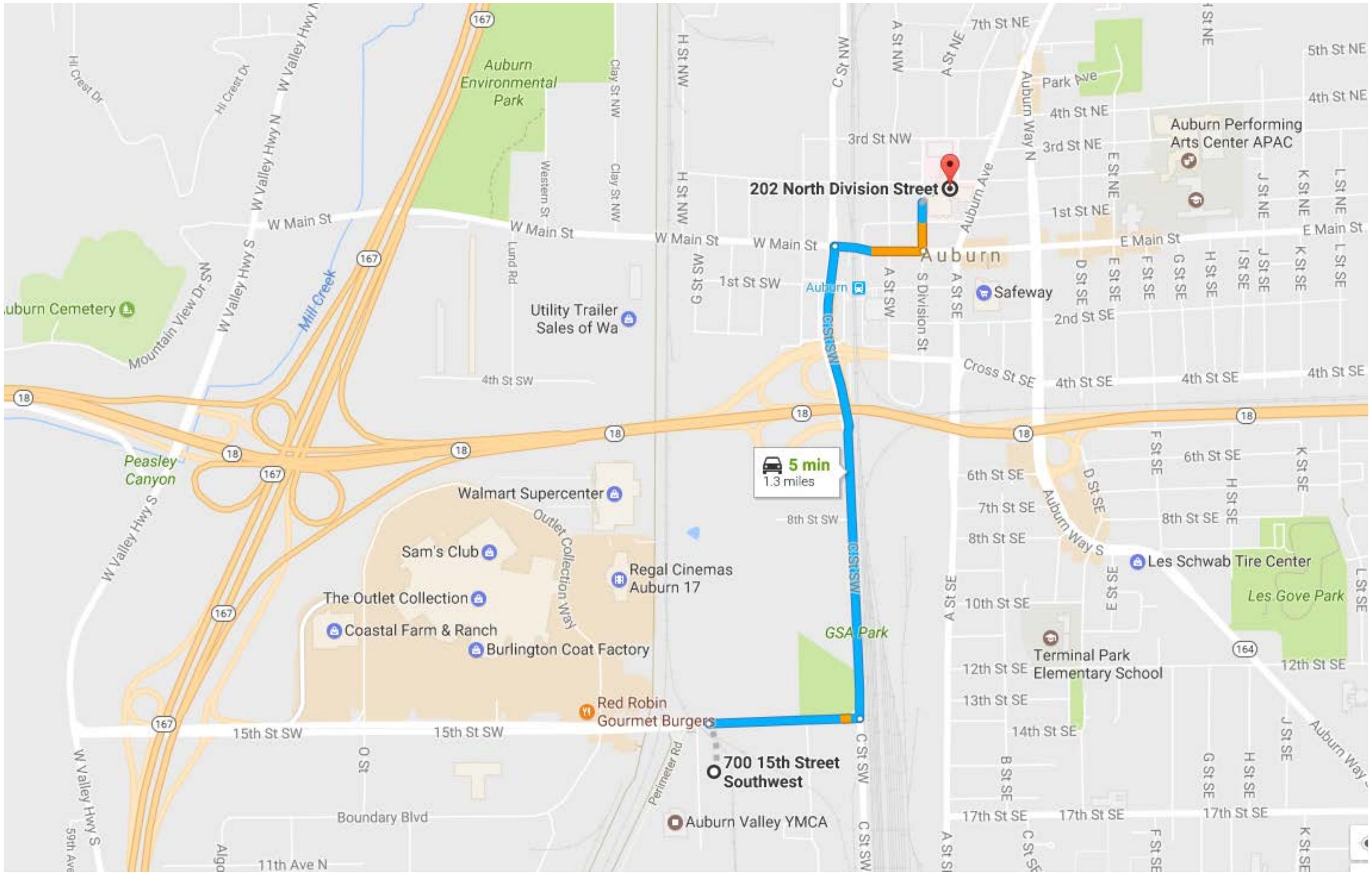


Table 2
Human Health Information for Constituents of Concern
Health and Safety Plan
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Contaminant	TLV (ACGIH)	STEL (ACGIH)	REL (NIOSH)	IDLH (NIOSH)	TWA (WISHA)	STEL (WISHA)	Source/Quantity Characteristics	Route of Exposure	Symptoms of Acute Exposure	Instruments Used to Monitor Contaminant
Aresenic	NV	NV	**0.002 mg/m^3**	5.0 mg/m^3	0.01 mg/m^3	5 mg/m^3	Present in groundwater.	Eye contact, dermal contact, ingestion.	Ulceration of nasal septum; dermatitis; GI disturbance; peripheral neuropathy; respiratory irritant; hyperpigmentation of skin.	Dust control, PPE
Benzene	**0.5 ppm**	2.5 ppm		500 ppm	1 ppm	5 ppm	Present in groundwater and soil.	Inhalation, ingestion, dermal contact.	Irritated eyes, skin, nose, respiratory system; dizziness; headache; nausea; dermatitis; bone marrow depression (carc).	PID
Cadmium	NV	NV	**0.005 mg/m^3**	9 mg/m^3	NV	NV	Present in groundwater.	Eye contact, dermal contact, ingestion.	Pulmonary edema; cough; chest tightness; headache; chills; muscle aches; nausea; vomiting; diarrhea; anosmia (susp carc).	Dust control, PPE
Copper	NV	NV	**1 mg/m^3**	100 mg/m^3	NV	NV	Present in groundwater.	Eye contact, dermal contact, ingestion.	Irritated eyes, nose, pharynx; nasal septum perforation; metallic taste; dermatitis.	Dust control, PPE
Cyanide	NV	NV	**5 mg/m^3**	50 mg/m^3	NV	NV	Present in groundwater.	Eye contact, dermal contact, ingestion.	Weakness; headache; dizziness; confusion; abdominal pain; nausea; vomiting.	Dust control, PPE
cDCE	**200 ppm**	4000 ppm	NV	1000 ppm	NV	NV	Present in groundwater and soil.	Inhalation, ingestion, dermal contact.	Irritated eyes; depression of central nervous system and respiratory system.	PID
Ethylbenzene	100 ppm	125 ppm	100 ppm	800 ppm	**100 ppm**	125 ppm	Present in groundwater and soil.	Inhalation, ingestion, dermal contact.	Irritated eyes, skin, mucus membrane; headache; dermatitis; narcosis; coma.	PID
Nickel	NV	NV	**0.015 mg/m^3**	10 mg/m^3	NV	NV	Present in groundwater.	Eye contact, dermal contact, ingestion.	Sensitization dermatitis; allergic asthma; pneumonia (carc).	Dust control, PPE

Table 2
Human Health Information for Constituents of Concern
Health and Safety Plan
Boeing Auburn Feasibility Study Work Plan
Auburn, Washington

Contaminant	TLV (ACGIH)	STEL (ACGIH)	REL (NIOSH)	IDLH (NIOSH)	TWA (WISHA)	STEL (WISHA)	Source/Quantity Characteristics	Route of Exposure	Symptoms of Acute Exposure	Instruments Used to Monitor Contaminant
PCE	25 ppm	100 ppm	NV	150 ppm	**25 ppm**	150 ppm	Present in groundwater and soil.	Inhalation, ingestion, dermal contact.	Irritated eyes, skin, nose, throat, respiratory system; nausea; flushed face, neck; dizziness; liver damage (carc).	PID
Toluene	**50 ppm**	NV	100 ppm	500 ppm	100 ppm	150 ppm	Present in groundwater and soil.	Inhalation, ingestion, dermal contact.	Irritated eyes, nose; confusion; euphoria; dizziness; dilated pupils; liver and kidney damage.	
TPH			**100 ppm**	400 ppm	300 ppm	500 ppm	Present in groundwater and soil.	Absorption, ingestion, inhalation.	Irritated eyes, nose, throat; dizziness; nausea; chemical pneumonia.	PID
TCE	50 ppm	100 ppm	**2 ppm**	1000 ppm	50 ppm	200 ppm	Present in groundwater and soil.	Inhalation, absorption, ingestion, dermal contact.	Irritated eyes and skin; dizziness; tremors; drowsiness; nausea; vomiting (carc).	PID
VC	**1 ppm**	5 ppm	NV	NV	NV	NV	Present in groundwater and soil.	Inhalation, ingestion, dermal contact.	Weakness; abdominal pain (carc).	PID
Total Xylenes	100 ppm	150 ppm	100 ppm	900 ppm	100 ppm	150 ppm	Present in groundwater and soil.	Inhalation, ingestion, dermal contact.	Irritated eyes, nose, throat; dizziness; excitement; nausea; vomiting; abdominal pain.	PID, colorimetric tube

Note:

1. Values that are most protective are in bold, red text.

Abbreviations/Acronyms

ACGIH = American Conference of Governmental Industrial Hygienists
carc = carcinogen
cDCE = cis-1,2-dichloroethene
IDLH = immediately dangerous to life and health
mg/m3 = milligrams per cubic meter
NIOSH = National Institute for Occupational Safety and Health
NV = no value
PCE = tetrachloroethene
ppm = parts per million
REL = recommended exposure limit
STEL = short-term exposure limit
susp carc = suspected carcinogen
TCE = trichloroethene
TLV = threshold limit value
TPH = total petroleum hydrocarbon
TWA = time-weighted average
VC = vinyl chloride
WISHA = Washington Industrial Safety and Health Act

Table 3
Action Levels for Respiratory Protection
Boeing Auburn Facility Feasibility Study Work Plan
Auburn, Washington

Monitoring Parameter	Reading	Level of Protection
	VOC ACTION LEVEL #1	
PID Screening		
VOCs	PID reading 0.3 to 1.0 ppm in breathing zone for more than 1 minute.	Employ fans or engineering controls to reduce VOCs in work area, if possible. Collect colorimetric tube VC readings and refer to action levels below.
Colorimetric Tubes		
VC	VC reading 0.1 to 1 ppm.	Establish 25-ft diameter exclusion zone around work area and upgrade to Level C half-face respirator with organic vapor/HEPA cartridge.
VC	VC reading > 1 ppm.	Evacuate area and move upwind. Establish 50-ft diameter exclusion zone around work area. Notify on-site contact and LAI Health & Safety Manager. Do not return to area of detection until VC reads < 1 ppm, upgrade to Level C PPE.
	VOC ACTION LEVEL #2	
PID Screening		
VOC	PID reading > 1 ppm in breathing zone for more than 1 minute.	Establish 25-ft diameter exclusion zone around work area and upgrade to Level C half-face respirator with organic vapor/HEPA cartridge. Collect colorimeteric tube VC and PCE readings and refer to action levels below.
Colorimetric Tubes		
VC	Follow ACTION LEVEL #1	Follow ACTION LEVEL #1
PCE	PCE reading 1 to 15 ppm	Establish 25-ft diameter exclusion zone around work area and upgrade to Level C half-face respirator with organic vapor/HEPA cartridge.
PCE	PCE reading > 15 ppm.	Evacuate area and move upwind. Establish 50-ft diameter exclusion zone around work area. Notify on-site contact and LAI Health & Safety Manager. Do not return to area of detection until PCE reads < 15 ppm, upgrade to Level C PPE.
	VOC ACTION LEVEL #3	
VOC (PID)	PIC reading > 25 ppm **instantaneous** reading.	Evacuate area and move upwind. Establish 50-ft diameter exclusion zone around work area. Notify on-site contact and LAI Health & Safety Manager. Do not return to area of detection until VOC reads < 25 ppm, upgrade to Level C PPE.

Abbreviations/Acronyms:

HEPA = high efficiency particulate arrestance
LAI = Landau Associates, Inc.
PCE = tetrachloroethene
PID = photoionizer detector
PPE = personal protection equipment
ppm = parts per million
VC = vinyl chloride
VOC = volatile organic compound

APPENDIX A

Health and Safety Forms

FORM 1
ACKNOWLEDGMENT

I have read the attached Health and Safety Plan for the Feasibility Study fieldwork at Boeing Auburn in Auburn, Washington. I have discussed any questions that I have regarding these materials with my supervisor, and I understand the requirements of the health and safety plan.

Employee ______________________________ Date ________________

Employee ______________________________ Date ________________

Employee ______________________________ Date ________________

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Employee ______________________________ Date ________________

Employee ______________________________ Date ________________

Employee ______________________________ Date ________________

Employee ______________________________ Date ________________

Site Safety Officer ________________________ Date ________________

BOEING

Safety Promise

I promise to do my job safely so I can return home every day as healthy as I left. I will do this for the sake of my family, my teammates and myself. Every decision I make affects me, my teammates and my family.

I Promise:

I will increase my awareness of potential hazards involved with everyday work.

I will not do work, or ask others to do work, that is unsafe.

I will speak up and ensure action is taken when I see an unsafe condition.

I will be open, listen and take action when others point out that I am doing something that is not safe.

I expect Boeing to create an environment where I am as safe working on Boeing products as I am using them, and I am part of that environment.

With my signature, I commit to put safety first each and every day:

Together, we will
Go for Zero – One Day at a Time.

GO4ZERO
One Day at a Time.

FORM 3
MODIFICATION TO HEALTH AND SAFETY PLAN
DATE ___/___/___

Modification: ____

____

____

____

Reasons for Modification: ____

____

____

____

Site Personnel Briefed:

Name: ______________________________	Date: ____________________
Name: ______________________________	Date: ____________________
Name: ______________________________	Date: ____________________
Name: ______________________________	Date: ____________________
Name: ______________________________	Date: ____________________
Name: ______________________________	Date: ____________________
Name: ______________________________	Date: ____________________

Approvals:

Site Safety Officer: ____

Manager: ____

Others: ____

LANDAU ASSOCIATES

FORM 4
EMPLOYEE EXPOSURE/INJURY INCIDENT REPORT
(Use additional pages if necessary)

Date:______________________ Time:______________________

Name:______________________ Employer:______________________

Site Name and Location:______________________

Site Weather (clear, rain, snow, etc.):______________________

Nature of Illness/Injury:______________________

____

Symptoms:______________________

Action Taken: Rest:____________ First Aid:____________ Medical____________

Transported by:______________________

Witnessed by:______________________

Hospital's Name:______________________

Treatment:______________________

Comments:______________________

____

What was the person doing at the time of the accident/incident?______________________

____

Personal Protective Equipment Worn:______________________

____

Cause of Accident/Incident:______________________

____

What immediate action was taken to prevent recurrence?______________________

____

Additional comments:

Employee's Signature/Date:______________________

Supervisor's Signature/Date:______________________

Site Safety Representative's Signature/Date:______________________

APPENDIX D

Sampling and Analysis Plan

Sampling and Analysis Plan
Boeing Auburn Facility
Auburn, Washington

October 23, 2018

Prepared for

The Boeing Company
Seattle, Washington

LANDAU ASSOCIATES

950 Pacific Avenue, Suite 515
Tacoma, WA 98402
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Sampling and Analysis Plan
Boeing Auburn Facility
Auburn, Washington

This document was prepared by, or under the direct supervision of, the technical professionals noted below.

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Project Coordinator:	Juliann Cooley

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APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

Boeing	The Boeing Company
bgs	below ground surface
CMT	continuous multichannel tubing
COC	chain of custody
COLIWASA	composite liquid waste sampler
°C	degrees Celsius
DI	de-ionized
DO	dissolved oxygen
DP	direct-push
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
facility	Auburn Fabrication Division facility
gpm	gallons per minute
ft	feet
HASP	health and safety plan
HSA	hollow-stem auger
ID	identification
IDW	investigation derived waste
in.Hg.	inches of mercury
L	liter
LAI	Landau Associates, Inc.
LLI	Eurofins Lancaster Laboratories, Inc.
mL/ft	milliliters per foot
NTU	nephelometric turbidity unit
OM	Osceola Mudflow
ORP	oxygen reduced potential
PCB	polychlorinated biphenyl
PDB	passive diffusion bag
PID	photoionization detector
PPE	personal protective equipment
PRT	post-run tubing
QA/QC	quality assurance/quality control
RI	remedial investigation
SAP	Sampling and Analysis Plan
SWMU	solid waste management unit
TWA	time weighted average
VOA	volatile organic analysis
VOC	volatile organic compound

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1.0 INTRODUCTION

The Boeing Company (Boeing) is currently undergoing corrective action at their Auburn Fabrication Division facility (facility) located at 700 15th Street Southwest in Auburn, Washington (Figure 1). Corrective action requirements are documented in Agreed Order No. DE 01HWTRNR-3345 dated August 14, 2002 and the First Amended Agreed Order dated February 21, 2006, both with Washington State Department of Ecology (Ecology). This Sampling and Analysis Plan (SAP) presents detailed descriptions of field procedures for corrective actions taking place at the facility and at downgradient properties (Site). Additionally, this SAP is intended to be used for other potential environmental investigations related to new or newly discovered releases at the site. This SAP should be used in conjunction with the Boeing Auburn Quality Assurance Project Plan (LAI 2016).

Various topics discussed in this SAP include:

- Drilling methods
- Monitoring well installation
- Well development
- Groundwater sampling
- Surface water and sediment pore water sampling
- Soil sampling
- Soil gas and air sampling
- Field documentation
- Sample handling and documentation
- Utility locating procedures
- Surveying
- Off-site field operations
- Waste handling.

2.0 DRILLING PROGRAM

This section describes the techniques used to advance soil borings for the installation of monitoring wells and collection of groundwater and/or soil samples for chemical analysis. Soil borings will be advanced using hollow-stem auger (HSA), rotosonic, or direct-push (DP) drilling techniques, depending on the expected conditions and boring depth. The completion depths of soil borings will be as described in pertinent work plans, as influenced by drilling conditions encountered and the depths of the water-bearing units. In general, shallow wells will be installed up to 30 feet (ft) below ground surface (bgs), intermediate wells will be installed from 40 to 60 ft bgs, and deep wells will be installed from 80 to 100 ft bgs. Water table wells are a subset of shallow wells and are installed with the screen across or near the water table. Depths of wells may vary depending on the data objectives for the well, depth of the geologic units, and varying geologic conditions within a unit. In particular, the final depth of deep zone wells will depend on the depth of the Osceola Mudflow (OM) deposit.

Near the Site, geologic conditions consist of alluvial sands and gravels that vary in thickness between 80 and 100 ft. The alluvial deposits are underlain by the OM, a lahar deposit originating at Mount Rainier approximately 5,700 years ago. The OM acts as an aquitard due to its silt and clay content and low permeability. It is important to protect the integrity of the OM to avoid potentially introducing a pathway for contaminated groundwater to travel beneath the aquitard. During the installation of deep wells, the boring will be advanced until the OM is identified, or to a depth of 110 ft bgs, whichever is shallower. Once the top of the OM is identified, drilling will stop and the well screen will be installed 1 ft above the contact or, if a silt layer is present, the well screen will be installed 1 ft above the silt layer.

Previous studies describe the OM as a heterogeneous deposit; typically gray and massive; containing gravel, sand, silt, and clay with occasional boulders; and possibly including wood and organic debris, angular volcanic clasts, or having mottled yellow patches and a sulfurous odor (Pacific Groundwater Group 1999; Dragovich et al. 1994). Borings completed as part of the project remedial investigation (RI) have described the OM as well-graded, gray, silty sand with clay and round to angular gravels, occasionally including trace organics or wood fragments, medium dense or stiff to dense, or very stiff. Distinctive features of OM soil samples observed during RI drilling are a sticky texture and are angular volcanic gravels. A layer of gray silt 1- to 5-ft thick overlying the OM has been described in a number of RI borings.

2.1 Drilling Methods

This section describes drilling methods to be used for investigation (HSA, rotosonic, or DP).

2.1.1 Hollow-Stem Auger

HSA drilling is accomplished with a truck-mounted or track-mounted drill rig. The HSA drilling method consists of rotating and applying pressure to a simple digging bit attached to helical auger flights. The bit loosens and pushes soil to the side of the borehole, where it is captured by the helical auger flights and lifted to the ground surface. A drill rod suspended in the hollow portion of the auger is used to simultaneously drive a center bit or plug that prevents drill cuttings from entering the hollow auger flights.

The HSA method allows for split-spoon sampling of soil borings utilizing the space within the hollow stem of the auger. Environmental or geotechnical split-spoon samples are retrieved by replacing the center bit with the split-spoon sampler and driving the sampler with an auto-hammer or down-hole hammer. The sampler and drill rod are then removed from the boring using the derrick cables. A standard penetration test split-spoon sampler, Dames and Moore U-Type, or equivalent split-barreled sampler may be used to collect soil samples for laboratory analysis.

2.1.2 Rotosonic

Rotosonic drilling is accomplished with a truck-mounted or limited-access, track-mounted drill rig. Rotosonic drilling uses high frequency mechanical oscillations, developed in a special drill head, to transmit resonant vibrations and rotary power through the drill tooling to the drill bit. Frequencies between 150 to 180 hertz are generated. These frequencies match the natural frequency of the drill tooling, causing no dampening of the vibratory wavelength to the bit and can be adjusted to optimize drilling in different formations.

One of the main advantages of the rotosonic drill is its ability to produce continuous core samples of both unconsolidated and consolidated formations. The core samples can be analyzed to provide a precise and detailed stratigraphic profile of any overburden condition including dry or wet saturated sands and gravels, cobbles and boulders, clays, silts, and hard glacial tills. Sample recovery near 100 percent is commonly achieved.

Another unique feature of the rotosonic drilling method is the ability to settle the filter pack and bentonite chip or pellet seal during well installation. This settling is achieved by the resonant vibration applied to the outer casing as it is extracted from the borehole leaving the well screen and riser, pack, seal, and grout or slurry installed in the borehole. The vibratory effect minimizes “bridging” and the potential problem of sand locking the well into the outer drilling casing and pulling it out as the casing is extracted.

2.1.3 Direct-Push

DP drilling is accomplished using a truck-mounted, track-mounted, or hand-portable DP rig. Depending on the manufacturer, make, and model, DP drill tooling is advanced by static push, pneumatic impact, or vibratory methods, or a combination thereof. Unlike rotosonic drilling, there is no rotation of the tooling. In its standard configuration, DP drilling collects a continuous soil core in a 2.25-inch diameter core barrel with a removable polyethylene liner. Once the desired depth is reached, the core is extracted from the ground and the liner and soil core are removed from the core barrel.

The main advantage to DP drilling is it is a fast way to collect high quality soil and groundwater grab samples in unconsolidated sediments where drilling depths are relatively shallow. DP drilling is most often used to collect one-time groundwater grab samples as described in Section 2.3. Permanent monitoring wells and piezometers can also be installed using DP drilling by using prepacked screens. In addition, DP drilling can be used to collect soil vapor samples as described in Section 5.

Due to the relatively low amount of energy imparted to the subsurface as compared to other drilling methods, DP drilling has significant depth limitations in over consolidated soils, soils with a high gravel content, and bedrock. In addition, as there is no way to properly construct a step-down seal with DP drilling, it is not an appropriate method for drilling that crosses more than one aquifer.

2.2 Equipment Decontamination

Prior to drilling at each location and prior to demobilization offsite, all drilling equipment exposed to soil and groundwater will be cleaned with a high-pressure steam cleaner. Water used for cleaning will be obtained from a potable source and transported to the drilling site or from an approved facility source. Contaminating substances will not be introduced into the borings or wells during any part of the drilling, well installation, or well development process. Containers used to transport drilling water may not have been used for any other purpose. Containers of decontamination water will be labeled and stored separately from other containers.

2.3 Borehole Groundwater Sampling

During drilling, borehole groundwater samplesmay be collected from discrete intervals different from the final well screen (monitoring wells) or where no permanent well will be installed (soil borings). Borehole samples can be collected either from a temporary well installed during drilling and then removed before continuing with well installation, or from the permanent well screen immediately after installation and before development. When a borehole sample is to be collected, water may not be used during drilling to control heave. Once the sample has been collected, added water may be used, as necessary, to complete installation of the well.

2.3.1 Temporary Well Installation

Temporary wells will be installed during drilling for sampling depths other than the final screened interval. Temporary wells will consist of a 5-ft long PVC screen and PVC casing. The driller will advance the exploration to the desired depth, install the temporary well, place a sand pack (if needed) to a height of 2 ft above the screen, and then pull the auger or casing (depending on drilling method) 5 ft up to expose the screen to the surrounding formation.

A new well screen will be used for each temporary well and will not be reused for construction of the permanent well. Riser pipe from a temporary well may be reused for deeper temporary wells in the same boring and for the permanent well installed at the same location. Reused riser pipe will be located at the same depth as in the temporary well.

2.3.2 Borehole Sampling Procedures

Temporary wells will be purged for 30 minutes or until field parameter readings can be taken including turbidity, pH, conductivity, and temperature stabilize, whichever is sooner. Borehole samples generally have very high turbidity, which does not substantially improve with additional purging. Therefore, the laboratory chain-of-custody (COC) will request that turbid samples either be allowed to settle or be centrifuged to allow collection of an aliquot from the clear portion of the liquid.

2.4 Well Installation

This section specifies the designs, procedures, and materials that will be used to construct monitoring and injection wells. The installation procedures are designed to avoid contamination of the water-bearing zone by drilling equipment, cross-contamination of wells during the drilling process, and vertical seepage of surface water to groundwater. Monitoring wells will be installed to obtain representative groundwater samples and evaluate hydrogeologic conditions. Injection wells are installed for the purpose of bioremediation.

The drilling subcontractor will install wells as overseen by a field geologist. The drilling subcontractor will be responsible for obtaining and submitting all well drilling permits, logs, and well identification (ID) tags as required by the State of Washington.

All wells will be constructed in accordance with the Ecology Minimum Standards for Construction and Maintenance of Wells (Washington Administrative Code [WAC] 173-360) or in accordance with a variance obtained from Ecology. The most current version of this WAC (or the variance if obtained) at the time of installation will take precedence over all other well drilling and construction practices discussed elsewhere in this SAP.

2.4.1 Conventional Monitoring and Injection Well Construction

A single well screen and riser pipe will be placed at the selected depth interval after completing the boring and before retracting the casing or auger. A sand filter pack will be installed in the annular space around the screen. A well seal, typically of bentonite chips, will be installed above the filter pack. A locking well monument set in a concrete-surface seal will occupy the top 2 ft. Dispersing agents such as phosphates or acids will not be used in well installation or development. Each segment of the constructed well is discussed in detail in the following paragraphs.

2.4.1.1 Well Screen and Filter Pack

New, clean, 2-inch diameter, Schedule-40, flush-threaded PVC riser pipe and factory-slotted well screens will be used for all conventional well installations. The screen length will be described in a pertinent work plans and be determined based on the target groundwater zone, lithologic conditions, and estimated wet season groundwater depth. Typical screen lengths will be 10 ft. A threaded bottom cap will be attached to each screen prior to installation.

The purpose of the well screen is to allow groundwater to easily enter the well while preventing entry of filter pack sand. Screens with a slot size of 0.010-inch or 0.020-inch will be used. A 0.020-inch slotted screen will be matched to a filter pack of size 10/20 silica sand (or equivalent). A 0.010-inch slotted screened can be matched to a filter pack of size 10/20 or 20/40 silica sand (or equivalent).

The sand pack is intended to minimize transport of fine-grained sediment into the well without restricting the flow of groundwater. Filter pack sand will be placed to approximately 2 ft above the screen as the drill casing is retracted. This 2 ft of filter pack sand above the top of the well screen will prevent migration of the overlying bentonite seal material into the screened intake zone.

Filter pack material will be poured slowly during placement to prevent bridging across the annulus. For wells constructed with HSA drilling where there is no vibratory energy during removal of the drill casing, the well screen will be surged frequently during placement to settle the sand pack. To monitor this settling, the top of the filter pack will be continuously sounded with a weighted measuring line (sounding tape) during placement of the filter pack. This process will be continued until the filter pack has filled the well annulus to the appropriate depth. The volume of sand emplaced will be recorded on the well construction log.

2.4.1.2 Well Riser

A flush-threaded, 2-inch-diameter, PVC well riser will be installed from the top of the screen to the ground surface. The riser will be cut flat at the top. A small, v-shaped notch or other permanent mark will be made in the lip as a mark from which all future water level readings will be made. By convention, the notch will be located on the north side of the well riser pipe.

2.4.1.3 Well Seal

A combination of bentonite chips or pellets, and bentonite grout will be used to construct the well seal. If using bentonite grout as an annular seal, a well seal of hydrated bentonite pellets or chips at least 3-ft thick will be installed above the filter pack to prevent the intrusion of overlying annular seal material (grout) into the filter pack. Grout will be placed using a tremie tube.

Cement bentonite grout will be used as the well seal for injection wells. Increased pressures and the need for a crack/shrinkage resistant well seal require specific well design parameters. These specific requirements may also be recommended at monitoring wells in the immediate vicinity of the injection area, as these wells can be subject to similar forces.

For most monitoring wells, bentonite pellets or chips will be used as the seal material up to 2 ft bgs. Bentonite chips or pellets will be poured into the annulus at a rate no greater than 3 minutes per standard sack.

2.4.1.4 Surface Completion

A concrete surface seal and a well monument will constitute the surface completion. The concrete surface seal will be placed in the upper 2 ft of the boring. The monument will consist of an aboveground protective steel casing or a flush-mount monument.

For aboveground completions, a 6-inch-diameter steel protective casing with a locking lid will be installed around the PVC well casing. It will extend no more than 6.5 inches above the top of the well casing and at least 2 ft bgs. A concrete pad will be poured around the steel monument. The protective aboveground casing will be set over the well such that the portion embedded in cement is greater than or equal to one-half the protective casing length, if possible. Sand will then be added inside the monument to 6 inches below the top of the well PVC. The pad around the well will be 6 inches thick, approximately 2 ft by 2 ft, sloped away from the well, and extend at least 3 inches bgs. Three metal posts (i.e., bollards), at least 3 inches in diameter, and painted with high-visibility paint (usually bright yellow) will be placed around each well or group of wells. The posts will be set in individual holes filled with concrete. If the posts are hollow, they will be filled with concrete after placement in the ground. The posts will not be placed in the concrete pad surrounding the protective casing. Keyed-alike locks for the wells will be obtained from the Boeing representative.

In areas where activity or traffic precludes the use of aboveground protective casings, flush-mount casings (minimum of 6 inches in diameter) will be used. The top of the flush monument will be at least 1 inch, but not more than 2 inches, above the surrounding surface grade to allow for drainage away from the well location. A concrete pad is not required if the monument is installed in asphalt or concrete; however, a concrete pad will be installed around monuments set in soft surfaces such as gravel, dirt, or grass. No metal posts will be required for protection.

For injection wells, surface completions will be as follows:

- Wells will be completed in 8-inch-diameter flush-mounted monuments with gasketed lids and bolts.
- Within the monument, injection wells will be completed with a 2-inch PVC male pipe thread adapter connected to a 2-inch galvanized steel threaded coupler. A lockable expanding plug will be used to close the well casing. A 2-inch galvanized steel nipple with an aluminum female cam lock (by female threads) will be threaded into the coupler for injection. Well casings must be centered within the monuments. The pipe thread adaptor and attached coupler will be glued to the well casing to create a pressure-tight connection for injection; both surfaces will be primed with glue applied to outside of casing only (not inside of fitting) to avoid dripping of excess glue down the well casing.

2.4.2 Multi-level Monitoring Well Construction

Solinst® continuous multi-channel tubing (CMT) multi-level wells may be used to monitor multiple groundwater zones from a single well. CMT wells are constructed from a single polyethylene tube with six channels running internally along its length and one cylindrical channel running down the center of the tubing. Each channel is completely separate from all other channels and screens are placed at specified depths in each channel to facilitate sampling from multiple groundwater zones.

Multi-level wells are assembled aboveground then inserted in the boring before the casing is retracted. Construction consists of creating intake ports in the various channels at the desired depths, installing watertight expansion plugs below each intake port, adding mesh screens, pre-grouting each channel segment below the screen, and sealing the bottom of the tubing with an additional expansion plug. The wells can be constructed onsite if space is available or constructed offsite and transported to the borehole location for installation. CMT wells are constructed in accordance with the Solinst CMT Multi-level System Assembly Manual (Appendix A; Solinst website 2016). Prior to installation, the outer CMT channels are grouted from below the sampling port to the bottom of the well. The purpose of pre-installing grout is to facilitate later decommissioning of the well by grouting instead of over drilling. Grouting is completed in accordance with the procedures described in the Solinst CMT Decommissioning Manual and Purge/Grout Adaptor Operating Instructions (Appendix A).

2.4.2.1 Well Layout

Before constructing the CMT well, sketch the well design; a template generated by Landau Associates, Inc. (LAI) is available for this purpose (Appendix B). This sketch may be a useful reference during construction and installation. Once the well is designed, mark the locations of the sampling ports on the CMT tubing by following these steps:

1. Lay out an appropriate length of plastic sheeting on the ground and uncoil the CMT tubing.
2. Cut the appropriate length of well tubing, while leaving additional length as “working” tubing to assist in handling of the well during installation.
3. Identify the anticipated location of the top of the well and mark it on the tubing.
4. From this point, measure the depth bgs where the Channel 1 sampling port will be assembled. A low profile repetitive marking “<< CMT >>” runs along the length of one of the channels, which designates Channel 1. By convention, Channel 1 is installed in the shallowest monitoring zone and the channels increase in number and depth clockwise around the tubing with the final and deepest port installed in the center channel, Channel 7.
5. Mark the anticipated center of the screen for sampling Port 1.
6. Draw a line parallel along the channel at least 6 inches above and below the depth mark to help guide the port cutting tool.
7. Make similar markings on Channels 2, 3, 4, 5, and 6 at the desired depths. The screen for Channel 7 is part of the well cap anchor and attaches to the bottom of the tubing.

2.4.2.2 Well Material and Tools

CMT wells are constructed with 1.7-inch-diameter polyethylene Solinst CMT, wire-mesh screens, Oetiker clamps, expansion plugs, an end cap that also contains the central well screen, and a well cap. Tools needed for construction are a measuring tape, a PVC cutter, a marking pen, and a CMT installation toolkit (available from Solinst, which includes a port cutting tool, a hex wrench, snips, Oetiker clamp pliers, a 10-inch-pound torque driver, and a small Allen wrench). Supplies needed for pre-grouting are Nittetsu superfine cement with “Mighty 150” superplasticizer (available at Surecrete in Seattle, Washington), a grout adapter, grout plugs, hex plugs, and an internal O-ring (available from Solinst).

2.4.2.3 Sample Port Construction

The openings for the sampling ports will be cut into each channel and wrapped with a wire screen. Construct the sample ports by following these steps:

1. Slide the port cutting tool over the tubing to Port 1 in line with Channel 1.
2. Align and center the cutting tool with the channel tracing. Hand-tighten the locking bolts on the back of the cutting tool to secure its placement.
3. Use the hex wrench to tighten the cutting bolts until they “bottom out.”
4. Use the snips to cut away the exterior wall of the channel between the top two holes (the bottom hole is a vent for the pre-grouting). The distance between the cutting tool-generated holes is only 3 inches, so, if the well design is for 6-inch screens, move the port cutting tool down the tubing another 3 inches and cut an additional hole for the pre-grouting vent. It is very important to snip with care, as any perforation of the channel walls will allow groundwater cross-connection between channels.
5. Once the channel wall between the cutting tool holes is removed, insert an expansion plug into the channel at the bottom of the area to be screened to seal the sampling port from the lower, pre-grouted section of tubing. Tighten the plug with the torque driver.
6. Center the wire mesh over the port opening and wrap it tightly around the tubing, and secure it at both ends with an Oetiker clamp. Construction of Port 1 is now complete.
7. Continue down the tubing and construct sampling Ports 2 through 6 in the same manner.

2.4.2.4 Pre-grouting

As an additional security measure, and to make future well decommissioning easier, grout each channel of the CMT below the sampling port prior to installation. Grouting the unused void below the port prior to installation ensures that, when the well is decommissioned through grouting in-place, the full length of the CMT well will be filled with grout. Pre-grout the channels by following these steps:

1. Insert the expanding hex plug into the center channel (Channel 7) to prevent Channel 7 from being grouted.
2. The pre-installation grout mixture comprises superfine cement and superplasticizer. Superplasticizer reduces the rate at which the concrete absorbs water, increasing the amount of time available to work with the grout before it sets (typically 15 to 30 minutes depending on the amount of superplasticizer used). To estimate the volume of grout needed, keep in mind that the volume of each of the outer six channels is 40 milliliters per foot (mL/ft) and the volume of the center channel is 30 mL/ft.

3. Prepare an initial mixture of 2:1 grout to water, add 1 ounce of superplasticizer per gallon of grout (or approximately 4 percent by weight of cement). The grout should be thin enough to pump through the 1/4-inch tubing, but not so thin that it pools in the bottom of the channels. Using a Marsh funnel and mud balance to measure the viscosity and weight of the grout mixtures to create a record of successful grout properties for grouting future wells is advised. Through experience, it has been discovered that a 100-ft well uses 12 32-ounce measuring cups of cement, 6 32-ounce measuring cups of water, and 15 ounces of superplasticizer. The grout is the correct viscosity when a full Marsh funnel empties in 2 to 2-1/2 minutes. It is best to use a fine screen to remove clumps when mixing the cement into the water. This will help the grout to mix more evenly and without lumps that can clog the channels.
4. Move quickly to pumping the grout before it starts to thicken. Solinst provides a grout adaptor that connects the CMT tubing to the grout hose; this allows the six outer channels to fill simultaneously from the bottom of the well (Appendix A). Typically, grout is pumped using a diaphragm hand pump; however, other pumps can be used, if needed.
5. Be sure the pressure relief valve (25 pounds per square inch) on the grout adaptor is unrestricted. In the event that the channel is blocked, it is possible to continue grouting by inserting 1/4-inch tubing down from the top via the vent hole (for this reason, it is advisable to have some 1/4-inch tubing and an adaptor available to connect it to the selected pump).
6. When a channel is full, grout will be expelled from the vent hole. Shut off the pump and plug the vent hole with bentonite and plastic plugs provided by Solinst. Grout may leak from the plug, so be sure that the screens are free of grout by covering or elevating the screens.
7. Repeat procedure for all outer channels (Channels 1 through 6). Once Channels 1 to 6 are pre-grouted, insert the expansion plugs into the bottom of the channels and tighten with the torque-driver.
8. Attach the well cap anchor to the bottom of the CMT tubing to complete Channel 7 and secure it with Oetiker and hose clamps.

2.4.2.5 Transporting the Well

If it is not possible to build the well onsite, the well must be transported from the assembly location to the borehole location, which can be accomplished by coiling the well around a large spool. During transport to the Site, it is possible that the pre-grouted channels may leak around the plugs and impact the sampling ports and associated screened sections. To minimize this potential, keep the screened sections covered and ensure the screens are clear before installation.

2.4.2.6 Installation

Lower the assembled CMT well into the borehole slowly. Backfill the annular space between the CMT and the borehole wall with filter sand pack (screened sections) and bentonite pellets (intervals between screened segments) as designated on the well design. Sand filter packs are 3 to 4 linear ft of 10/20 or 20/40 silica sand centered on each sampling port. Backfill with bentonite pellets between sand pack intervals. Coated bentonite pellets are the preferred annular seal material in order to delay dehydration of the bentonite and allow additional time to frequently check the height of the pellets in relation to the screens. The bentonite should be poured into the annulus at a rate no greater than 3 minutes per standard package of bentonite chips. Continuously measure the depth of materials in the annular space to ensure placement at the correct depth and to minimize the potential for bridging. Bentonite chips or pellets above the water table should be hydrated after placement.

As described in the conventional well installation section of this SAP, the well seal will extend to approximately 2 ft bgs followed by a surface completion. To minimize the curvature of the tubing at the top of the well, install a length of 2-inch PVC as a straightening sleeve at the top of the CMT that extends a maximum of 5 ft bgs. The top of the PVC should line up with the top of the well. Use a level to ensure that the straightening sleeve is even and cut the top of the CMT tubing to the final elevation. If the tubing is not level, each individual channel may need to be surveyed. A well cap with numbered channel identifiers should be installed to identify the channels corresponding to the individual sampling ports. Surface completion should be done using the same guidelines as described for conventional wells (Section 2.4.1.4).

2.5 Well Development

The purpose of development following installation is to improve the hydraulic connection between the well and the formation to facilitate collection of representative groundwater samples. The goals of well development include creating an effective filter pack around the screen, rectifying damage to the formation caused by drilling, removing fine particles (silt and clay) from the formation near the borehole, and assisting in restoring the natural water quality of the aquifer near the well. To accomplish these goals, well development stresses the formation around the screen and filter pack so that mobile silt and clay are drawn into the well and removed to facilitate the collection of samples at an acceptably low turbidity level. Additional well development is completed for injection wells to facilitate extracting groundwater and injecting bioremediation amendments with as little resistance to flow as possible. Well development procedures for conventional monitoring wells, multi-level wells, and injection wells are outlined below. All water removed from the wells during development will be contained and disposed of as described in Section 11.0.

Well development may begin no sooner than 24 hours after installation to allow bentonite seals to cure. The depth to water and total depth of the well will be measured before and after well development. The drilling contractor or LAI will perform the development. Well development performed by the drilling contractor will be overseen by an LAI geologist. Well development and general well information will be documented on a well development log as described in Section 2.6.3. The groundwater depth should be recorded after the groundwater has had adequate time to recover. Depending on the diameter of the pump intake hose, it may not be possible to measure the groundwater depth during pumping. Development procedures for each type of well are listed below; procedures may be modified in the field as conditions warrant and as approved by the project manager.

2.5.1 Conventional Monitoring Wells

1. Use a weighted 1.5-inch-diameter PVC or stainless-steel bailer with a ceramic-ball check valve to remove sand and fines from the bottom of the well casing. Carefully lower the bailer to the bottom of the well and gently raise and lower it to collect the fines. Withdraw the bailer from the well and pour out (rinse if necessary) the fines and purged water. Repeat until no more sediment is retrieved from the bottom of the well.
2. Surge the well screen interval with the bailer or a surge block several times.
3. Pump water from the well using a centrifugal pump or airlift. Raise the pump intake incrementally to remove turbidity through the entire screened interval. Periodically record the pumping rate and the turbidity of discharged water. Continue pumping water from the well until the turbidity is significantly reduced.
4. Again, surge the well with the bailer or a surge block.
5. Measure and record the total depth of the well. Evaluate whether fines are present in the bottom of the casing.
6. Pump again and continue pumping until the well yields water with a turbidity of 50 nephelometric turbidity units (NTUs) or until a minimum of 10 casing volumes have been pumped from the well. If water was added to the well during drilling, a minimum of 200 percent of the volume of water added to the well must be purged during development. Record the final turbidity of the well on the well development log.

2.5.2 Multi-level Monitoring Wells

1. Insert the dedicated 1/4-inch (outer diameter) Teflon® tubing into each channel. Due to the narrow nature of CMT wells, it is very difficult to remove tubing from a CMT well if it slips down below the top of the channel; thus, tubing should be longer than the full length of the well by no less than 5 ft.
2. Pump water from the well using a peristaltic pump. During the purge, lower the intake of the tubing incrementally throughout the screen section in a surging-like motion in order to maximize the mobilization and removal of fines. Periodically record the turbidity of discharged water.
3. Continue pumping until reaching a turbidity of 50 NTUs or until a minimum of 10 casing volumes have been pumped from each well channel. Record the final turbidity of the well on the well development log.
4. Measure and record the total depth of each individual well channel and the static water level. Due to the narrow nature of the CMT wells, the Solinst multi-level water-level indicator will be required. Evaluate whether fines are present in the bottom of the casing.

2.5.3 Injection Wells

The general goal for injection well development is to purge water at or above the planned injection/extraction rate for a given well with the final purge water having a NTU value of less than 50. This is accomplished by alternating mechanical surging to mobilize fines followed by purging groundwater at a high flow rate. Due to geologic formation limitations, it is not always possible to develop an injection well to the point that the purge rate exceeds the planned injection rate.

1. Calculate the casing volume and estimated purge volume[1]. Final purge volumes will be performance-based and communicated to the project manager.
2. Remove sand and fines from the bottom of the well casing using a weighted 1.5-inch-diameter PVC or stainless-steel bailer with a ceramic-ball check valve. Carefully lower the bailer to the bottom of the well and gently raise and lower it to collect the fines. Withdraw the bailer from the well and pour out (rinse if necessary) the fines and purge water. Repeat until no more sediment is retrieved from the bottom of the well.
3. Surge the well screen interval with a surge block 10 to 15 times for each 5-ft length of screen. The surge block should be appropriately sized and fitted with a rubber gasket tight enough to the inside of the well screen to generate a pressure wave that loosens silt within the sand pack and screen slots. The surge block can be operated manually (by hand), or by specialized vehicles outfitted for well development.
4. Pump water from the well using a centrifugal pump capable of at least 290 gallons per minute (gpm) under zero head conditions[2]. The pump capacity should be scaled up as project conditions require. During the purge, the intake of the hose should be lowered incrementally throughout the screen section and, on occasion, quickly raised and lowered in a surging-like motion in order to maximize the mobilization and removal of fines. Periodically record the pumping rate and the turbidity of discharged water. Continue pumping water from the well until the turbidity is significantly reduced, stabilized, or until the well goes dry, whichever comes first.
5. Repeat steps 4 and 5 above until the well yields water during pumping with a turbidity of less than 50 NTUs. If NTU values stabilize above this 50 NTU goal, contact the project manager.

2.6 Drilling and Well construction/Development Documentation

A field geologist will maintain detailed records of drilling and well installation and development activities. These records will consist of soil boring and well installation and development logs, information recorded in field notebooks, and driller’s daily field reports. Field forms including examples of the field logs and development sheets are included in Appendix B.

2.6.1 Soil Boring Logs

A qualified geologist will log soil borings using the form provided in Appendix B or an equivalent form. Log entries will include the following:

- Boring location.
- Dates and times of drilling.
- Drilling equipment such as type of rig, size of bits, drill rod designations, and sampler types.
- Boring dimensions.

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[1] Based on results of the summer 2015 Algona pilot test, the estimated purge volume for this project could range from 200 to 550 gallons.

[2] A 3-inch diameter, 8-horsepower trash pump is adequate for this purpose, as was used during the summer 2015 Algona pilot test, in which purge rates ranged from 20 to 40 gpm.

- Stratigraphy – descriptions of soil will be according to the Unified Soil Classification System. Descriptors will include soil composition, density, color, approximate percentages of grain sizes present, and a qualitative estimate of moisture content. Deep wells may include identification of the OM deposit.
- Sample depths.
- Depth to groundwater.
- Additional sample features such as odor, the presence of volatile organic compounds (VOCs) (based on screening with a photoionization detector [PID]), non-native debris, and the presence of free product if present.

2.6.2 Well Construction Logs

A graphic log (example in Appendix B) showing well construction details will accompany each boring log. Construction logs will include the following:

- Well location and designation (Water Table, Shallow, Intermediate, Deep, or Multi-level)
- Date completed
- Boring dimensions
- Ecology Well Tag ID Number
- Well screen and riser pipe material descriptions and lengths
- Composition and depths of filter pack materials, bentonite well seal, and surface concrete
- A description of the surface monument and protective mechanisms.

2.6.3 Well Development Logs

Well development logs will contain the following information:

- Well location and designation
- Screened interval and casing diameter
- Date and time of development
- Weather conditions
- Static water levels measured before and after development
- Total depth of well before and after well development
- Volume of water in the well casing
- Descriptions of development equipment (pumps, surge blocks, hose/tubing diameter, etc.)
- Descriptions of water quality measurement equipment
- Equipment calibration data
- A record showing water volumes purged from the well, purge rates, water quality parameter measurements (turbidity), and presence of fines in the bottom of the well.

2.6.4 Field Screening Documentation

As described in the health and safety plan (HASP), the onsite geologist will use a PID to monitor the field staff breathing zone for volatile organic gases. If action levels exceed the levels listed in the HASP, drilling will be discontinued. Drilling will proceed only when volatile organic gas concentrations have returned to an acceptable level.

Headspace analysis, if required by the pertinent work plan, will be conducted on a sample from each soil core at each boring location. Headspace analysis is performed by collecting a small amount of soil in a clean Ziploc® bag, sealing the bag, breaking up the soil and letting it sit for 2 to 5 minutes, and then screening the headspace in the bag for VOCs using a PID. All field screening results will be entered in the comments section of the soil boring logs.

2.6.5 Daily Driller's Report

The driller will prepare and maintain a field drilling report on a daily basis. The drilling report will specify the amount of hours worked, material used, unusual problems, and other special comments and observations. The driller will provide a copy of the log for approval to the onsite geologist at the end of each day.

3.0 GROUNDWATER SAMPLING

LAI will conduct groundwater sampling described in the current site-wide groundwater monitoring plan. Samples will be collected from all new monitoring wells. The first round of samples will be collected no sooner than 5 days after development of the new conventional wells; the first round of samples will be collected no sooner than 14 days after development of new multi-level wells, where drilling water was added.

3.1 Well Depth and Static Water Level Measurement

Before sampling begins, the static water level of each well, or well channel (for multi-level wells), will be measured with a water level indicator. The static water level in multi-level well channels will be measured with a specialized water level indicator. The probe and attached tape for all water level indicators will be thoroughly rinsed with de-ionized (DI) water and wiped with a clean towel before use in each well or individual well channel. The water level indicator will be constructed of chemically inert materials to prevent damage of the equipment and cross-contamination between wells.

After the well cap is removed (but prior to removal or significant disturbance of down-hole sample tubing or passive sampling devices), the depth to water will be measured by slowly inserting the water level indicator probe into the well casing. As the probe enters the water, a buzzer and indicator light will be activated. The probe will be gently inserted into and retracted from the water surface so that the water surface can be determined accurately. The depth at which the water level buzzer and light activate represents the groundwater surface. The graduation mark on the water level tape adjacent to the reference mark on the rim of the PVC well casing represents the depth to water. After initially determining the depth to water, the probe will be re-inserted to re-check the measurement. This measurement will be recorded on the groundwater sampling form to a precision of 0.01 ft.

3.2 Passive Diffusion Bag Sampling

Conventional 2-inch, PVC groundwater monitoring wells can be sampled for VOCs using a passive diffusion bag (PDB). The PDBs typically arrive from the laboratory pre-filled with DI water. Once the PDB is submerged in groundwater within the well screen, molecules diffuse through the semi-permeable membrane of the PDB until equilibrium with the surrounding groundwater is reached. Water in the PDB reaches equilibrium with the surrounding groundwater within approximately 2 weeks, depending on flow conditions.

The depth to groundwater should be measured before removing the PDB from the well. The PDB should then be removed slowly from the well to avoid excessive disturbance of the water column in the well. Once the PDB is removed from the well, it is sampled by using a sharp plastic straw to puncture the PDB, and then pouring the water into the sample containers. Water that remains in the PDB after sample containers are filled is drained into a bucket, and, as a part of standard Boeing protocol, is disposed of in accordance with Boeing’s current groundwater waste profile. Unlike conventional sampling methods, the well is not purged, and field parameters are not collected. The empty PDB can be discarded as municipal solid waste, and a new PDB can be installed at this time if the well is scheduled to be sampled again within approximately 1 year.

3.3 Low-Flow Purging

Low-flow sampling minimizes disturbance to the aquifer during groundwater sample collection. The low pumping rate induces laminar flow in the immediate vicinity of the sampling pump intake; thus, drawing groundwater horizontally from the aquifer and into the sampling device.

Purging and sampling will be performed using a peristaltic pump with dedicated polyethylene or Teflon tubing. Conventional wells will have dedicated tubing that is stored in the well. Multi-level wells will have dedicated 1/4-inch tubing that may be stored in labeled Ziploc bags between sampling events. Tubing cannot be stored in some multi-level well channels because it would prohibit closing the well cap or inserting the water level indicator probe. To avoid cross contamination, when removing or inserting the dedicated tubing, it is important that the tubing does not touch the ground surface or other objects. The downhole end of the tubing will be cut at an angle to distinguish it from the sampling end.

The end of the sample tubing will be positioned at 2 to 3 ft above the bottom of the well or within the well screen for CMT wells. For wells screened across the water table, the end of the sample tubing will be positioned approximately 1 ft below the surface of the water table. Care will be taken to gently insert the tubing to minimize disturbance of any sediment that may have accumulated in the well. Purging will proceed by pumping groundwater from the well at a rate of approximately 0.5 liters per minute (L/min). The flow rate will be measured by filling a 1-liter (L) container and measuring the rate of filling using a stopwatch. Some wells may need to be pumped at slower rates to avoid drawdown of the water column within the well.

Specific conductance, temperature, dissolved oxygen (DO), oxygen reduction potential (ORP), pH, and turbidity will be measured during purging using field meters. In-field measurements will utilize a flow-through cell. The field meters will be calibrated each morning before sampling in accordance with the manufacturer’s instructions. All in-field measurements made during purging will be recorded on a groundwater sampling sheet at intervals of approximately 3 minutes. When readings have stabilized over three measurements, purging may cease and samples may be collected. Stabilization is reached when three successive readings are within ±0.2 standard units for pH, ± 1 degree Celsius (°C) for temperature, and ±10 percent for other parameters. If one or more of the readings have not stabilized within 30 minutes, samples will be collected and the unstable readings will be noted on the sampling form. Purge water will be contained in 5-gallon buckets dedicated to the site and transported back to the drum storage area.

3.4 Sample Collection and Analyses

Groundwater samples will be collected after water quality parameters have stabilized during low-flow purging. The pump will not be turned off for an extended period of time nor will the pumping rate be changed between the purging and sampling process. Samples that do not require filtering will be collected into the laboratory-provided sample container directly from the end of the sample tubing. Sample bottles for volatiles analyses will be filled with no headspace, while avoiding overfilling that would dilute the preservative.

Samples collected for dissolved metals analysis will be field-filtered. An in-line, 0.45-micron cartridge filter will be attached to the sample discharge line. Groundwater will be passed through the filter for approximately 1 minute prior to filling the sample bottle. The bottle will then be filled directly from the discharge outlet on the filter. The bottle will be filled to just below the neck to prevent overfilling and loss of the sample preservative.

Samples collected for total cyanide analysis will be field-filtered. An in-line 0.10-micron cartridge filter will be attached to the sample discharge line and bottles will be filled using the same procedure as described for metals above. Matrix interference will be field-tested prior to collection of samples (oxidizers using a potassium iodide test strip and sulfide using a lead acetate test strip). A dropper will be used to collect a small portion of sample and place a drop onto the test strip. Positive or negative indications on the test strip will be noted on the sample collection form. If the potassium iodide (oxidizer) test strips shows positive, a reducing agent (sodium arsenite, sodium thiosulfate, or ascorbic acid) will be added to a non-preserved sample bottle prior to sample collection.

All samples will be stored in coolers with ice and transported using proper COC procedures to Boeing's contracted laboratory. Additional information regarding proper COC procedures is included in Section 10.5 of this report.

4.0 SOIL SAMPLING

Occasionally, releases of hazardous materials or petroleum products may occur at the facility or historical releases may be encountered during construction. These releases often comprise oils, cutting fluid, or metals used in the machining process and are typically limited to shallow soil. Upon Boeing's request, LAI will be on site to oversee soil sampling and removal as necessary.

If soil excavation is required, field screening (headspace analysis, sheen testing, visual observation of color and staining, and/or observation of odor) will be used to guide the extent of excavation. Headspace analysis is performed by collecting a small amount of soil in a Ziploc bag, sealing the bag, breaking up the soil, and letting it sit for 2 to 5 minutes. The tubing from a PID is then inserted into the Ziploc bag, the bag is resealed around the tube, and the highest reading for each compound measured by the PID is recorded. Sheen testing is performed by agitating a small volume of soil in a stainless steel bowl with clean water to see if a sheen is generated.

Soil samples will be selected from the most impacted zone as indicated by field screening or from directly above the water table when drilling when there is no evidence of contamination. Samples will be collected from the excavation base and side walls or from soil in an excavator bucket using the jar and clean, stainless steel sampling spoons. Sampling spoons will be cleaned between samples using an Alconox® wash, tap water rinse, and final DI water rinse. All samples will be collected in laboratory-provided containers appropriate for the analyses.

Soil samples for volatile constituents will be collected using U.S. Environmental Protection Agency (EPA) Method 5035A procedures. The procedures involve using a small coring device or open-ended syringe to collect an undisturbed soil sample of a specified weight, which is then placed in a pre-preserved VOA vial. This method minimizes loss of VOCs to volatilization during the sampling process. The contracted analytical laboratory will provide specific sampling equipment and instructions on how to collect the samples (e.g., sample quantity to for each VOA vial). EPA Method 5035A will not be used to collect samples of disturbed soil (such as drill cuttings) for waste disposal characterization because the method is intended to be used for relatively undisturbed soil.

Soil samples for non-volatile constituents including, but not limited to, metals, diesel-range petroleum hydrocarbons, polychlorinated biphenyls (PCBs), and semi-volatile organic compounds will be collected in laboratory provided jars of an appropriate size for the number of analyses being conducted. Care will be taken to collect an appropriately representative sample. Larger samples may be mixed in stainless steel bowls to homogenize the sample before collecting into sample jars. Sampling spoons and bowls will be cleaned between samples using an Alconox wash, tap water rinse, and final DI water rinse. Soil analyses will depend on the nature of the release.

All samples will be stored in coolers with ice and transported using proper COC procedures to Boeing's contracted analytical laboratory.

5.0 AIR SAMPLING

Air sampling procedures presented in this section are applicable to aboveground samples collected from, indoor air, crawlspaces, ambient air, and other indoor and outdoor locations where air sampling is desired. Current applicable air sampling guidance for Washington State[3] will be used to supplement these procedures and for determining procedures, such as the sample duration, locations, and procedures specific to the particular building being sampled. Air samples may be collected in various methods and sample containers such as Summa canisters, passive diffusive samplers, Tedlar® bags, and sorbent tubes. The two most commonly used methods of sample collection at this site (Summa canister and passive diffusive sampling) are discussed in the following sections.

For all air sampling methods, atmospheric conditions during the sampling period will be collected. Conditions including temperature, barometric pressure, wind direction, wind speed, and precipitation totals, will be recorded using a combination of publicly available meteorological data from the nearest weather station, and information collected from the specific buildings (if applicable) regarding average indoor temperatures.

5.1 Summa Canister Sampling

Summa canisters are evacuated stainless steel canisters that use vacuum pressure and a flow controller to collect air over a specified time or at a specified rate. The canisters are reused, cleaned, and certified by the laboratory after each sampling event. Summa canisters can be used to collect many types of air samples including indoor air samples and ambient air samples.

The procedure for indoor air also applies to crawl space and basement air sampling. Indoor air sample locations will be 8-hour, 10-hour, or 24-hour (dependent on exposure scenario) time-weighted average (TWA) samples. The TWA samples will be collected using 1-L or 6-L laboratory-certified evacuated Summa canister depending on the desired reporting limits. Each laboratory is certified for different reporting limits depending on the analytical method, the size of the canister, and the residual vacuum in the canister after sampling. Required certification (batch or individual) of each canister is also dependent on the analytical method. Always communicate the desired reporting limits for each constituent and discuss appropriate analytical methods, sample containers, and certification with the laboratory prior to placing a canister order. Each Summa canister will be equipped with a pressure gauge that indicates the vacuum pressure inside the canister and a flow controller that regulates the air collection rate. Duplicate samples require a co-locator attachment from the laboratory. Canisters will be clearly labeled with signs indicating the purpose of the canisters and that the canisters are not to be interfered with or moved.

Indoor air canister intakes will be set-up in accordance with the typical activities and breathing height of the receptors in the area being sampled. For example, in a home, the canister may be placed at the

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[3] Guidance in effect at the time this report was prepared was draft guidance from Ecology (Ecology 2009).

level of a sitting receptor if the area is primarily used as a sitting room or at the height of the bed in a bedroom.

Ambient air samples will be set-up outside the building either at the air intake for a heating, ventilation, and air conditioning system (if the system only takes air in) or upwind of the building as high as reasonably possible to represent air quality at heights representative of building intake locations. If ambient air samples are placed upwind of the building of interest, the final location will be selected at time of sampling and the canister inlet valve will be placed at a height greater than or equal to 5 ft aboveground.

The TWA Summa canisters will be evacuated to a vacuum pressure of 25 to 30 inches of mercury (in.Hg.) by the laboratory. Record the initial pressure on the vacuum gauge before opening. A final vacuum pressure reading greater than ambient (i.e., 0 in.Hg.) indicates a valid sample; however, canister closure will be targeted for a vacuum pressure of 5 in.Hg. to provide a margin of safety. Canister pressures will be checked within 1 to 2 hours after beginning sampling to evaluate whether airflow controllers are functioning properly. Any canisters observed to have a faulty flow controller will be replaced with a backup canister and flow controller.

Summa canisters will be shipped using the original shipping packaging under COC procedures to Boeing's contracted air laboratory; air COCs include initial and residual vacuum pressures, Summa canisters and flow controller IDs, analytical methods, and other applicable information.

5.2 Passive Diffusive Sampling

Passive diffusive samplers provide a TWA sample over a longer time period such as 21 days. The most common sampler type for trichloroethene is the Radiello® sampler; specifically model 130 (R130). A Radiello sampler consists of a diffusive protective body made of porous polypropylene in which a cartridge of adsorbent media is inserted. Due to the narrow and cylindrical (radial) design of the adsorbent cartridge, the uptake rate is at least three times that of axial diffusive sampling designs. The type of adsorbent is selected based on analytic needs.

Sample collection will use the following protocol:

- Immediately prior to placement at the planned sample location, the adsorbing cartridge will be removed from its protective packaging and placed in the previously assembled Radiello supporting plate/diffusive body. The identification label associated with each adsorbing cartridge will be attached to the supporting plate and the ID information will be recorded on the sample collection form. During assembly, nitrile gloves will be worn to minimize any potential contamination of the adsorbing cartridge.
- After the sample period is complete, samplers will be retrieved from the sample locations. At the time of removal, the adsorbing cartridges will be placed back in the original protective tube and the adsorbing tube ID label will be placed on the protective tube; such that the barcode is parallel to the axis of the tube.

The sample stop date and time, to the nearest minute, will be recorded on the sample collection form. Samples will be kept cool, but do not need to be chilled on ice. Completed sample containers will be shipped under COC procedures to Boeing’s contracted air laboratory.

6.0 SOIL GAS SAMPLING

Soil gas samples may be collected from borings outside of a building footprint or directly below building slabs (i.e., sub-slab). These sampling methods are described below.

6.1 Soil Gas Sampling from Borings

Soil gas sampling can be conducted from shallow borings at discrete depths. Borings can be advanced using a mechanized drill rig (DP probe or other) or hand tools. Mechanized drill rigs may use special tooling for collection of soil gas from temporary monitoring points. If a permanent monitoring point is desired, the vapor implant setup should be used and set in an appropriate protective monument for the location.

The sampling procedures below indicate a helium leak test and shut-in test should be conducted prior to sampling. There may be instances when either of these is not possible or practical. Both are recommended, but optional. If a situation arises where a shut-in test is not practical, this indicates that the aboveground portion of the sample train has not been checked for leaks and a helium shroud must be placed over the entire sample train during sample collection. If a shut-in test is conducted prior to sampling, the helium shroud does not need to cover the portions of the sample train subject to the shut-in test. Regardless of whether a helium leak test and shut-in test are conducted prior to sampling, a helium shroud will be placed over the surface completion of the sampling point and laboratory samples will be analyzed for helium to evaluate the integrity of the surface completion. Although a helium leak test is recommended in order to identify potential leaks prior to sample collection, no changes to the sampling procedure are required if a helium leak test is not conducted because a helium shroud will be employed during sampling and helium will be analyzed in the laboratory samples.

6.1.1 Direct Push Post-Run Tubing Setup

If using a DP drill probe to conduct soil gas sampling, specialized tooling called post-run tubing (PRT) can be used for soil gas sample collections. The PRT setup comprises probe rods, an expendable drive point and point holder, PRT tubing adapter (connects sample tubing to holder), and either Teflon or Nylaflow® sample tubing. After the probe rod (with expendable drive point and point holder) has been driven to depth, the PRT tubing adapter is attached to the sample tubing and is fed into the probe rod. Once the bottom of the PRT tubing adapter reaches the bottom, it is connected to the point holder, which seals off the sample tubing from the air in the annulus of the probe rods. At the ground surface, the sample tubing can then be directly connected to the purge and sampling devices. The PRT tooling setup does not allow for a soil characterization sample to be collected; however, some soil cuttings may be generated. If the soil cuttings do not allow for adequate soil characterization, a second borehole may be driven adjacent to the soil gas sample boring to allow for additional soil characterization and evaluation of the depth of the groundwater table if needed. The detailed sampling procedures are listed below:

- The probe rod fitted with an expendable drive point and point holder will be driven to the targeted depth above the measured groundwater elevation.
- Dedicated soil gas sampling tubing and a PRT tubing adapter will be inserted into the drilling rod and connected to the expendable drive point holder.
- The rod will be pulled back 1 ft, leaving the expendable point at the bottom of the borehole. This will leave approximately 1 ft of borehole exposed from which the soil gas sample will be collected.
- A surface seal of hydrated bentonite or clay will be placed around the drill rod at the surface and leak checked to prevent intrusion of atmospheric air. Once the seal is constructed, a closed ball valve will be placed on the end of the sample tubing to allow the soil vapor to equilibrate without exposure to ambient air.

Once the seal is constructed, the sample location should be left undisturbed for a minimum of 30 minutes to allow for the soil vapor to equilibrate. A helium leak test, shut-in test, and purge should be conducted prior to sample collection. Appendix C presents detailed procedures for the helium leak test, shut-in test, purge, and sample collection.

Sample containers will be shipped using the original shipping packaging under COC procedures to Boeing's contracted air analysis laboratory of other appropriate air laboratory[4].

6.1.2 Vapor Implant Setup

The vapor implant setup can be used with any of method of borehole construction (mechanical or hand tool) and may be used either for soil gas or sub-slab sampling; instructions provided here are primarily for use as a soil gas sampling point. The vapor implant setup comprises a porous vapor implant, sand, dry granular bentonite, hydrated bentonite or cement, and either Teflon or Nylaflow sample tubing. After the borehole has been completed to the desired depth, any excess soil is removed and approximately 2 inches of sand is installed in the bottom of the hole. The vapor implant is attached to a length of sample tubing and installed at the bottom of the hole. Additional sand is used to create a filter pack around the implant, extending approximately 2 inches above the top of the vapor implant screen if space allows. A layer of dry granular bentonite is installed above the filter pack; ideally, this layer should be at least 2 inches thick if using hydrated grout to seal the remainder of the borehole. Hydrated bentonite grout or other annular seal material is placed above the top of the dry granular bentonite to the surface. At the ground surface, the sample tubing can then be directly connected to the purge and sampling devices with minimal potential for leakage and reduction of the dead volume that must be purged prior to sampling. The detailed vapor implant construction procedure is as follows:

- The borehole will be completed to the targeted depth above the measured groundwater elevation and the soil core removed.

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[4] H&P Mobile Geochemistry in Carlsbad, California was used during 2015 soil gas sampling.

- Two inches of sand will be installed at the bottom of the boring (less may be used if constructing the implant for a sub-slab vapor point). A dedicated vapor implant and sampling tubing (Teflon or Nylaflow) will be inserted into the boring.
- Sand will be installed around the vapor implant to approximately 2 inches above the top of the vapor implant. Two inches of dry granular bentonite will be installed above the filter pack. Hydrated bentonite grout will be installed to the surface.
- Once the seal is constructed, a closed ball valve will be placed on the end of the sample tubing to allow the soil vapor to equilibrate without exposure to ambient air.

Once the seal is constructed, the sample location should be left undisturbed for a minimum of 30 minutes to allow for equilibration. Following this equilibration period, a helium leak test, shut-in test, and purge should occur prior to sample collection. Appendix C presents the detailed procedures for the helium leak test, shut-in test, purge, and sample collection. Boreholes will be abandoned and sealed appropriately at the surface.

Summa canisters will be shipped using the original shipping packaging under COC procedures to Boeing's contracted air laboratory; air COCs include initial and residual vacuum pressures, Summa canisters, flow controller IDs, analytical methods, and other applicable information.

6.2 Sub-Slab Sampling

Sub-slab soil vapor sampling is accomplished by drilling a hole through the slab, inserting a sample collection device, and sealing the hole around the sample collection device so that ambient air cannot enter the subsurface. Sample points may be constructed two ways, either by inserting a Cox-Colvin Vapor Pin™ (Vapor Pin) of approximately 3 inches in length into each core or by placing a vapor implant and sealing the hole with hydrated bentonite. The sections below describe the installation process for both the Vapor Pin and the vapor implant.

Once the seal is constructed, the sample location should be left undisturbed for a minimum of 30 minutes to 2 hours for equilibration depending on the construction of the vapor point. Following this equilibration period, a helium leak test, shut-in test, and purge should occur prior to sample collection. The detailed procedure for the helium leak test, shut-in test, purge, and sample collection is presented in Appendix C. Sample points will either be decommissioned and sealed appropriately at the surface or installed using an inset method (using concrete as a surface seal), which allows for secure, unobtrusive covering and repeat sampling.

Summa canisters will be shipped using the original shipping packaging under COC procedures to Boeing's contracted air laboratory; air COCs include initial and residual vacuum pressures, Summa canisters, flow controller IDs, analytical methods, and other applicable information.

6.2.1 Cox-Colvin Vapor Pin Setup

Vapor Pins are comprised of a barbed, stainless-steel sample point fitted with an inert, compressible, silicon sleeve. Each Vapor Pin will be installed using a hammer and specialized installation tool to drive the Vapor Pin into a 5/8-inch-diameter vertical core within the slab. Driving the Vapor Pin into the core compresses the sleeve, creating a seal between the sample point and slab surface. Typically, slabs are thicker than 3 inches, so the bottom of the Vapor Pin will rest within the slab core, above underlying soil. After the Vapor Pin is installed, the end with a hose barb is exposed at the ground surface. A fitted cap will be attached to the barb to allow the sub-slab soil vapor to equilibrate without exposure to ambient air.

6.2.2 Vapor Implant Setup

Vapor implants are typically installed in a 1-inch-diameter vertical core within the slab; larger cores may be used, but are not anticipated for this sampling event. Vapor implants comprise a porous sampling tip and sample tubing placed in the core. Teflon or Nylaflow tubing may be used as sample tubing. The porous sampling tip should extend 1 to 2 inches below the slab. The void space around the sampling tip will be backfilled with drilling grade silica sand up to the bottom of the slab.

Granular bentonite will be used to seal the annular space between the sample tubing and the slab within the core. Two to three inches of dry bentonite will be placed on top of the silica sand. Additional hydrated bentonite grout will be added in 1- to 2-inch lifts until the bentonite is within ½ inch from the top of the slab.

6.2.3 Permanent Sub-Slab Soil Gas Surface Completion

Vapor implants may be installed using the inset method to allow for secure covering between repeat sampling events. Installation of the permanent sub-slab soil gas monitoring points will use the vapor pin or vapor implant setup with an alternate surface completion. Before coring the 1-inch-diameter core to depth, a 1.5-inch diameter core will be completed to a maximum depth of 2 inches below grade. Next, the 1-inch diameter core will be completed through the center of the 1.5-inch-diamter core to depth. If using a vapor implant, approximately 2 inches of hydraulic cement will be placed around the tubing at the top of the core hole, flush, but not over-topping the bottom of the 1.5-inch-diamter core. A stainless-steel insert with exterior threads will be placed around the tubing, approximately half imbedded in the cement. Ensure that the stainless-steel cover will securely screw onto the threads and sit flush with the floor surface. Install a barbed luer connector with a cap or a silicone cap on the end of the tubing to prevent vapor migration between the indoor air and the subsurface. Once the tubing end is capped, install and secure the stainless-steel cover, ensuring that it is flush with the existing concrete slab grade. Samples will be collected from the permanent sub-slab soil gas sampling points using the procedure described in Appendix C including a shut-in test, helium leak test, and purge before collecting the sample for each sampling event.

7.0 SURFACE WATER SAMPLING

Surface water sampling will occur only after a period of no measureable precipitation over a 48-hour period. These criteria will minimize stormwater runoff contribution at sampling locations. If prolonged rainfall occurs during the sampling window, it may not be practical to wait 48 hours prior to sampling. If this is the case, Ecology will be consulted about sample time and sampling may occur within 48 hours of a rainfall event with permission from Ecology.

Sampling may be conducted using a composite liquid waste sampler (COLIWASA), dedicated tubing with a peristaltic pump, or dipper. The sample collection method will depend on water depth, accessibility, and availability of an electrical source. Samples will be collected no more than 4 inches above the bottom of the water column and at least 2 inches below the water surface, if possible. If less than 4 inches of water is present, the sample will be collected from the approximate mid-point of the water column. The approximate water column thickness will be recorded on the sample collection form for each sample. If adequate water is available, field parameters will be measured at the time of sampling and recorded on the surface water sample collection form (Appendix B). A multi-parameter probe (YSI 556 MPS) will be used to monitor the following field parameters: pH, temperature, and conductivity. Field parameters will be measured by submerging the instrument probe directly into the surface water or by pumping water through a flow through cell if using the peristaltic pump.

The COLIWASA is a rigid, hollow tube (i.e., bailer) with a stopper on one end and an open/close mechanism on the other. The COLIWASA is known as a depth discrete sampling method (EPA 2013, Byrnes 2009). A description of the COLIWASA sampler is presented in ASTM International (ASTM) Standard D5495. The COLIWASA is constructed of polypropylene, which will not react with VOCs. Additionally, each sampler is dedicated and will be disposed of after one use. Sampling procedures for the COLIWASA are as follows:

- With the stopper closed, lower the stopper end to the desired sampling depth; the stopper is then released and water from the desired depth fills the tube
- The stopper is then closed and the sampler is removed from the water
- An appropriate sample volume is collected from the COLIWASA and placed in the designated sample container
- The sampling process will be repeated until all sample bottles are filled for a particular location
- Once the sample is collected, any remaining water in the sampler will be discarded.

Where the water column thickness is less than about 4 inches, a stainless steel ladle will be used to collect the water quality sample. The ladle is known as a dipper sampling method (EPA 2013, Byrnes 2009). Sampling procedures for the ladle are as follows:

- The ladle will be dipped into surface water being careful not to stir up sediment.
- The ladle will then be decanted into the sampling container. This process will be repeated until all sample bottles are full.
- The ladle will be decontaminated (Section 9.5) and then reused at the next sample location.

Where sampling access is limited or water depth prevents use of the COLIWASA or dipper methods, a peristaltic pump and dedicated tubing will be used to collect the surface water sample. Sampling procedures for the pump and tubing are as follows:

- Dedicated sample tubing will be attached to a rigid pole to allow control of the sampling location and depth. The tubing intake will be placed 4 inches above the bottom of the water column.
- At the time of sampling, a field meter will be used to monitor field parameters using a flow-through cell.
- Field parameters will be allowed to stabilize. Once stabilized, replicate readings will be recorded on the sample collection form.
- Sample containers will be filled directly from the sample tubing.

All samples will be placed in laboratory-provided sampling containers. All samples will be stored in coolers with ice and transported using proper COC procedures to Boeing’s contracted laboratory.

8.0 SEDIMENT PORE WATER SAMPLING

Sediment pore water sampling can either be completed using one-time sampling location sediment diffusion sampling canisters or semi-permanent piezometers. The procedures for each of these sampling techniques is described below.

8.1 One-Time Sampling

A sediment pore water sample can be collected from a surface water body using an EON Sediment Diffusion Sampler canister (canister) placed directly into the sediment below the water column. The canister is approximately 20-inches long, 2 inches in diameter, and constructed of slotted PVC well casing with a riveted pointed tip and screw-top lid. A pre-filled PDB is inserted into the canister, and the entire assembly is placed directly into the sediment. The filled canister will be placed so the canister will remain fully submerged during the sampling.

After the PDB has equilibrated for a sufficient period (minimum 2 weeks) using the canister method, the canister is removed from the sediment and the PDB is extracted from the canister. A sample is collected in accordance with the PDB sampling procedures (Section 3.2).

8.2 Continued Sampling

Samples can be collected by advancing a standard PVC well casing and screen directly into the sediments below the water column. The PVC casings will be advanced using hand tools. Samples can be collected from the piezometers using low-flow sampling techniques or PDB sampling techniques. If low-flow sampling techniques are used, procedures will be in accordance with those described in Section 3.3. If using a PDB, the PDB is lowered using a weighted cord to the bottom of the screened interval. Once the PDB has equilibrated for a sufficient time period (minimum 2 weeks), the PDB is pulled out of the well casing using the attached cord. A sample is collected in accordance with the PDB sampling procedures (Section 3.2).

9.0 SUPPORT ACTIVITIES

This section describes various support and preparation activities related to well installation and groundwater sampling. Support activities for other types of environmental fieldwork will be described in work plans.

9.1 Utility Locates

No more than 2 weeks before any drilling or coring program begins, utility locates will be conducted. Each location will be marked in the field with white paint or a stake with flagging. A One-Call Utility Locate form will be filled out for each location (Appendix B) and the One-Call Utility Locate Service[5]. For locations within the facility or for other access-restricted areas, a meet time will be requested. The on-site Boeing representative will need to be present to escort the public utility locator on site. All utilities listed by the One-Call service will be contacted if specific markings are not visible within the requested locate radius around each boring. An additional private utility locator will be hired to clear each location.

9.2 Permits and Access Agreements

Right-of-way permits and property access agreements will need to be acquired from the appropriate municipalities and property owners before the drilling program can begin. Boeing and LAI will work collaboratively to facilitate such agreements.

9.3 Traffic Control

Traffic control procedures will be used at all locations where drilling activities will impact a roadway or walking path. Traffic control plans will be prepared, as needed.

9.4 Well Surveying

A licensed land surveying subcontractor will survey the horizontal and vertical coordinates of monitoring well locations. The vertical coordinates will be measured at the lip of the PVC well casing at the notched point that will be used for future groundwater measurements. Horizontal coordinates (x, y) will be measured to the nearest 0.1 ft and vertical (z) elevations will be measured to the nearest 0.01 ft. Horizontal coordinates will be measured in Washington State Plane south zone coordinates referencing the North American Datum 1983 (NAD83). Vertical elevations will be measured in National Geodetic Datum of 1929 (NGVD 29). Geographic coordinates of borings will be collected in the field using a handheld global positioning system unit. The accuracy of the global positioning unit is typically better than +/- 1 ft.

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[5] Contact information for One-Call Utility Locate Service is the website: www.callbeforeyoudig.org/washington/ or call 1-800-424-5555.

9.5 Decontamination Procedures

Non-dedicated sampling equipment will be decontaminated between sample locations. Sampling equipment includes all devices that used to collect or contain a sample prior to placement into a laboratory-provided sample container, or used downhole in a well (e.g., water level indicator and depth sounding tape). Before initial use, sampling equipment that may contribute to the contamination of a sample must be thoroughly decontaminated, unless specific documentation exists to show that the sampling equipment has already been decontaminated. Pre-cleaned equipment and sample jars in factory-sealed containers do not require decontamination.

Decontamination will be performed according to the following procedure:

- Scrub equipment thoroughly with phosphate-free detergent (Alconox) and potable water using a brush to remove any particulate matter or surface film
- Rinse with potable water
- Final rinse with DI water
- Keep decontaminated equipment in a clean location to prevent recontamination.

10.0 SAMPLE HANDLING AND DOCUMENTATION

This section describes sample handling and documentation procedures. The procedures described are designed to provide a thorough record of events surrounding the collection of each sample and ensure that data collected in the field are usable.

10.1 Sample Labeling

Gummed paper labels which adhere strongly to glass or plastic will be used. Labels will be prepared with waterproof indelible ink and will include the following information:

- Project number
- Sample ID number
- Date and time of sampling
- Name(s) of sampling personnel
- Analysis and type of preservatives added.

To ensure a consistent sample tracking mechanism, each sample collected will be given a unique sample ID number using a consecutive numbering system or an alphanumeric system. The consecutive numbering system consists of five primary types: groundwater monitoring wells, surface water samples, borings, air samples, and test pits. The sample ID numbers derived from the consecutive numbering system will share the following general structure. In general, the sample ID number will include the Boeing Auburn site code (A), a location type (either GW for groundwater monitoring well, SB for soil boring, TP for test pit, SW for surface water), a consecutive number provided by Boeing, and a date or a depth (borings). For multi-level well water samples, the date will be preceded by the multilevel well channel and channel depth. For borehole water samples, the date will be preceded by the sample depth. Additional details and examples are provided in the following sections.

Field duplicate samples will share the following general structure. Field duplicate samples will be given fictitious sample ID numbers beginning with a 9 (900 series numbers for monitoring wells and surface water and 9000 series numbers for borings and test pits). No indication that the sample is a duplicate will be provided on the sample label or the COC form. A cross-reference of sample ID numbers for duplicates will be clearly recorded on the water sampling form or borehole log.

The following sections below describe the creation of the sample ID number, which will be used for samples collected throughout the project.

10.1.1 Groundwater - Conventional Wells

The sample ID for conventional wells will be created as follows:

- Site code for Boeing Auburn Plant (A)
- Location type: Groundwater monitoring well (GW)
- Well number (a three-digit consecutive number, assigned by Boeing)
- Date of sample collection by year, month, and day (20110603).

Thus, a groundwater sample collected from the Boeing Auburn Plant at groundwater monitoring well 125 on June 3, 2011, would be assigned the following sample ID number:

AGW125-20110603

A	GW	125	20110603
Boeing Auburn Plant	Location type (groundwater monitoring well)	Well number	Date: yyyymmdd

Additional example sample ID numbers for the Boeing Auburn Plant are as follows:

- AGW055R-20110918 represents a water sample collected from monitoring well 055R on September 18, 2011
- AGW900-20110918 represents a field duplicate collected at the same time as the above monitoring well sample.

10.1.2 Groundwater - Multi-level Wells

The sample ID for multilevel wells will be created as follows:

- Site code for Boeing Auburn Plant (A)
- Location type: Groundwater monitoring well (GW)
- Well number (a three-digit consecutive number, assigned by Boeing)
- Channel number (1-7)
- Screen depth (ft bgs)
- Date of sample collection by year, month, and day (20110603).

Thus, a sample collected from the Boeing Auburn Plant at multi-level groundwater monitoring well 201, from channel 2, from a depth of 30 ft, on June 3, 2011, would be assigned the following sample ID number:

AGW201-1-30-20110603

A	GW	201	2	30	20110603
Boeing Auburn Plant	Location type (groundwater monitoring well)	Well number	Channel number	Depth of screen (ft bgs)	Date: yyyymmdd

10.1.3 Groundwater – Injection Wells

The sample ID for injection wells will be created as follows:

- Location type: Injection well (IW)
- Well number (a two-digit consecutive number, assigned by Boeing)
- Date of sample collection by year, month, and day (20150603).

Thus, a groundwater sample collected from the Boeing Auburn Plant at injection well 37 on June 3, 2015, would be assigned the following sample ID number:

IW37-20150603

IW	37	20150603
Location type (injection well)	Well number	Date: yyyymmdd

10.1.4 Groundwater – Well Borehole Sample

Collect borehole groundwater samples from a boring during construction of a monitoring well. Borehole samples will have the bottom depth of the screen added between the well number and the date. For example, AGW183-30-20110505 is a borehole sample collected from the boring during construction of well 183. The sample ID indicates bottom of the screen at 30 ft bgs and sample collection on May 5, 2011.

10.1.5 Soil/Solid – Well Borehole Sample

This section describes the creation of the sample ID number used for soil samples collected during the installation of a monitoring well. The sample matrix could be asphalt, concrete, soil or other solid material, and will not be included in the sample ID number. The sample ID number will be created as follows:

- Site code for Boeing Auburn Plant (A)
- Location type: Groundwater monitoring well (GW)
- Well number (a three-digit consecutive number, assigned by Boeing)
- Sample collection depth in ft bgs.

Thus, a sample collected from the Boeing Auburn Plant during construction of groundwater monitoring well 183 at a depth of 6 ft bgs on August 5, 2011, would be assigned the following sample ID number:

AGW183-6

A	GW	183	6
Boeing Auburn Plant	Location type (groundwater monitoring well)	Well number	Depth (ft bgs)

Additional example sample ID numbers for the Boeing Auburn Plant are as follows:

- AGW081-5 represents a soil sample collected during construction of monitoring well 081 at a depth of 5 ft bgs
- AGW900-5 represents a field duplicate collected at the same time as the sample listed above
- AGW081-0.5 represents a sample of concrete from the surface to 0.5 ft bgs.

10.1.6 Surface Water and Pore Water Samples

The sample ID for surface water samples will be created as follows:

- Location type: Surface Water (SW), Pore Water (PW)
- Water Type (if necessary), for example, RD for roadside ditch; YP for yard pond
- Location number (for pore water samples this number would be the same as the co-located surface water sample)
- Depth (if a paired depth pore water sample)
- Date of sample collection by year, month, and day (20110603).

Thus, a surface water sample collected from the Boeing Auburn Plant at surface water location 19 on June 3, 2011, would be assigned the following sample ID number:

SW-19-20110603

SW	19	20110603
Location type (surface water)	Location number	Date: yyyymmdd

Additional example sample ID numbers for the Boeing Auburn Plant are as follows:

- SW-15-20110918 represents a surface water sample collected from location 15 on September 18, 2011
- PW-15-20110918 represents a pore water sample collected from co-located surface water sample location 15 on September 18, 2011
- PW-28-5-20172004 represents a permanent pore water sample collected from the screen located at 5 ft bgs, collected from co-located surface water sample location on April 20, 2017.
- SWRD-12-20130501 indicates a roadside ditch surface water sample collected in the project area from location SWRD-12 on May 1, 2013
- SW900-20110918 represents a field duplicate collected at the same time as the above surface water sample.

10.1.7 Borings

This section describes the creation of the sample ID number used for samples collected from a boring not completed as a monitoring well. Borings also do not include samples, which are hand augured. The sample matrix will not be included in the sample ID number, but will be recorded in the field logbook. Groundwater samples will include the date to distinguish them from soil/solids samples. The sample ID will be created as follows:

- Site code for Boeing Auburn Plant (A)
- Location type: Boring (SB)
- The boring number will be a four digit consecutive number, assigned by Boeing
- Sample collection depth in ft bgs.
- For water samples, the date of sample collection by year, month, and day (20110603).

Thus, a soil sample collected from the Boeing Auburn Plant at boring number 0827 at a depth of 12 ft bgs would be assigned the following sample ID number:

ASB0827-12

A	SB	0827	12
Boeing Auburn Plant	Location type (boring)	Boring number	Depth (ft bgs)

Additional example sample ID numbers for the Boeing Auburn Plant are as follows:

- ASB0273-0.2 represents a sample (e.g., concrete, asphalt, soil, etc.) collected from boring 0273, from a depth of 0.2 ft bgs
- ASB0273-15 represents a sample (e.g., concrete, asphalt, soil, etc.) collected from boring 0273, from a depth of 15 ft bgs
- ASB9000 represents a field duplicate collected at the same time as the sample listed above
- ASB9273-30-20110505 is a borehole groundwater sample collected with the bottom of the temporary screen at 30 ft bgs and sample collection on May 5, 2011.

10.1.8 Air Samples

This section describes the creation of the sample ID number which will be used for soil gas (collected outside of a building footprint), sub-slab soil vapor, indoor air (inclusive of crawl space/basement air), and ambient air samples. Sample identification will be as follows:

- Location type: soil gas (SG), sub-slab soil vapor (SSV), indoor air (IA), or ambient air (AA)
- The sample number will be a three digit consecutive number
- R for Radiello, if applicable
- Date of sample collection by year, month, and day (20110603).

Thus, a sub-slab soil vapor sample collected at sample location 003 June 3, 2011, would be assigned the following sample ID number:

SSV003-20110603

SSV	003	20110603
Location type (sub-slab soil vapor)	Sample number	Date: yyyymmdd

Additional example sample ID numbers are as follows:

- IA045-20120123 would represent an indoor air sample collected on January 23, 2012
- AA046-20120123 would represent an ambient air sample collected on the same day as the above sample
- IA046-R-20120123 would represent an indoor air sample collected using a Radiello sampler on the same day as the above sample.

10.1.9 Test Pits

This section describes the creation of the sample ID number used for test pits. Sample identification will be as follows:

- Location information
- Location type: Test pit (TP)
- Test pit number
- Date of sample collection by year, month, and day (20110603).

Thus, a test pit sample collected from the Boeing Auburn Plant Waste Water Plant number 4 collected on January 14, 2010 would be assigned the following sample ID number:

WWPTP-4-20100114

WWP	TP	4	20100114
Location information (wastewater plant)	Location type (test pit)	Test pit number	Date: yyyymmdd

Additional example sample ID numbers are as follows:

- WWPTP-1-20100114 would represent a test pit sample collected at the Waste Water Plant from test pit 1 on January 14, 2010
- WWPTP-2-20100115 would represent a test pit sample collected at the Waste Water Plant from test pit 2 on January 15, 2010.

10.1.10 Other Samples

This section describes the creation of the sample ID number, which will be used for samples not associated with borings, monitoring wells, test pits, or air sample locations (such as composites, drums, and stockpiles). The sample ID number will be determined in the field for specific quick response events. All samples not falling under the criteria listed above (groundwater monitoring wells, borings, test pits, or air sample) will begin with “AGR”, followed by a building or solid waste management unit (SWMU) number, if applicable. The sample ID number will be created as follows:

- Site code for Boeing Auburn Plant (A)
- Location type other (GR)
- Building number with the 17 removed or SWMU number, if applicable
- Other descriptive information, if applicable
- Sample collection depth in ft bgs, if applicable.

Thus, a sample collected from the Boeing Auburn Plant at Building 17-07, from location B at a stockpile 1, from a depth of 3 ft bgs would be assigned the following sample ID number:

AGR07-SP-B-3

A	GR	07	SP01	B	3
Boeing Auburn Plant	Location type (all other samples)	Building no.	Stockpile	Location B at the stockpile	Depth (ft bgs)

Additional example sample ID numbers for the Boeing Auburn Plant are as follows:

- AGR34-SP01-A-0.5 represents a composite soil sample collected from location A, at stockpile 1 near Building 17-34, at a depth of 0.5 ft bgs
- AGR34-SP99-A-0.5 represents a field duplicate collected at the same time as the above sample.

The designated "SP" is for stockpile in this example. Other designations or words may be used as appropriate, for example, AGR34-DrumA or AGR34-PaintA.

When composite samples are collected, the Consultant Field Team Leader will ensure that the locations of sub-samples composited to form the project sample are clearly identified in the project field notebook.

10.2 Field Logbooks

Permanently bound field logbooks with waterproof paper will be used in the field because of their compact size, durability, and secure page binding. The pages of the logbook will be numbered consecutively and will not be removed for any reason. Entries will be made in waterproof indelible ink.

Logbooks will document the procedures performed by field personnel. Each entry will be dated, legible, and contain accurate and complete documentation of the individual's activities. Documentation in the field logbook will be at a level of detail sufficient to explain and reconstruct field activities without relying on recollection by the field team members. Because the logbook is a complete documentation of field procedures, it will contain only facts and observations. Language will be objective, clear, concise, and free of personal interpretation or terminology that might be misconstrued.

No erasures are allowed. If an incorrect entry is made, the information will be crossed out with a single strike mark and the change initialed and dated by the team member making the change.

Both electronic and paper copies of the field logbooks will be made and stored with the project files.

10.3 Sample Preservation and Handling

This section describes the preservation, handling, and storage requirements of sample containers.

10.3.1 Sample Containers

Water and soil samples [primary as well as quality assurance/quality control (QA/QC)] will be collected in glass or plastic containers supplied by the contract analytical laboratories. The containers will have screw-type lids to ensure the bottles are adequately sealed. Teflon inserts located inside the lids of the containers will prevent sample reaction with the lid and improve the quality of the seal. The sample containers will be pre-cleaned and certified under COC procedures. Commercially available, pre-cleaned containers are acceptable. The contract laboratories' sample container shipment documentation will record batch numbers for the containers. With this documentation, containers can be traced and wash analyses can be reviewed. The sample container wash analysis certificates will be retained in the project file.

Soil vapor and air samples may be collected in Summa canisters[6]. Canisters will be certified clean for the corresponding analysis and reporting limits.

10.3.2 Sample Preservation

Before shipping sample bottles to the field, LLI will add the required preservatives to the sample bottles that will be used for groundwater. LLI will provide or affix waterproof labels to the bottles, on which the type of analysis and the type and amount of preservative will be written.

Sample preservation procedures are used to maintain the original character of analytes during storage and shipment. Regardless of the nature of the sample, absolute stability for all constituents cannot be achieved. Preservation techniques, such as pH control and refrigeration, may retard physiochemical and biochemical changes. Generally, analyzing the sample as soon as possible is the best way to minimize physicochemical and biochemical changes.

Samples will be placed in the appropriate laboratory-supplied sample container and chilled (on ice in a cooler) immediately upon sample collection. The samples will be transferred to LLI by no later than the second day after the groundwater sampling events. LLI will meet all specified holding times and should make every effort to prepare and analyze the samples immediately after they are received.

10.3.3 Storage Requirements

Samples will be placed in secure, on-site storage or remain in the possession of the sampling personnel until they are shipped or delivered to LLI. Immediately after collection and during shipment to LLI, samples will be stored in Ziploc bags (or equivalent) in coolers on ice at approximately 4°C. Ice packaged in Ziploc bags will be used to maintain the temperature in the shipping containers at approximately 4°C. Ice will be replenished as needed to ensure adequate cooling of samples during storage and shipping.

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[6] Other types of sample containers may be used such as sorbent tubes or Tedlar bags.

10.4 Sample Documentation

Entries into the field logbook or other relevant sampling forms for sampling events may include, but not necessarily be limited to, the following:

- Project name, location, and number
- Name of person maintaining the field logbook
- Rationale for collecting the sample
- Date and time of sampling
- Sample numbers
- Cross-reference of numbers for split and blank samples
- Media sampled
- Field observations
- Geographical location of the sampling point in reference to site facilities
- Physical location of the sampling point
- Method of sampling, including procedures, equipment, and any departure from the procedures specified in the RI Work Plan or the SAP
- Results of field measurements and calibration record (e.g., water quality readings)
- Sample preservation
- Type and quantity of container used for each sample
- Weather conditions at the time of sampling and previous events that may influence the representative nature of a sample – at a minimum, include temperature and sky cover
- Photographic information, when appropriate, to briefly describe what was photographed and why, the date and time, the compass direction of the picture, number of picture in file
- Sketches, when appropriate, with locations referenced to existing structures in the area (i.e., trees, existing monitoring wells)
- Analyses requested
- Disposition of the sample (i.e., laboratory to where it is being shipped) and point of contact
- Shipping confirmation number of sample shipment, when applicable
- Other pertinent observations, such as the presence of other persons on the site (those associated with the job or members of the press, special interest groups, or passersby), and actions by others that may affect performance of site tasks
- Type of personal protective equipment (PPE) used if other than Level D
- Name(s) of sampling personnel
- Name of Field Team Leader and site Health and Safety Officer
- Names and time of arrival/departure of visitors and equipment to the site

- Summary of site safety meetings and levels of protection
- For air samples, other information such as the canister ID, flow controller ID, sample collection times (start and stop), pressure readings (start and stop), flow controller flow rates, and types of samples collected (SSV, IA, and AA) will be recorded on field sample collection forms to be kept in the project files. The sample location and height must also be recorded.

10.5 Chain-of-Custody Procedures

Verifiable sample custody is an integral part of all field and laboratory operations associated with this site investigation. The primary purpose of the COC procedures is to document the possession of the samples from collection through storage and analysis to reporting. COC forms will become the permanent record of sample handling and shipment. The Field Investigation Manager or his/her designee will be responsible to the Project Manager for monitoring compliance with COC procedures.

Field sampling personnel are responsible for the care and security of samples from the time the samples are collected until they have been turned over to the shipping agent or laboratories. A sample is considered to be in one's custody if it is in plain view at all times, in the physical possession of the sampler, or stored in a locked place where tampering is prevented.

Empty coolers containing ice will be available at the study area for use each day in the field. Samples collected during the day will be stored in shipping coolers beginning at the time of collection. The coolers will be locked inside the field vehicle when sampling personnel are not present.

A COC form will be filled out for each cooler that is shipped. Only samples in that cooler will be listed on the COC. An example of the COC records that will be used is shown in Appendix A. Each COC form will contain the following information:

- Site name and contract number
- Company name
- Project number
- Sample ID numbers
- Date and time of sampling
- Type of sample and number of sample containers associated with each sampling point
- List of analyses requested
- Metals analyses will be separated into dissolved or total categories under analyses requested columns; the list of metals for analysis will be specified in the comments section of the form along with information about field filtering and/or preservation of groundwater samples
- Number of containers for each sample
- Name and signature of sampling personnel
- Shipping confirmation number, when applicable

- Comments regarding matrix spike/matrix spike duplicate (MS/MSD) samples, or any other information that is necessary for the lab
- Spaces for transfer of custody acknowledgment.

When the COC form is complete, field team members will crosscheck the form for possible errors. Any corrections made to each record will be with a single strike mark that is dated and initialed. The person who initials corrections will be the same person who relinquishes custody of the samples.

10.5.1 Transfer to Project Laboratories

Samples will be shipped to LLI by overnight delivery service or picked up by a courier for overnight delivery. LLI will provide return shipping labels as well as packing supplies, bubble wrap, secondary containment bags, absorbent pads, etc., to secure samples during transit. The COC form that has accompanied a cooler from the time of sample collection will be signed, dated, placed in a Ziploc bag, and taped to the inside lid of the cooler.

When VOCs are being analyzed in groundwater, a trip blank provided by the laboratories will be placed in each cooler. The trip blank will consist of two labeled vials filled with laboratory-provided DI water; two vials constitute one trip blank. The trip blank must be included on the COC form. This sample will be analyzed for possible contamination from outside sources.

A temperature blank (provided by the lab) must also be included in each cooler.

11.0 INVESTIGATION-DERIVED WASTE HANDLING AND DISPOSITION

IDW generated during the RI will be stored, handled, and disposed of according to guidelines described in this section. According to the EPA guidelines, the most important elements of managing IDW include:

- Leaving the site in no worse condition than existed before the investigation
- Removing wastes that present an immediate threat to the human health or the environment
- Complying with federal and state applicable or relevant and appropriate regulations to the extent practicable
- Planning and coordination of IDW management
- Minimizing the quantity of generated wastes.

11.1 Expected Types of Investigation-Derived Waste

The methods for handling and disposing of IDW were developed under the assumption that it is unlikely that any of the IDW generated during this project will require special handling or disposal. The following sections discuss the different types of IDW that will be generated during this project.

11.1.1 Drill Cuttings

Drill cuttings resulting from soil boring activities will be placed in 55-gallon drums, lined tub skids, or roll off containers. Disposal will be in accordance with appropriate regulations and Boeing disposal practices.

11.1.2 Development and Purge Water

As a part of standard Boeing protocol, development and purge water is disposed of in accordance with Boeing's current groundwater waste profile[7]. During development of the monitoring wells, field personnel will observe the water for visual and olfactory evidence of contamination. Water generated during development of the wells will be contained in 55-gallon drums or other transportable liquid containers. The drums will be labeled and stored on site in a specified containment area. The water will be stored until laboratory analysis of groundwater samples is complete and IDW disposal options are evaluated. Disposal will be in accordance with appropriate regulations and Boeing disposal practices.

Use of low-flow, minimal drawdown or passive sampling procedures greatly reduces the volume of water produced during monitoring well purging. It is anticipated that a maximum of approximately 2

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[7] Boeing disposes of development and purge water as hazardous waste at the time of this report; changes may occur in the future that update this designation.

(low-flow sampling) or 0.25 (passive sampling) gallons of groundwater will be purged from each well (per sampling round) during the sampling process.

11.1.3 Decontamination Solutions

Decontamination solutions will consist of a 1 percent solution of non-phosphatic laboratory detergent (Alconox) and distilled water. Alconox is nontoxic, nonhazardous, and biodegradable. Decontamination solutions will be stored along with other decontamination water in 55-gallon drums pending laboratory analytical results.

11.1.4 Personal Protective Equipment

Level D PPE will be used while performing sampling tasks for this project, unless additional PPE is required by the applicable health and safety plan. The only PPE that will need disposal will be nitrile gloves. The nitrile gloves will be bagged and disposed of with other inert solid wastes. When working in PCB-contaminated soil, protective booties (or rubber boots to be decontaminated), and Tyvek® suits may be needed to protect clothing from becoming contaminated.

11.1.5 Solid Wastes

Non-hazardous solid wastes such as used paper towels, used gloves, and used sampling hoses will be placed in plastic refuse sacks and discarded into a receptacle identified by the on-site geologist.

11.1.6 Drum Sampling for Disposal

All development purge water will be sampled for constituents determined by Boeing. Boeing will provide the sample containers, coolers, COCs, and labels. Samples will be returned to the Wastewater Pre-Treatment Plant located on the facility.

11.1.7 Drum Handling

All drums with soil or water will be returned to the facility at the end of each day and placed in the pre-determined drum storage area. All drums will have labels provided by Boeing. Soil, decontamination rinse water, and concrete slurry drums will have a green non-hazardous waste label. All purge water drums will have a white hazardous waste label. These labels can be acquired from the on-site Boeing field representative. Drums will be stored according to the following procedures:

- The bolt must be over the label and facing down
- The bolt and label must be facing the side of the pallet the forks slide into so that when a forklift operator picks up the pallet, they can see the labels easily
- The drums must be wiped clean of soil clumps and the labels easy to read
- No more than four drums will be placed on a pallet
- Only drums of like material will be placed on the same pallet
- Only like materials will be stored in each drum.

12.0 FIELD CORRECTIVE ACTIONS

The ultimate responsibility for maintaining quality throughout the site investigation rests with the contractor Project Manager. The day-to-day responsibility for ensuring the quality of field and laboratory data rests with the Field Investigation Manager and field staff.

Any nonconformance with the established QA/QC procedures will be expeditiously identified and controlled. If procedures are not in compliance with the established protocol, corrective actions will be taken immediately. Subsequent work that depends on the non-conforming activity will not be performed until the identified non-conformance is corrected.

The Field Investigation Manager will review the procedures being implemented in the field for consistency with the established protocols. Sample collection, preservation, labeling, and other procedures will be checked for completeness. Where procedures are not strictly in compliance with the established protocol, the deviations will be field documented and reported to the Project Manager. Corrective actions will be defined by the Field Investigation Manager and Project Manager and documented as appropriate. Upon implementation of the corrective action, the Field Investigation Manager will provide the Project Manager with a written memo documenting field implementation. The memo will become part of the project file.

13.0 CONTACT INFORMATION

Contact information for Boeing personnel, subcontractors, and relevant off-site property contacts are listed below:

Company	Contact/Title	Phone	Email	Comments
Boeing	Carl Bach/ Project Manager	(206) 898-0438	carl.m.bach@boeing.com	Provides IDW and Auburn facility employee communication support
Boeing	Jim Swortz/ Auburn Facility contact	(360) 790-1767	James.p.swortz@boeing.com	Notify when scheduling relevant field work
Boeing	Jennifer Parsons/ Field Engineer	(206) 715-7981	Jennifer.p.parsons@boeing.com	Notify when scheduling relevant field work
APS	Bill Phillips/ Manager	(206) 517-1857		Private utility locates
One-Call Utility Locate		(800) 424-5555		Public utility locates
The Outlet Collection	Security	(253) 833-2155		Notify when sampling or drilling at The Outlet Collection
Prologis/ Starbucks	Jo Ann Bahain/ Prologis Property Manager		jbahain@prologis.com	Notify at least 24 hours ahead of time for all field work on property
City of Algona	Diana Quinn		Dianaq@algonawa.gov	Email prior to any field work on City of Algona right-of-way
General Services Administration (GSA)	Dwayne Smith	206-304-7635	dwayne.smith@gsa.com	Email 2 weeks prior to accessing GSA wells
Primus	Diane Knisely		deknisely@pccaero.com	Email 2 weeks prior to accessing Primus wells
Prologis (formerly DCT Industrial)	Eleanor Romero		eromero@prologis.com	Email 2 weeks prior to accessing DCT Industrial well
Commercial Crating & Box Packaging, Inc.	Catherine Liao	(253) 804-8616 (206) 369-6156		Call to get access code to well AGW216
Landau Associates	Jennifer Wynkoop/ Project Manager	(253) 926-2493	jwynkoop@landauinc.com	
TestAmerica (analytical laboratory)	Sheri Cruz/ Project Manager	(253) 922-2310	sheri.cruz@testamericainc.com	
Cascade Concrete Sawing & Drilling		(253) 872-7578		
Cascade Drilling, LP		(253) 883-5200		Subsurface drilling
K&D Services		(425) 252-0906	wadispatch@kndservices.net	Traffic control

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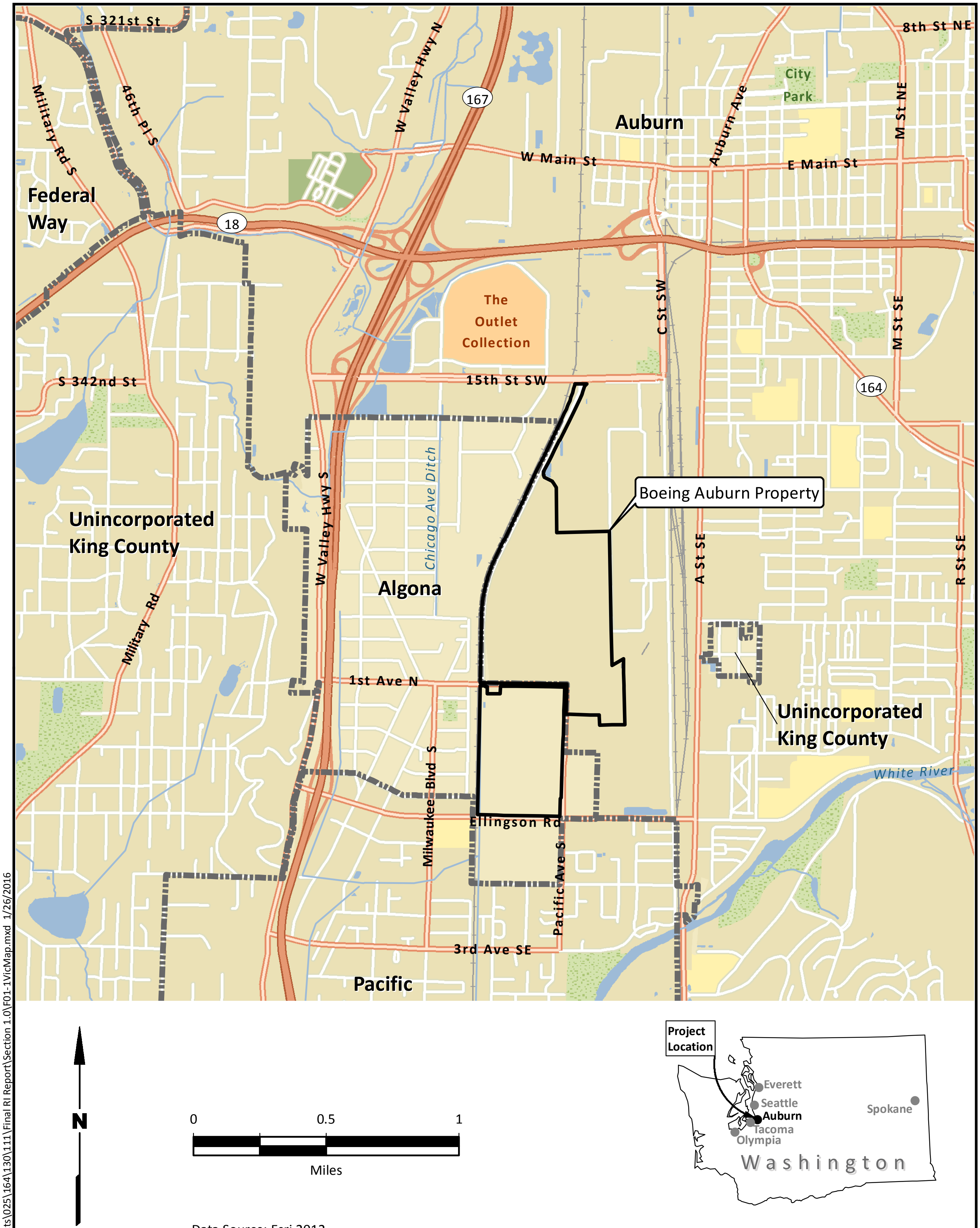

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Landau Associates

Boeing Auburn Auburn, Washington	**Vicinity Map**	Figure 1

APPENDIX A

CMT Manuals

CMT Multilevel System Assembly Manual

Printed in Canada
11/2004

Solinst®

CMT Manual Table of Contents

CMT Multilevel System Pre-installation Requirements

Please complete this form to verify that proper consideration has been given to design and borehole specifications for each CMT Multilevel System to be installed. (CMT tubing 1.7" OD, Guide Point Port 1.75" OD, Guide Point Port with Anchor 3.75" OD).

1/ **Minimum information required for effective design of the CMT Multilevel System:**

Accurate borehole depth ________________ Borehole Angle _____________________

Depth to which CMT System is to be installed _______________________

Borehole geology __________________

Drilling Method ______________________

Casing size (minimum ID) _________________

Depth to base of well casing _____________________

Number of Monitoring Zones ________________________

Approximate Depth to Static Water Level _____________________

Expected Maximum Pressure Heads at each Port location _______________________

Site Conditions (eg. dry field, bush, swamp, paved, etc.) ___________________________

Any special surface requirements for completion ____________________________________
of installation (eg. flush mounted, angled, etc)

Solinst can assist the client in the design and component selection for the CMT Multilevel System based on the above requested information, but final design and installation details remain the responsibility of the purchaser.

2/ **Ensure that these additional items are available on site during installation:**

- CMT Installation Toolkit (as shown at right)
- Measuring tape
- Hacksaw
- Marking pen or wax pencil
- Model 103 Tag line for checking backfill depths
- Model 101M or 102 Water Level Meters
- At least two client representatives to supervise and assist with installation. Solinst can provide a technician to assist with the installation upon request.
- Support stand (if purchased separately)
- Adjustable wrench

Tip: Practice making one or two ports in a short section of CMT before starting out on the real thing.

Introduction

The Solinst Model 403 CMT Multilevel monitoring well system represents a revolution in multilevel groundwater monitoring. The CMT System provides the simplicity of a bundle type installation with the benefits of backfilling or sealing around a single tube.

This manual describes the above-ground assembly of CMT wells. This consists of creating intake ports in the various channels at the desired depths, installing water-tight plugs below each intake port, adding mesh screens, sealing the bottom of the tubing, and attaching low-profile borehole centralizers to the tubing. For installations in bedrock or cased 2” wells, inflatable packers can be attached to the CMT tubing to seal the borehole between the various intake ports.

Assembling CMT wells is straightforward and can be performed by either drilling contractors or environmental consultants. The wells can be assembled on site after the borehole is being drilled or off site and then transported to the job location. While the assembly of CMT wells is not difficult, it is important to follow all of the steps described in this manual. It is especially important when creating the monitoring ports to avoid cutting into one of the adjacent channels. Doing so creates a hydraulic connection between the two channels that cannot be repaired. Please read this manual carefully before assembling your first CMT well. In addition we suggest that you practice making one or two ports in a short section of CMT tubing before starting out on the real thing.

Preparation

Before making any ports in the CMT tubing, make a sketch of the desired well design. Show the depths of the desired monitoring zones and centralizers (if used) in feet/meters below ground surface. Also, show the depths of the desired lifts of sand and bentonite graphically on the figure. This will come in handy when you are measuring the depths of the backfill materials when you are building the well. If you are building a CMT well where alternating layers of sand and bentonite backfill are added from the surface, try to allow for two feet or more of sand above and below the monitoring ports to ensure that the bentonite does not cover the monitoring ports.

Remember to allow sufficient wellhead access when you install the protective cover over the well. Plan on using a large well cover (greater than 4” diameter is recommended) to allow plenty of room to access the wellhead. A diagram showing suggested dimensions of the wellhead and protective cover is shown in Figure 1 for flushmount and above ground completions.

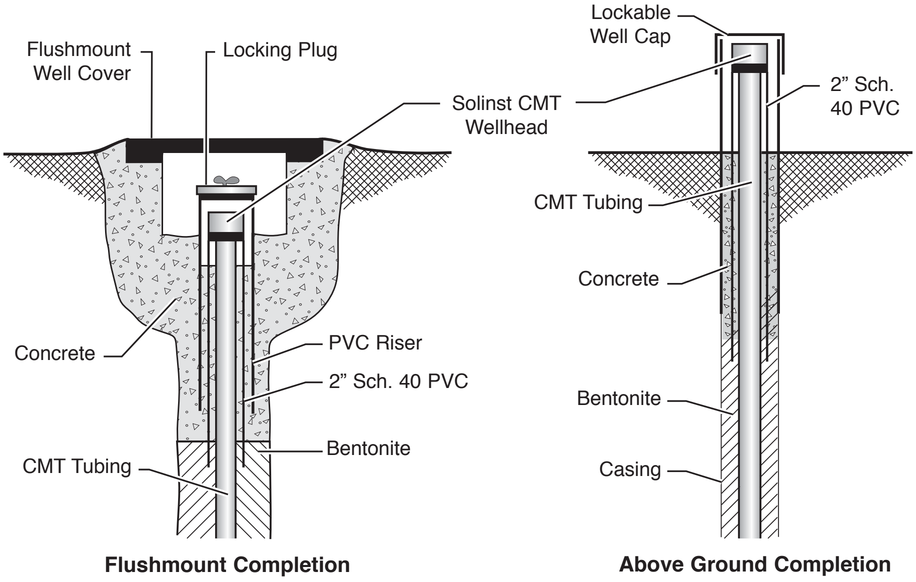

Figure 1

Example 1: Assembling Standard CMT Multilevel Systems

Table 1 shows the design of a hypothetical CMT Multilevel System designated well "ML-1." Each channel in this well can be used for both collecting a groundwater sample (with either a peristaltic pump, inertial pump or micro double valve pump) and measuring the depth to water. Each channel therefore functions both as a sampling port and an observation port.

Table 1
Hypothetical Design for a Standard CMT Well (Well ML-1)

Example

Monitored Zone	Channel Number	Depth to Center of Port (from ground surface)
1	1	23
2	2	34
3	3	48
4	4	55
5	5	69
6	6	77
7	7	92

Note: Newly uncoiled CMT tubing has a memory which can make it difficult to lay out straight. Sand bags help to hold down the ends of the tubing. The "memory" goes away relatively quickly, especially in warm weather. Placing the tubing on black plastic sheeting can warm the tubing, helping it straighten out more quickly.

Note: The channel identifier on the CMT tubing is intentionally subtle to avoid being a conduit for vertical leakage.

Note: The Channel 1 identifier is a low profile repetitive marking "<< CMT >>".

Marking the CMT Tubing with the Locations of the Monitoring Ports and Cutting the Tubing to the Proper Length

Uncoil the CMT tubing on the ground or other flat surface. Stretch out a measuring tape at least as long as the depth of the well, next to the CMT tubing.

Allowing for your desired wellhead stick up (2-3 feet above ground surface), place the end of the measuring tape below the length of tubing you want above ground. This is your measuring point which represents ground surface and all depths below this point use depths below ground surface.

3) The next step is to make marks on the CMT tubing at the depths corresponding to the midpoint of the desired monitoring ports. Before you do this, you will note that there is a faint channel identifier, a low profile repetitive marking "<< CMT >>" that runs along the entire length of the CMT tubing opposite one of the outer channels. This channel identifier facilitates identification of the various internal channels anywhere along the length of the tubing. The channel that has the identifier is always Channel 1. By convention, Channel 1 corresponds to the shallowest monitoring zone. The other five outer channels are numbered clockwise from 2 through 6 as you are looking down on the completed well from above. The center channel is Channel 7 and is always the deepest monitoring zone.

4) Make a mark across Channel 1 on the exterior of the CMT tubing at the depth corresponding to the center of the uppermost monitored port (23 feet below ground surface in our hypothetical example; Figure 2). A permanent marker or a "China marker" wax pencil works well for this. Write "Port 1" on the CMT tubing about 6 inches above the mark.

Figure 2

5) Next, draw a line along the Channel 1 identifier (i.e., parallel with the tubing) extending approximately 6" above and 6" below the depth mark (Figure 3). You will use this line (and other similar lines drawn at the other port depths) to index the Port Cutting Guide. This ensures that you cut holes only in the intended channels corresponding to the desired monitoring zones (as shown in Table 1).

Figure 3

6) Make similar marks at the depths corresponding to the next five monitoring zones (i.e., 34, 48, 55, 69, and 77 feet below ground surface). Make the marks identical to the ones you drew at Port 1. That is, draw the depth mark across Channel 1 and draw the longitudinal line along the Channel 1 identifier. The Port Cutting Guide has been indexed so that it always references the Channel 1 identifier when it is used to cut holes in the five other outer channels. Label these depth marks as Port 2, Port 3, etc..... about 6 inches above each mark. Finally, make a mark at the depth of the deepest monitoring port (i.e., the internal channel, Port 7), which is also the bottom of the well, at 92 feet. Cut the CMT tubing at this mark using a hacksaw, sharp knife, or PVC cutter.

Figure 4

7) The design of the well has now been transferred to the CMT tubing.

Note: When using the Port Cutting Guide, ensure that the cutting bolts are located below the number 1 on the front of the Guide. The locking bolts go below the number 4 on the back of the Port Cutting Guide.

Cutting the Outer Ports and Vent Holes

8) Slide the Port Cutting Guide over the CMT tubing down to Port 1. Align the notch stamped "1" on the Port Cutting Guide with the line you drew along the Channel 1 identifier. Position the Port Cutting Guide so that the depth mark "+" (indicating the centre of the Port) is visible in the window in the center of the Port Cutting Guide (Figure 5). Secure the Port Cutting Guide to the CMT tubing by tightening the knurled Locking Bolts on the underside of the guide (Figure 6). Tighten the bolts, **by hand only**, to prevent the Port Cutting Guide from moving.

Figure 5

Figure 6

9) Next, cut three holes, as described below into Channel 1 using the cutting bolts screwed into the Port Cutting Guide.

Start by threading a cutting bolt into one of the holes located on the same side as the window. Use the hex wrench to tighten the Cutting Bolt. Tighten the bolt a few revolutions, then loosen it one revolution. Continue doing this until the Cutting Bolt "bottoms out" (Figure 7). Remove the Cutting Bolt. There should be a plastic disk inside of the cutting bolt. If there isn't, re-insert the cutting bolt and repeat the cutting process (make sure that the knurled Locking Bolts are tight). Push out the piece of plastic from the inside of the Cutting Bolt by inserting an Allen wrench through the small hole drilled in the head of the Cutting Bolt (Figure 8). Repeat this process to cut all three holes. The two upper holes will provide the port plug access and the lowest hole is the vent hole (Figure 9).

Figure 7

Figure 8

Figure 9

Note: The two upper holes allow you to use snips to cut away a panel of plastic between the two holes, creating a 3-inch-long port in Channel 1. The bottom hole is a vent hole. A vent hole is needed to allow air to escape from the channel beneath the monitoring port when the CMT tubing is inserted into the water-filled borehole during well installation.

Note: The vent hole does not allow cross connection with other monitoring zones because the bottom of the channel is sealed with a water-tight plug.

10) Loosen the cutting tool and move it “down” the CMT and out of the way. Next, use the snips as shown in Figure 10 to cut out the panel of plastic between the upper two port holes. **Do this carefully and keep the snips parallel to the channel side wall to avoid cutting into the walls separating Channel 1 from Channels 2 and 6**. Make the opening as large as possible to facilitate the insertion of the expansion plug as described in the next step.

Figure 10

11) Insert an expansion plug through the opening (Figure 11) so that it seals Channel 1 below the monitoring port and above the vent hole. If necessary, use the torque driver to gently push the plug into place (Figure 12). Use the snips to trim the port opening if you have difficulty inserting the plug. Tighten the plug to a torque of 10 inch-pounds using the supplied torque driver.

Figure 11

Figure 12

12) The last step in making the Channel 1 port consists of wrapping the stainless steel mesh around the port, forming a well screen over the opening. Center the mesh over the port opening and wrap it tightly around the CMT tubing (Figure 13). Use the low profile Oetiker clamps and pliers to firmly secure the mesh to the tubing. Use two clamps for each monitoring port (Figure 14). Construction of Port 1 is now finished. You are now ready to make Port number 2.

Figure 13

Figure 14

13) Slide the Port Cutting Guide down to Port 2. Position the Port Cutting Guide exactly as you did for Port 1. The depth mark should be visible in the window of the Port Cutting Guide and the longitudinal Channel 1 identifier should be indexed to the number "1" stamped on the guide (Figure 15). Now, rotate the Port Cutting Guide (without moving its position along the CMT tubing) so that the longitudinal line is now indexed to the number "2" stamped on the guide (Figure 16). This positions the Port Cutting Guide so that the cutting bolts will cut holes only into Channel 2. Secure the Port Cutting Guide using the knurled Locking Bolts as before. Cut the two port holes and one vent hole into Channel 2. Next, loosen the cutting tool and slide it down the tubing out of the way.

Figure 15

Figure 16

Note: To avoid installing ports in the wrong channels start by positioning the Port Cutting Guide so that the depth mark is visible in the window, then rotate the guide so that the appropriate number (corresponding to the port number) is indexed against the line you drew earlier along the longitudinal Channel 1 identifier. This step is very important

Note: At some sites, you may decide that it is not necessary to monitor every channel. In that case, only cut ports in the desired channels.

When constructing the bottom assembly, only insert the expandable plugs into the monitored channels, leaving the other channels open so that they can fill with water as the CMT tubing is inserted into the borehole (e.g. If only three channels are monitored, only those channels should have plugs inserted at the base.) This reduces buoyancy during well installation.

14) Snip away the panel of plastic between the upper two holes, creating an opening for Port 2.

15) Next, insert an expansion plug though the opening, positioning it below the monitoring port, and tighten it to 10 inch-pounds as before. Finally, wrap a piece of stainless steel mesh around the opening and secure it with two stainless steel clamps. You have now finished constructing Port 2.

16) Continue the steps described above for Ports 3 through 6.

Configuring the Bottom of the CMT Tubing (Zone 7)

17) Insert an expansion plug into each of the six channels. (Figure 17) Tighten each to a torque of 10 inch-pounds using the torque driver.

18) Slide the Guide Point Port Assembly (Figure 18) over the end of the CMT tubing and secure it to the tubing with two stainless steel clamps (Figure 19). The end of the Guide Point Port Assembly is tapered to prevent the bottom of the CMT tubing from getting snagged on a rock ledge or casing joints as it is being inserted into a borehole.

Figure 17

Figure 18

Figure 19

19) If desired, an anchor (3.75" diameter) can be attached to the Guide Point Port using a hex bolt (Figure 20). An anchor is used during installations where it is helpful to secure the bottom of the CMT to keep it from moving during well construction. Once the tubing has been inserted, use sand placed on top of the anchor to secure the well. This will prevent it from being pulled up as drive casing or augers are withdrawn from the borehole. Holes have been drilled in the anchor to allow water in the borehole to pass through the anchor when the CMT well is inserted.

Figure 20

Note: Solinst has developed special tubing centralizers that ensure that the tubing is centered in the borehole during well construction. The fins on the centralizers are low-profile to prevent them from obstructing the tremie tube, or sand and bentonite pellets poured from the surface.

Attaching Tubing Centralizers

20) Place the centralizers over the CMT tubing at the desired depths. Centralizers are generally placed along the CMT tubing at intervals ranging from every 5 to every 15 feet. Attach the centralizers securely to the CMT tubing using two stainless steel clamps (Figure 21).

The CMT well is now ready to be inserted into the borehole.

Figure 21

Note: The Solinst Tag Line, (Model 103), is recommended for accurate sand and bentonite placement.

Note: On the underside of the wellhead is a groove to fit 2" dia. PVC riser pipe.

Figure 22

CMT Placement

21) Lower the assembled CMT System into the borehole slowly.

If buoyancy is a problem, wait, as the channels below water level will slowly fill and allow the system to be lowered further. To speed this process along, pour or pump clean water into the vent holes.

When the required depth is reached, suspend the system with the System Support Clamp to prevent it from moving during well construction (Figure 22).

22) Complete the installation by carefully pouring or using a tremie to place sand and bentonite at appropriate levels to seal the borehole annulus

Attaching the Standard Wellhead (after the well has been installed)
23) After the well has been built, cut the CMT tubing to the final elevation. You may choose to finish your CMT installation off above ground surface. If so, you can leave the CMT stick-up as is and install the standard wellhead or "house" the CMT inside a cut length of 2" dia. PVC riser pipe (not supplied). On the underside of the wellhead cap is a groove which is designed to allow a 2" dia PVC riser pipe to "key" into the wellhead. Locate Channel 1 and slide the Standard Wellhead over the tubing (Figure 22). Remember, Channel 1 has the identifier on the outside of the tubing. Secure the wellhead to the CMT tubing by tightening the hex screw on the side of the wellhead.

Optional Flow Control Monitoring Assembly
Under flowing artesian conditions or for vapor sampling, the CMT can be fitted with a special flow control monitoring assembly to allow the user to collect a sample, measure hydraulic or pneumatic pressure, and prevent uncontrolled flow from the well.

Monitoring Options

Water levels and samples can be accurately obtained using the following high quality Solinst instruments:

Water Level Measurement

Model 102 Water Level Meter

A narrow coaxial cable Model 102 Water Level Meter with a 1/4” dia probe can be used to monitor water levels in any CMT Channel.

Sampling Methods

Depending on your site’s depth to water and your sampling protocol, Solinst offers various sampling options.

Model 410 Peristalitic Pump

Ideal for sample retrieval from shallow water levels less than 30ft (9m).

Mini Inertial Pump

Mechanical pump used inside 1/4” LDPE tubing. Typical flow rates of 50 to 250mL/min. If your site’s water level is deeper than 50ft (15m), Teflon tubing is recommended

Model 408M 3/8” Dia. Flexible Micro Double Valve Pump

Small and flexible design makes this gas drive pump ideal for delivering high quality samples, in combination with the Model 466 Electronic Control Unit. Flow rates of 20 to 150mL/min make the 408M suitable for low flow sampling applications. Constructed of Stainless Steel and LDPE for lengths less than 50ft (15m) and Teflon tubing for any depths up to 200ft (60m) applications. This is the only viable option in wells with depth to water over 150 ft.

408 Accessories

Multi-purge Manifold

A multi-purge manifold can be considered for purging multiple CMT channels simultaneously using 408M Micro Double Valve Pumps

Model 466 Electronic Control Unit

The 408M is durable and easy to operate using the presets and fine tuning capabilities built into the Solinst Model 466 Electronic Control Unit.

Well Completion

Model 103 Tag Line

The Model 103 Tagline is ideal to aid accurate placement of sand and bentonite during borehole completion.

Model 403 Well Head Seal Assembly

For flowing conditions or vapor monitoring, Solinst offers a monitoring assembly, which applies a pressure seal to the individual CMT channel. This facilitates sampling through the well head at the surface.

CMT Decommissioning

Introduction

The CMT® (Continuous Multichannel Tubing) System is a multilevel groundwater monitoring system constructed from a single extruded polyethylene tube, 1.1" (28 mm) or 1.7" (43 mm), that has either three or seven isolated channels running internally along its length, respectively (Figure 1). Each channel, approximately 3/8" (9.5 mm) diameter, can be used to monitor groundwater heads/levels and quality at separate specific depths in a borehole. Ports are constructed on site at desired depths along the CMT tubing, using plugs to seal off the unused channels below each port and at its base.

Sand packs and bentonite seals are placed in the annular space between the CMT tubing and the borehole wall. This is done by backfilling from the surface, or with the sand and bentonite cartridges developed for the 3-channel CMT System. It is necessary to ensure that the unused portion of each channel, below the constructed port, is sealed to prevent groundwater from deeper zones migrating up the tubing causing cross-zone contamination. This can be achieved by inserting a plug at the bottom end of the channel and a second plug just below the port. This allows the lower unused portion of the channel to fill with water from the monitored zone through a vent hole placed just below the port plug, as the System is lowered into the borehole. Although many regulators are comfortable with this method of installation and the decommissioning methods described herein, some local regulators require that, in preparation for decommissioning, this unused portion of each channel be filled with grout prior to installation. If this is required in your area, please see page 3 for pre-installation instructions.

Thousands of CMT multilevel monitoring wells have been installed at contaminated sites in North America and around the world. Many of these sites have been cleaned up and the CMT wells are no longer needed. Thus, there is a need to decommission the wells in accordance with industry and local standards.

Figure 1
CMT Tubing (3 and 7 Channel) with wellhead identifying channels.

Options for Decommissioning CMT Wells

Several methods for decommissioning CMT wells have been tried in the last few years.

<u>Over-drilling and grouting the borehole</u> has been performed successfully at many sites. However, in soft materials the drill bit has a tendency to deviate from the original borehole. In some cases, this has resulted in partial system removal, leaving some doubt as to whether the multilevel wells have been fully decommissioned.

<u>Removal of the CMT system</u> by pulling should NOT be attempted as the low tensile strength of the polyethylene tube causes it to stretch and break before the entire length can be removed. Experience has shown that even a shallow 50 ft. (15 m) System may not be possible to completely remove in this manner.

<u>Grouting the CMT wells in place</u> is the easiest and most reliable option for decommissioning the wells. Tremie grouting is a simple, reliable way to decommission CMT wells. The grouting is done routinely in the geotechnical industry and a wide variety of grout compounds and mixtures are readily available. Further, tremie grouting of wells and other earth structures is an accepted sealing method throughout North America and Europe.

At a minimum, the channels should be completely filled with grout to prevent them from conveying water vertically in the multilevel. In addition, it may be desirable in some cases to inject grout into the sand pack adjacent to the various ports in the CMT wells. However, this is often unnecessary since the sand-packed intervals of CMT wells are often relatively short and are already hydraulically isolated in the boreholes by bentonite seals placed between the sand-packed intervals when the wells were constructed.

For best results, grouting of CMT wells should be performed "from the bottom up" using a tremie tube that is inserted into the CMT channel being sealed. The grout is then pumped through the tremie tube and into the CMT channel. The tremie tube is either left behind or removed incrementally as the grout is added, leaving a continuous column of grout within the CMT channel. The channels can be grouted sequentially or all at once using several tremie tubes (one in each channel). Because of the relatively small inside diameter (ID) of the CMT channels, however, it is necessary to use a tremie tube that has an outside diameter (OD) no larger than approximately 1/4" (6 mm). Adding grout through such a small diameter tremie tube requires the use of a low-viscosity grout that flows easily.

In order to provide guidance to it's CMT customers on decommissioning CMT wells by tremie grouting, Solinst undertook a research and testing project in spring 2005 to identify and test various methods and products for decommissioning CMT wells by in-place grouting. This Technical Bulletin presents the results of Solinst's research and testing.

Testing of Grouting Products & Procedures

The first step in developing a successful grouting technique for decommissioning CMT wells is to find an appropriate grout with the following characteristics:

1. Environmentally friendly, does not introduce any contaminants of concern into the subsurface.
2. Low viscosity, to allow injection through 1/4" (6 mm) polyethylene tremie tube.
3. Appropriate composition to allow rapid setting and reliable long-term seal.

In order to source the grout, Solinst contacted a local grouting company. Multiurethanes (MU) has operated since 1988 offering a range of grouting materials, equipment, accessories and services (see web-site at www.multiurethanes.com).

Bench scale testing was conducted July 2005 at the Multiurethanes facility in Mississauga, Ontario, Canada by both Solinst and Multiurethanes personnel. A model CMT well was first constructed using a 5 ft. (6 mm) length of straight 7-channel CMT tubing, built with one port and two centralizers. This assembly was placed within a 4.75" (12 cm) ID clear acrylic cylinder (Figure 2). The annulus between the CMT tubing, and the cylinder was filled with dry #0 (16-35 mesh) filter sand. Six of the seven channels were plugged at the wellhead using mechanical plugs, and grout was injected into Channel 1. The recipe selected for the test was 55 lbs (25 kg) of Ultrafine Cement, 2.2 lbs (1 kg) of Superplasticizer (4% by weight of cement) and 110 lbs (50 kg) of water.

The Superplasticizer turns the otherwise viscous cement mixture into an easy-to-pump fluid for a short period (typically 15-30 minutes) before the cement grout starts to set. In the bench scale grouting test, "Spinor A12 Microfine Cement" was choosen which is an ultrafine blast furnace slag cement. Its composition is chemically similar to ordinary "Portland Cement". Microfine or ultrafine cement is typically used in the geotechnical industry for permeation grouting, construction of curtain walls and subsoil water barriers in soils where conventional cement grouts (ie Portland) cannot penetrate.

The grout mixture was pumped into Channel 1 of the CMT tube at a rate of 0.50 US gpm (2 L/min.). Due to the small size of the CMT model and the lack of water to displace, grout was injected directly into channel 1. Grout was quickly observed exiting the port screen and soaking through the sand at the Port 1 location (Figure 3). Approximately four minutes from the beginning of the injection, grout reached within 3" (76 mm) of the top of the sand in the test cylinder and grouting was stopped. Pressure at the wellhead while injecting reached a maximum of 25 psi. The total volume of the grout used was 3.5L in 13L of sand (about a 1 to 4 ratio, corresponding to a sand porosity of about 0.27). The preferential flow of grout during pumping was upward in the sand pack. Below the port in the sand pack, the flow was gravitational and fingered its way through the sand. A 2:1 water to cement ratio in this specific test was very successful in permeating out into the filter pack. Examination of the column weeks later provided evidence that all the grout had entered the column sand and solidified. However, higher water to cement ratios may be necessary for deeper applications with lower porosity values.

Figure 2
CMT model assembly in 4.75" (12 cm) acrylic cylinder, later filled with sand and used in grout testing.

One important issue that was examined was the ability of this low viscosity mixture to be transmitted through the narrow 1/4" (6 mm) tube (i.e., tremie tube) that is inserted in the CMT channels. The low viscosity grout used in the test described above was pumped through 172 ft (52 m) length of 1/4" OD (6 mm) x 0.17" ID (4 mm) LDPE tube at a pressure of 90 psi, considerably higher than the pressure needed in the shorter test cylinder. A discharge rate of 0.9L/min (0.24 US gpm) was achieved through the end of the tubing.

Further testing of different grout mixtures indicated that a somewhat higher ratio than 2:1 of water to cement may be preferable when tremie grouting through long 1/4" (6 mm) lines.

Figure 3
CMT model showing grout seeping into the sand annulus through the the screen of the constructed port and trial batches of grout in pails.

Recommended Grouting Procedures

The most crucial aspect of grouting is to formulate the right recipe for the grout, whether using bentonite or cement and plasticizer with water. Every application is unique, due to factors such as length of monitoring interval, depth of port, hydraulic conductivity of the formation, and the static level in the channel.

A reasonable starting point is somewhere between a 2:1 and 3:1 water to cement ratio, with an addition of plasticizer at approximately 4% by weight of cement. It is prudent to mix a variety of grout compositions prior to the actual field decommissioning to determine how well they set and how easily they can be pumped through small diameter tubing.

The other items to have on site for the grout injection is the 1/4" (6 mm) tubing and a grout pump. The pump used by some grout experts is an electric airless paint sprayer, that can provide a flow rate of 0.5 US gpm or about 2 L/min with pressures of 0 to 2000 psi. This style is preferred over a standard grout pump because it has a lower piston stroke and therefore allows for a more controlled injection rate. They can generally be rented from local equipment rental outlets.

In addition to the equipment listed in the previous paragraph, remember to bring the following:

- A supply of clean water is needed to test circulation and clean equipment on-site.
- Containers to both mix (large pail or tub) and feed (a graduated bucket) the grout into the pump and through the tubing.
- A mechanical mixer (drill style mixer works well) to mix the cement, water, and plasticizer in small easy to handle batches.
- A mesh screen to place over the graduated bucket, when pouring from the mixing tank, to prevent any coarse clumps from entering the grout tube and blocking it (Figure 4).

Figure 4
Screening of clumps in grout mix using mesh over mixing bucket. Mixture of cement and plasticizer is being stirred using a drill mixer prior to being pumped into CMT Channel in the model.

Pre-Installation Grouting

The option exists to grout the lower (below port) section of tubing prior to installing a CMT system. With this approach the plugs would still be used but rather than having portions of the tubing filled with water (depending on your regulations) a low viscosity grout bentonite/cement would fill the space. It would then be possible, when or if decommissioning is required, to seal all CMT channels from top to bottom.

When considering the use of cement to seal CMT systems both prior to installation and then as a final decommissioning procedure, one concern that has been raised is the heat of hydration of cement and its possible effect on the CMT tubing. The approximate melting point of CMT tubing, a medium density polyethylene, is estimated in the literature at approximately 150°C or 300°F. Different types of cement, the volume of fluid or water inside the CMT to dissipate heat and the volume of cement used are all important factors in how much heat is released during hydration. However, most cements (typically Type I Portland) used to complete environmental installations are required in low volumes (typically a 2" annulus, or less in the channels) and are not injected as a large mass. Temperature increases in the order of 10-15°C (50-60°F) could be anticipated for a completion with a 2" annulus. The risk therefore of a CMT system melting due to the heat produced from cement hydrating is low and has never been reported by a client or contractor. Actual field applications where the lower segments of the CMT channels were sealed, during well construction, are discussed in detail in the following section.

Pre-grouting the lower CMT channels below the intake ports has been done successfully by certified CMT installers on several projects. In some cases, a cement grout was pumped simultaneously into all the outer channels through the bottom end of the CMT tubing prior to insertion into the borehole. The injection was performed using a boot device that was pushed on the end of the system and secured with hose clamps (Figure 5). Grout was pumped simultaneously into all outer channels until it flowed out of the vent holes (Figure 6). After all of the channels below the ports were full of grout, standard explansion plugs were inserted into the base of each outer channel and tightened. A bottom guide tip and port assembly was attached to the bottom of the CMT tubing and the system was lowered to the desired depth in the borehole. A slightly different approach was taken on a 50-foot CMT installation by another certified CMT installer. On this project, the contractor used a standard peristaltic pump to to inject low viscosity cement grout through the bottom of each of the outer channels up to the vent hole. The contractor used 1/4" (6mm) OD polyethylene tubing to convey the grout from the grout reservoir into the various CMT channels (Figure 7). An advantage of filling the lower sections of the CMT with grout prior to installing the tubing is that it is possible to visually confirm that each section is completely filled with grout from the bottom of the well right up to the vent hole, leaving no void spaces.

Figure 5
Pre-installation grouting of CMT by injection using a grout boot device.

Figure 6
Grout exiting vent hole during pre-installation grouting.

Figure 7
Pre-installation grouting of CMT by injection of grout through 1/4" (6 mm) tubing using a peristaltic pump.

Another option, that has not yet been field tested, is to inject grout into the open CMT channels below each intake port via the vent holes as the tubing is lowered into the borehole. The CMT would be constructed, as usual, at the ground surface with plugs inserted in all outer channels at the bottom end of the CMT tubing. The contractor then would proceed to insert the CMT tubing into the borehole until the first (i.e., deepest) vent hole is easily accessible (e.g., a few feet above the ground surface). Then, a 1/4" (6mm) OD polyethylene tremie tube is inserted into the vent hole and pushed to the bottom of the channel (i.e., to the bottom end of the CMT tubing). Grout is then pumped down through the tremie tube, filling the lower, unused portion of the channel below the intake port. The tremie tube is incrementally retracted as the grout is pumped into the channel. This procedure is then repeated to fill each of the channels as the CMT tubing is being inserted into the borehole. An advantage of this method of pre-grouting the lower portions of the CMT channels is that this procedure can be performed at sites where it is not possible or desirable to lay the tubing on the ground. This type of pre-installation grouting procedure is very similar to the grouting technique that is described below for complete decommissioning of a CMT well when it is no longer needed.

Further field testing and discussion is planned in order to select the preferred methods and the optimal grout bentonite/cement mix to effectively seal lower sections of the CMT. See Solinst's website for updates and reports as they become available.

Grouting for Final Well Decommissioning

Using a tremie technique, a 1/4" (6 mm) tube is placed in each channel down to the depth of the port. Grout is injected, using a pump, through the tubing. Volumes of grout used during this process should be monitored and recorded to ensure that grout has completely filled the channel. For calculations, the volume in the outer 6 channels of a 7-channel CMT is 40 ml/ft. The volume of the central channel of the 7-channel CMT system and each channel of the 3-channel system, is 30 ml/ft. To simplify this procedure, leaving the grout tube in place for each channel may be preferable, rather than trying to remove the tube and potentially creating void space and also to minimize concerns with disposal. It may be necessary to top up the channel with additional grout, after allowing 24 hrs for setting.

Although the bench scale testing (described above) was conducted using a pressure grouting technique, in an actual field application tremie grouting would likely be the preferred option. This is due to the depth that grout would be placed and displacement issues (air and water) in the channels.

Remember that although the Superplasticizer makes the grout more fluid and easier to pump, its effect lasts for only about 15 to 30 minutes, depending on how much is added. After that brief period of time, it is consumed or "used up" by the cement and its viscosity lowering ability is greatly reduced.

As with any grouting project there are three steps that are recommended, to minimize the chance of this procedure failing due to a blockage:

1. Always experiment with the grout composition in advance of the actual field application so that a consistency is reached that can be injected to the deepest port depth and will still provide an effective seal.
2. Before injecting grout to the port location using a tremie tube, always test the pumping system with water first to be sure that flow is consistent through the pump and tubing. Only after flow is confirmed should the pump be switched to injecting grout.
3. In the event that there are no "grout returns,", i.e., the grout is not pumped back to the ground surface after a volume equal to the volume of the sand pack voids and the volume of the channel has been pumped, it may be the case the grout is being lost to the formation surrounding of the sand pack. In this case, it may be advisable to increase the viscosity of the grout mixture by reducing the amount of water added to cement.
4. Once grout injection has begun, the flow must not be stopped until the channel has been completely filled. If the flow is halted even for a matter of minutes it is very likely that further injection through the same tube will not be feasible. To continue the procedure, lower a second clean tube down into the channels after the initial tube is removed. In order to get this tube down it is advisable to flush water through as it is lowered, to prevent clogging. Then continue with the grouting procedure until the channel is full.

Summary

A review of your local well decommissioning guidelines or regulations should be performed prior to deciding the best approach for installation or decommissioning of any CMT well. The decommissioning procedure outlined above is believed to be the best option currently available to decommission existing and future CMT installations. It is deemed to be the most reliable method to seal the installation with minimal risk verses some of the other options discussed on page 1. Tremie and other forms of pressure grouting have been performed on geotechnical, environmental, and water supply projects for decades around the world. Also, there are many low-viscosity, environment-friendly grouts suitable for tremie grouting CMT wells. To grout a CMT system experienced professionals could obtain the equipment themselves to seal the installation by following the procedure outline in this document, or contact Certified CMT Installers or grouting experts (eg. Multiurethanes) for field assistance and guidance.

Depending on the type of sand pack, depth of the ports and water within the installation it may be necessary to vary the percentages of water, cement/bentonite grout and plasticizer used to seal the system for each decommissioning project. This document should be used as a guide and provides a starting point for optimizing the sealing of CMT installations in various environments. Should you have further questions or concerns please do not hesitate to contact either Solinst, Multiurethanes, or a certified CMT installer.

For further information contact: Solinst Canada Ltd.
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35 Todd Road, Georgetown, Ontario, Canada L7G 4R8
Web Site: www.solinst.com E-mail: instruments@solinst.com

Solinst®

Solinst®

Purge/Grout Adaptor Operating Instructions

Model 403 7-Channel

Grouting Option

Tools and Materials Needed for Grouting

1. 7-Channel CMT Purge/Grout Adaptor Assembly (#108130) Includes:
    - Purge/Grout Adaptor
    - 1 x Gear Clamp (#107095)
    - 2 x Internal (#V130) O-rings (one extra) (#103807)
    - 12 x Grout Plugs (#104027)
    - 1 x Hex Plug (#107096)
2. Tools from the 7-Channel Standard Installation Tool Kit (#106223)
    - 7-Channel Torque Driver (#106715)

Note: 2" = 50 mm, 1" = 25 mm, 1/4" = 6 mm, 1/8" = 3 mm

Grout Adaptor Operating Principles

Once the ports are completed in the CMT, and prior to installation, the vent holes, located below each of the port openings, are fitted with Grout Plugs. This helps reduce the amount of excess grout flowing from the vent holes during the grouting process.

The Purge/Grout Adaptor is then attached to the bottom of the CMT. The Grout Adaptor allows the connection of a 1" diameter NPTM grout line. The unused CMT channels below each port opening can be filled with grout from the bottom port up. A pressure relief valve (25 psi) is built-in to the adaptor to avoid over-pressurizing the CMT channels.

Grout Adaptor Setup Instructions

1. With the ports completed, lay the CMT on the ground and use the torque driver to install and torque the Hex Plug into the bottom/base of the CMT (in middle Channel 7).
2. Insert the Grout Plugs to restrict flow into each vent hole.
3. With the top-mounted 1/4" compression fitting still attached, unscrew and remove the upper black Delrin® fitting from the top of the Grout Adaptor. This will allow access forthreading the 1" diameter grout line.
4. Be sure to keep the O-ring inside the base of the Adaptor. This will ensure a seal between the Adaptor and the CMT tubing.

5. Place the Adaptor onto the base of the CMT tubing and slide up by about 2". Tighten the Gear Clamp at the base of the Adaptor to secure it to the CMT.
6. Plug the Side-mounted Discharge with a grout bypass line.

Grouting Instructions

1. With the CMT assembly still lying on the ground, thread the 1" diameter grout line directly onto the top of the Grout Adaptor.
2. Proceed to grout until the grout reaches and exits the Grout Plugs, in each of the vent holes.
3. Remove the Grout Adaptor and clean. Wipe the end of the CMT clean.
4. Install and torque the Base Plugs into each of the outer CMT channels.
5. Remove the centre Hex Plug and install the guide point port.

Decontamination Suggestions

Follow your usual cleaning protocols and procedures. Washing the Adaptor can be easily accomplished with a small brush and suitable cleaning solution.

1" diameter Grout Line connected to Grout Adaptor, attached to bottom of CMT.

Grout exiting the Grout Plug, below the Port Screen.

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November 26, 2008

(#109095)

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APPENDIX B

Field Sampling Forms

LANDAU ASSOCIATES

As-Built
Well Completion Form

Exploration No.: ____________________

Well No. (If different than Expl. No.): ______

Client/Owner: ______________ Project No.: ______________

Project Name: ________________________________

Drilling Co.: ________________________________

LAI Rep(s): ________________________________

Installation Start Date: ______________ Hour: __________

Installation Finish Date: ______________ Hour: __________

Well Type: ☐ Single ☐ Nested ☐ Clustered

BORING AND WELL DIMENSIONS AND INSTALLATION DETAILS

DOE Unique Well No.: ________________________

Number of Pipes in Boring: ________________________

Boring Diameter at Top of Hole: ________________________

Does Diameter of Hole Change? ________________________

Boring Diameter at First Step Down: ________________

Depth of First Step Down: ________________

Boring Diameter at Second Step Down: ________________

Depth of Second Step Down: ________________

Well Completion Date: ________________________

Elevation of Well Cover: ________________________

Elevation of Top of Well Pipe: ________________________

Depth to Water: ________________________

Date: ______________ Time: ______________

____

____

MATERIALS USED

__________ Sacks of ______________ Sand

__________ Sacks of ______________ Concrete/Cement

__________ Sacks of ______________ Grout Mix Used

__________ Sacks of Bentonite Chips

__________ Feet of ______-inch PVC Blank Casing

__________ Feet of ______-inch PVC Slotted Screen

__________ Threaded End Cap

__________ Waterproof Well Seal/Slip Cap

__________ Flush Mount/Aboveground Protective Monument

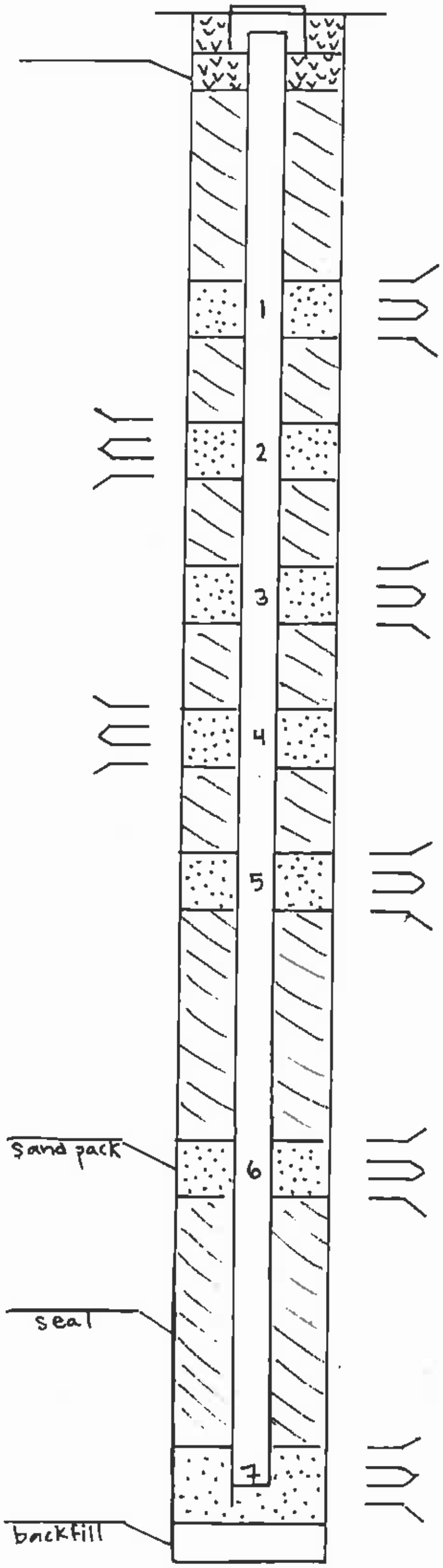
__________ Protective Posts

____

____

____

\\Edmdata\wproc\000MasterForms\Field\Well As-Built Form.cdr



TestAmerica Sacramento
880 Riverside Parkway

West Sacramento, CA 95605
phone 916.373.5600 fax

Canister Samples Chain of Custody Record

TestAmerica Laboratories, Inc. assumes no liability with respect to the collection and shipment of these samples.

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

TestAmerica Laboratories, Inc.

Client Contact Information	**Project Manager:**	**Samples Collected By:**	COC No:
Company Name:	**Phone:**		_______ of ______ COCs
Address:	**Email:**		
City/State/Zip			**For Lab Use Only:**
Phone:	**Site Contact:**		Walk-in Client:
FAX:	**TA Contact:**		Lab Sampling:
Project Name:	**Anaylsis Turnaround Time**		
Site/Location:	Standard (Specific):_________________		Job / SDG No.:
P O #	Rush (Specifiy):____________________		(See below for Add'l Items)

Sample Identification	**Sample Date(s)**	**Time Start**	**Time Stop**	**Canister Vacuum in Field, 'Hg (Start)'**	**Canister Vacuum in Field, 'Hg (Stop)'**	**Flow Controller ID**	**Canister ID**	**TO-15 (Med / Std / Low / SIM)**	**MA-APH**	**EPA 3C**	**EPA 25C / 25.3**	**ASTM D-1946 / 1945 / 3588**	**EPA 15/16**	**TO-3**	**Other** (Please specify in notes section)	***Sample Type***	**Indoor Air**	**Ambient Air**	**Soil Gas**	**Landfill Gas**	**Other** (Please specify in notes section)	**Sample Specific Notes:**

Temperature (Fahrenheit)			
	Interior	**Ambient**	
Start			
Stop			

Temperature (Fahrenheit)			
	Interior	**Ambient**	
Start			
Stop			

Special Instructions/QC Requirements & Comments:

Samples Shipped by:	**Date / Time:**	**Samples Received by:**
Samples Relinquished by:	**Date / Time:**	**Received by:**
Relinquished by:	**Date / Time:**	**Received by:**

Lab Use Only: **Shipper Name:** **Opened by:** **Condition:**

Form No. CA-C-WI-003, Rev. 1, dated 05/10/2013

Summa Canister Field Test Data/Chain of Custody

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For Lancaster Laboratories use only
Acct. # ______________ Group # ______________ Sample # ______________
Instructions on reverse side correspond with circled numbers.

① Client Information

Client
Account #

Project Name/#

Project Manager
P.O. #

Sampler
Quote #

Name of state where samples were collected

③ Turnaround Time Requested (TAT) (circle one)

Standard

Rush (specify) ______________

④ Data Package Required?

Yes No

⑤ EDD Required?

Yes No

② Sample Identification / ⑥ Analyses Requested

Sample Identification	Sample Collection Date	Time Start (24 hr clock)	Time Stop (24 hr clock)	Canister Pressure In Field ("Hg) (Start)	Canister Pressure in Field ("Hg) (Stop)	Interior Temp. (F) (Start)	Interior Temp. (F) (Stop)	Flow Reg. ID	Can ID	Can Size (L)	Controller Flowrate (ml/min)	EPA TO - 15	EPA 18 ☐ BTEX ☐ MTBE	EPA 25 (select range below)	Helium as tracer	O2/CO2	Library Search	

⑦ Instructions/QC Requirements & Comments

EPA 25 (check one)

☐ C1 - C4
☐ C1 - C10
☐ C2 - C4
☐ C2 - C10
☐ C4 - C10 (GRO)

⑧

Canisters Shipped by:	Date/Time:	Canisters Received by:	Date/Time
Relinquished by:	Date/Time:	Received by:	Date/Time:
Relinquished by:	Date/Time:	Received by:	Date/Time:

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The white copy should accompany samples to Lancaster Laboratories. The yellow copy should be retained by the client.

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7056.01

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VAPOR / AIR Chain of Custody

DATE:___________
Page ____ **of** _____

Lab Client and Project Information

Lab Client/Consultant:	Project Name / #:
Lab Client Project Manager:	Project Location:
Lab Client Address:	Report E-Mail(s):
Lab Client City, State, Zip:	
Phone Number:	

Sample Receipt (Lab Use Only)

Date Rec'd:	Control #:
H&P Project #	
Lab Work Order #	
Sample Intact: ☐ Yes ☐ No ☐ See Notes Below	
Receipt Gauge ID:	Temp:
Outside Lab:	
Receipt Notes/Tracking #:	
Lab PM Initials:	

Reporting Requirements

☐ Standard Report ☐ Level III ☐ Level IV
☐ Excel EDD ☐ Other EDD:_________________
☐ CA Geotracker Global ID:__________________

Turnaround Time

☐ 5-7 day Stnd ☐ 24-Hr Rush
☐ 3-day Rush ☐ Mobile Lab
☐ 48-Hr Rush ☐ Other:_____

Sampler Information

Sampler(s):
Signature:
Date:

Additional Instructions to Laboratory:

☐ Check if Project Analyte List is Attached

**** Preferred VOC units (please choose one):***

☐ µg/L ☐ µg/m^3 ☐ ppbv ☐ ppmv

SAMPLE NAME	FIELD POINT NAME (if applicable)	DATE mm/dd/yy	TIME 24hr clock	SAMPLE TYPE Indoor Air (IA), Ambient Air (AA), Subslab (SS), Soil Vapor (SV)	CONTAINER SIZE & TYPE 400mL/1L/6L Summa or Tedlar or Tube	CONTAINER ID (###)	Lab use only: Receipt Vac	VOCs Standard Full List ☐ 8260SV ☐ TO-15	VOCs Short List / Project List ☐ 8260SV ☐ TO-15	Oxygenates ☐ 8260SV ☐ TO-15	Naphthalene ☐ 8260SV ☐ TO-15 ☐ TO-17m	TPHv as Gas ☐ 8260SVm ☐ TO-15m	TPHv as Diesel (sorbent tube) ☐ TO-17m	Aromatic/Aliphatic Fractions ☐ 8260SVm ☐ TO-15m	Leak Check Compound ☐ DFA ☐ IPA ☐ He	Methane by EPA 8015m	Fixed Gases by ASTM D1945 ☐ CO2 ☐ O2 ☐ N2			

Approved/Relinquished by:	Company:	Date:	Time:	Received by:	Company:	Date:	Time:
Approved/Relinquished by:	Company:	Date:	Time:	Received by:	Company:	Date:	Time:
Approved/Relinquished by:	Company:	Date:	Time:	Received by:	Company:	Date:	Time:

**Approval constitutes as authorization to proceed with analysis and acceptance of conditions on back*

LANDAU ASSOCIATES

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☐ **Tacoma** (253) 926-2493
☐ **Spokane** (509) 327-9737
☐ **Portland** (503) 542-1080
☐ ____________

Chain-of-Custody Record

Date ____________

Page ______ of ______

Project Name ____________ Project No. ____________

Project Location/Event ____________

Sampler's Name ____________

Project Contact ____________

Send Results To ____________

Turnaround Time
☐ Standard
☐ Accelerated
☐ ____________

Sample I.D.	Date	Time	Matrix	No. of Containers	Testing Parameters											

Observations/Comments

_X_ Allow water samples to settle, collect aliquot from clear portion

_X_ NWTPH-Dx - run acid wash/silica gel cleanup

____

___ run samples standardized to ____________ product

___ Analyze for EPH if no specific product identified

VOC/BTEX/VPH (soil):
___ non-preserved
___ preserved w/methanol
___ preserved w/sodium bisulfate
___ Freeze upon receipt

___ Dissolved metal water samples field filtered

Other ____________

Special Shipment/Handling or Storage Requirements

Method of Shipment

Relinquished by
Signature ____________
Printed Name ____________
Company ____________
Date ____________ Time ____________

Received by
Signature ____________
Printed Name ____________
Company ____________
Date ____________ Time ____________

Relinquished by
Signature ____________
Printed Name ____________
Company ____________
Date ____________ Time ____________

Received by
Signature ____________
Printed Name ____________
Company ____________
Date ____________ Time ____________

WHITE COPY - Project File **YELLOW COPY - Laboratory** **PINK COPY - Client Representative**

Rev 8/09

Boeing Lab Transition/Chain of Custody

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For Lancaster Laboratories use only
Acct. # ____________ Group # ____________ Sample # ____________
Please print. Instructions on reverse side correspond.

① **Client Information**

Site Location: ____________
Site Project: ____________
Site Program/#: ____________
Boeing PM: ____________
Consultant Contact: ____________
Report To: ____________
Invoice To: ☐ Boeing EHS ☐ Other (specify): ____________
Samplers: ____________ # of Coolers: ____________

⑤ **Analyses Requested**

⑥ **Comments/Remarks**

② **Sample Identification**	Collected		④ Matrix	No. of Containers													
	Date	Time															

Additional Comments:

⑦ **Turnaround Time Requested (circle)**

Standard	5 day	4 day
72 hour	48 hour	24 hour

Other (Specify):

Temperature upon Receipt: ____________ °C
Custody Seals Intact?: Yes No

			⑨
Relinquished by:	Date/Time	Received by:	Date/Time
Relinquished by:	Date/Time	Received by:	Date/Time
Relinquished by:	Date/Time	Received by:	Date/Time
Relinquished by commercial carrier (circle): UPS FedEx Other: ____________		Received by:	Date/Time

Lancaster Laboratories Inc., 2425 New Holland Pike, Lancaster, PA 17601 717-656-2300
The white copy should accompany samples to Lancaster Laboratories. The yellow copy should be retained by the client.

Issued by Dept. 40 Management
7063.01

LANDAU ASSOCIATES

Subcontractors Daily Activity Record

Project Name ______________________________
Project No. ______________________________
Location ______________________________
Date ______________________________
Landau Rep. ______________________________
Client ______________________________
Weather ______________________________

CONTRACTOR INFORMATION

Contractor ______________________________
Project/Health & Safety Briefing Conducted: ☐ Yes ☐ No

☐ Drilling ☐ Grading
☐ Excavation ☐ Other ______________

Contractor Rep. ______________________________

TIME LOG (Documented by Landau Associates Representative at end of each working shift)

	Total	A.M.						A.M.						P.M.						P.M.					
Activity	Hours	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Mobe/Moves																									
Drilling/Excavation																									
Installation																									
Decontamination																									
Standby																									
Down time																									

Remarks: Explain all down time. Explain all stand-by time and who authorized it, unusual difficulties, etc.

EXPENDABLES: ITEMIZE QUANTITY, SIZE, ETC.

Item	Quantity	Type	I.D.	O.D.	Length	Billing

Subsurface Data	Depth	Samples

PERSONNEL EQUIPMENT

Position	Name	Hrs	Support Equipment	Status (A.D.S.F.)	Hours Oper.	Down	Standby

A – Available; D – Down; S – Standby; F - Field

LANDAU ASSOCIATES

Page ___ of ___

Drum/Tank Inventory

Project Name ______________________________ Project Number ______________________

Location ______________________________ Date ______________________

Client ______________________________ Landau Representative ______________________

Drum/Tank Number	**Date Generated**	**Contents**	**Estimated Quantity**	**Suspected Contaminants**	**Generation Source**	**Disposal Method / Date Disposed**	**Sketch of Site and Drum/Tank Location**

LANDAU ASSOCIATES

Field Report

Project No.: ____________________ Report No.: __________

Client: ____________________ Date: __________

Project Name: ____________________ DPD Permit No.: __________

Location: ____________________

Weather Conditions: ____________________

Prepared By: ____________________

Visitors: ____________________

Unsatisfactory Conditions & Recommended Correction: ____________________

____

Attachments: None____________________

Signed:____________________

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC’s Site: Boeing Auburn

Exploration No. ____________
Page ________ of ________
Date ________ Hour ________

Log of Exploration - RotoSonic

LANDAU ASSOCIATES
ENVIRONMENTAL | GEOTECHNICAL | NATURAL RESOURCES

Project Name ____________________ Project No. ____________

Client/owner ____________________ Exploration Operator ____________

Exploration Method ________________________________

Logged by ____________________ Exploration Completed ____________

Ground Surface Conditions ________________________________

Location Sketch (show dimensions to mapped features)

North Arrow

Coordinates: “x” (East)________ “y”(North) ________ Method ________ Elevations ________ Datum ________

Weather Conditions ________________________________

Sampler and Hammer Information

a = 3.25-in. O.D. – D&M	1 = 300-lb./30-in. Drop
b = 2.0-in. O.D. – SPT	2 = 140-lb./30-in. Drop
c = Shelby Tube	3 = Pushed
d = Grab Sample	4 = Vibrocore
g = 2.5-in. O.D.– WSDOT	5 = ____________
h = 3.0-in. O.D. – M.Calif.	
i = ____________	

Water Level Information

Date						
Time						
Depth to Water						
Hole Depth						
Casing Depth						

Run Depth (top) (ft.)	Run Length (ft.)	Recovery Length (ft.)	Retained Depth (top) (ft.)	Retained Length (ft.)	Run Number	Sample Number	Date/Time	Other Test Data: ____	USCS Symbol / Unit Contact	Graphic Log	Depth Scale (ft)	Sample Description Color, secondary soil type, PRIMARY SOIL TYPE with modifiers and minor components (density/consistency, moisture)(geologic unit)	Comments on Heave, Water Conditions, & Drilling Action
											0		
											1		
											2		
											3		
											4		
											5		
											6		
											7		
											8		
											9		

Total Depth ____________ Finish Date ____________ Hour ____________ Continued

Exploration No. ______________
Page __________ of ________

Log of Exploration - RotoSonic

LANDAU ASSOCIATES
ENVIRONMENTAL | GEOTECHNICAL | NATURAL RESOURCES

Rn Dpth	Rn Len	Rec Length	Rt.Depth	Rt.Lngth	Run #	Sample #	Date/ Time	Other	USCS	Graphic	Depth	Sample Description	Comments
											0		
											1		
											2		
											3		
											4		
											5		
											6		
											7		
											8		
											9		
											0		
											1		
											2		
											3		
											4		
											5		
											6		
											7		
											8		
											9		

Landau Associates

Exploration No. ____________________
Date __________ Hour ____________

Log of Exploration

Project Name ________ Project No. _____

Client/Owner ______ Exploration Operator __________

Exploration Method _ __________________________________

____

Logged by _ ____ Exploration Completed ______________

Ground Surface Conditions ____

Weather Conditions ____

Location Sketch (show dimensions to mapped features)

○ North Arrow

(East) (North)

Coordinates: "x" __________ "y" __________ Method __________

Elevations _____________________ Datum _________________

Sampler and Hammer Information	
a = 3.25-in. O.D. – D&M b = 2.0-in. O.D. – SPT c = Shelby Tube d = Grab Sample g = 2.5-in. O.D.– WSDOT h = 3.0-in. O.D. – M.Calif. i = _______________	1 = 300-lb./30-in. Drop 2 = 140-lb./30-in. Drop 3 = Pushed 4 = Vibrocore 5 = ______________

Water Level Information			
Date			
Time			
Depth to Water			
Hole Depth			
Casing Depth			

Sample Depth (top) (ft.)	Sample Length (ft.)	Recovery Length (ft.)	Retained Depth (top) (ft.)	Retained Length (ft.)	Sample Number	Sampler/Hammer Codes	Blow Counts	Other Test Data) ______	USCS Symbol / Unit Contact	Depth Scale (ft)	Sample Description Color, secondary soil type, PRIMARY SOIL TYPE with modifiers and minor components (density/consistency, moisture)(geologic unit)	Comments on Heave, Water Conditions, & Drilling Action
										0		
										1		
										2		
										3		
										4		
										5		
										6		
										7		
										8		
										9		
										0		
										1		
										2		
										3		
										4		
										5		
										6		
										7		
										8		
										9		
										0		

Total Depth _____________ Finish Date ________________ Hour _____________ Continued

Photograph Log

Roll No./Phone No.	Comments

LANDAU ASSOCIATES

Groundwater Low-Flow Sample Collection Form

Projec.: ____________________ Project Number ____________________

Event: ____________________ Weather: ____________________

Sample Number: ____________________ Date: ____________________ Time: ____________

Well Name: ____________________ Landau Representative: ____________________

WATER LEVEL/WELL/PURGE DATA

Well Condition: Secure (YES or NO) Damged (YES or NO) Describe: ____________________

DTW Before Purging (ft) ____________ Time: ____________ GW Meter No.(s) ____________________

Begin Purge: Date/Time: ____________ End Purge: Date/Time: ____________ Gallons Purged: ____________

Purge water disposed to: ☐ 55-gal Drum ☐ Storage Tank ☐ Ground ☐ Other ____________

Time	Temp (°F/°C)	Cond. (uS/cm)	D.O. (mg/L)	pH	ORP (mV)	Turbidity (NTU)	Purge Volume (gal)	Comments/Observations
	Purge Goals: Stabilization of Parameters for 3 consecutive readings within the following limits							
	+/-1 deg	+/-10%	+/-10%	+/-0.2 units	+/-10 %	+/-10%		

SAMPLE COLLECTION DATA

Sample Collected With: ☐ Bailer ☐ Pump/Pump Type peristaltic pump

Made of: ☐ Stainless Steel ☐ PVC ☐ Teflon ☐ Polyethylene ☐ Other ☐ Dedicated

Decon Procedure: ☐ Alconox Wash ☐ Tap Rinse ☐ DI Water ☐ Dedicated

(By Numerical Order) ☐ Other ____________________

Sample Description (color, turbidity, odor, sheen, etc.): ____________________

Replicate	Temp (°F/°C)	Cond. (uS/cm)	D.O. (mg/L)	pH	ORP (mV)			Comments/Observations
1								
2								
3								
4								
Average:								

QUANTITY	ANALYSIS
	Iron (mg/L)

Duplicate Sample No(s): ____________________

Sample Location: ____________________

Comments: ____________________

Signature: ____________________ Date: ____________________

LANDAU ASSOCIATES

PROJECT Boeing Auburn RI PROJ. NO. 025164.120.101

EVENT ______

Pore Water
Sample Collection Form

SAMPLE NO. ______

DATE COLLECTED ______ TIME ______

WEATHER ______ COLLECTOR ______

WATER LEVEL/WELL/PURGE DATA

Sample Type: ☑ Pore Water

Depth of Water Column: ______

Sample Interval below Sediment Surface: ______

Precipitation Info: ______

Depth of Mill Creek (at SWSG-4): ______

Sample Location: ______

Canister Install: **Date/Time** ______ **Canister Removal:** **Date/Time** ______

Excess Water Disposal to: ☐ Bucket or Drum ☐ Ground ☐ Other ______ ☐

SAMPLE COLLECTION DATA

Sample Collection Device: ☑ PDB ☑ PVC Pore Water Sampler Dedicated? ☑ Yes ☐ No

☐ Other ______

Decon Procedure (if not dedicated): ☐ Alconox Wash ☐ Tap Rinse ☐ DI Water ☐ Other ______

Sample Description (color, turbidity, odor, sheen, etc.): ______

QUANTITY	Analysis
3-40 mL VOA	Boeing 38 VOC's
2-40 mL VOA	SIM for vinyl chloride

Duplicate Sample No(s): ______

Comments: ______

Signature: ______ Date ______

LANDAU ASSOCIATES

PROJECT ______________ PROJ. NO. ______________

EVENT ______________

SAMPLE NO. ______________

DATE COLLECTED ______________ TIME ______________

WEATHER ______________ COLLECTOR ______________

Surface Water
Sample Collection Form

WATER LEVEL/WELL/PURGE DATA

Sample Type: ☐ Groundwater ☒ Surface Water ☐ Other

Depth of Water Column: ______________ Location of Sample Within Water Column: ______________

Precipitation Info: ______________

Sample Location: ______________

Begin Purge: Date/Time ______________ **End Purge: Date/Time** ______________

Purge Water Disposal to: ☐ 55-gal drum ☐ Storage Tank ☒ Ground ☐ Other ______________

Time	**Temp.** (°F/°C)	**Cond.** (uS/cm)	**DO** (mg/L)	**pH**	**ORP** (mV)	Comments/Observations
	Purge Goals: Stabilization of parameters for 3 consecutive readings within the following limits					
	+/-1 deg	+/-10%	+/-10%	+/-0.2 units	+/-10 %	
Average:						

SAMPLE COLLECTION DATA

Sample Collected With: ☐ Coliwassa ☐ Ladel ☐ Pump/Type ______________

Made of: ☐ Stainless Steel ☐ PVC ☐ Teflon ☐ Polyethylene ☐ Other ☐ Dedicated

Decon Procedure: ☐ Alconox Wash ☐ Tap Rinse ☐ DI Water ☐ Dedicated ☐ Other

Sample Description (color, turbidity, odor, sheen, etc.): ______________

pH Meter: YSI Cond Meter: YSI ORP Meter: YSI Calibration Date: ______________

QUANTITY	Analysis
3-40 mL VOA	Boeing 38 VOC's
2-40 mL VOA	SIM for vinyl chloride

Duplicate Sample No(s): ______________

Comments: ______________

Signature: ______________ Date ______________

Page ____ of ____

LANDAU ASSOCIATES

Air Sample Collection Form: Ambient / Indoor / Crawlspace

Project Name: ______________________________ Project Number: ______________________

Client: ______________________________ Sample Number: ______________________

Landau Rep: ______________________________ Date/Time Collected: ______________________

Location Information: ____

SAMPLE TYPE

☐ Ambient Air ☐ Indoor Air ☐ Crawlspace ☐ Basement ☐ Other: _______________

WEATHER DATA

Rainfall < 1" in 24 hrs.? (YES or **NO**) Irrigation not w/in 5 hrs.? (YES or **NO**) Standing water near sampling location? (YES or **NO**)

Air Temperature _________ °F or °C Wind Direction ___________ Wind Speed __________ mph Humidity ___________ %

Barometric Pressure___________ in Hg or mBar Is sampling occurring after frontal system during stable pressure? (**YES** or NO)

SAMPLE COLLECTION DATA

Sample Container: ☐ Summa Canister, Size (liters) _______________ ☐ Tedlar Bag, Size (liters): ____________________

Canister number: ______________

☐ Passive / Diffusive ☐ Other: ___________________________________

Manufacturer: ________________________

Sample Type: ☐ Grab ☐ Integrated (composite sample over time)

Height of Sample Above Floor/Ground: __________________ feet (to nearest tenth)

Ground/Floor Type: Soil, Wood, Carpet, Tile, Concrete Other: ____

Sample Collection/Purge Pump (if used): ____

Summa Canister, Pre-Sampling and Post-Sampling

Initial Vacuum: _________ in Hg Vacuum After Sample Collection: ______________ in Hg

LABORATORY ANALYSES:

____

____

Duplicate Sample Number(s): ____

Comments: ____

____

Signature: ______________________________ Date: ______________________

LANDAU ASSOCIATES

Page ____ of ____

Sub Slab Vapor / Soil Gas Sample Collection Form

Project Name: ______________________________ Project Number: ______________________

Client: ______________________________ Sample Number: ______________________

Landau Rep: ______________________________ Date/Time Collected: ______________________

Location Information: ____

SAMPLE TYPE

☐ Sub Slab Vapor ☐ Soil Gas ☐ Other: ____________________________

WEATHER DATA

Rainfall < 1" in 24 hrs.? (YES or **NO**) Irrigation not w/in 5 hrs.? (YES or **NO**) Standing water near sampling location? (YES or **NO**)

Air Temperature __________ °F or °C Wind Direction __________ Wind Speed __________ mph Humidity __________ %

Barometric Pressure __________ in HG or mBar Is sampling occurring after frontal system during stable pressure? (**YES** or NO)

SOIL GAS AND SUB SLAB INFORMATION AND AND PURGE DATA

Nature of Location: PERMENANT or TEMPORARY (circle one) ☐ Post-Run Tubing (PRT) ☐ Soil Gas Monitoring Well ☐ Other: ____________

Installation Method : ☐ Direct Push Drill Rig ☐ Hollow Stem Auger ☐ Rotosonic ☐ Other: ________________

☐ Hand Driven ☐ Rotohammer ☐ Vapor Pin Manufacturer:________________

If Permanent, Is Well Secure? (YES or NO or NA) Damaged (YES or NO) YES-Describe: ______________________

Materials: ☐ PVC Pipe ☐ Stainless Steel ☐ Teflon ☐ Nylon or Polyethylene Tubing ☐ Other: ____________

Well/Hole Diameter: _______ inches Total Depth of Well: _______ ft Depth to Groundwater: _______ ft

Vacuum/Pressure of source (in. H_2O): ____________________ Time: ______________

Purge Volume Calculation: ____

Purge: Begin Time ____________ End Time ____________ Casing Volume (ft^3): ___________

Flow Rate (liter or ml/min): ________________ Volume Purged (ft^3): _____________

VOLUME EXAMPLES

Diameter (in)	OD (in)	ID (in)	Vol (ft^3/ln ft)
0.25 (tubing)	0.250	0.170	0.00016
1 (sch. 40)	1.315	1.029	0.006
1.25 (sch. 40)	1.660	1.380	0.010
2 (sch. 40)	2.375	2.067	0.020

Vol. Purged (ft^3)	Temp. (°F/°C)	PID (ppm)	Other	Comments/Observations

LEAK TEST OPTIONS

☐ Shut-in Test Starting Vacuum: _________ in H2O *(target 100 inches H2O)* Test Duration: _________ minutes *(target > 1 min)*

Ending Vacuum: ___________ in H2O *(target no noticable vacuum decrease)* Result: PASS FAIL (circle one)

☐ Helium Shroud Design: ______________________________________ Helium Source Concentration:__________

Shroud Tracer Concentration Fluctuation: _________ % *(target ± 10%)* Tracer Equilibration Time: ___________*(target min. 5 min)*

Sample Air Tracer Concentration: ________ % of Shroud Conc. *(target <5%)*

☐ Water Bath (vapor pins only)

SAMPLE COLLECTION DATA

Sample Container: ☐ Summa Canister, Size (liters) ___________ Canister #:_________________ ☐ Tedlar Bag, Size (liters): ______________

☐ Passive / Diffusive Manufacturer:________________________ ☐ Other: ________________

Sample Type: ☐ Grab ☐ Integrated (composite sample over time)

Sample Collection/Purge Pump (if used): ____

Summa Canister, Pre-Sampling and Post-Sampling: Initial Vacuum: __________ in Hg Vacuum After Sample Collection: ___________ in Hg

LABORATORY ANALYSES: ____

Duplicate Sample Number(s) and Comments: ____

____

Signature: ______________________________ Date: ________________

LANDAU ASSOCIATES

Page ___ of ___

Utility Locate Checklist

Project Name ______________________________ Project No. ______________________________

Location ______________________________ Date ______________________________

Client ______________________________ Landau Rep. ______________________________

Exploration Number	**TV & Telep.**	**Lighting & Elect.**	**Fuel & Gas**	**Water**	**Drains & Sewer**	**Access / Restriction**	**O.K. To Drill/Exc.**	**Remarks**
(White)	(Orange)	(Red)	(Yellow)	(Blue)	(Green)			

Vapor Intrusion Assessment Building Survey

LANDAU ASSOCIATES

Project No.: ____________________

Client: ____________________ Date/Time: __________

Project Name: ____________________

Location: ____________________

Weather Conditions (note wind direction/intensity): ____________________

Prepared By: ____________________

1. OCCUPANT:

   Interviewed: Y / N

   Last Name:____________________First Name:____________________

   Contact Info:____________________

   Number of Occupants/persons at this location:____________________

   Age of Occupants:____________________

2. OWNER OR LANDLORD: (Check if same as occupant____)

   Interviewed: Y / N

   Last Name:____________________ First Name:____________________

   Address:____________________

   Contact Info:____________________

3. BUILDING CHARACTERISTICS:

   a. Type of Building: (Circle appropriate response)

Residential	School	Commercial/Multi-use
Industrial	Church	Other:

   b. If the property is residential, type? (Circle appropriate response)

Ranch	Split Level	Colonial
Raised Ranch	Contemporary	Mobile Home
Cape Cod	Apartment House	Townhouse/Condos

Duplex Log Home Modular

Other:

c. If multiple units, how many?

d. If the property is commercial, what type?

Business Type(s):

Does it include residences (i.e., multi-use)? Y / N If yes, how many?

4. OCCUPANT/OWNER QUESTIONAIRE

a. Typical hours home and rooms most occupied:

b. Building age:

c. Type of heating used in the building: (circle all that apply – note primary)

Hot air circulation Heat pump Hot water baseboard

Space heaters Steam radiation Radiant floor

Electric baseboard Wood stove Outdoor wood boiler

Other stove:

d. Primary type of fuel used in the building:

Natural gas Fuel oil Kerosene

Electric Propane Solar

Wood Coal

e. Boiler/furnace located in:

Basement Outdoors Main floor Other:

f. Ventilation:

Central air   Window units   Open window   Heat pump   Ceiling fan

None

g. Is there a radon mitigation system for the building/structure?   Y / N

Date of Installation:

Is the system active or passive?   Active / Passive

h. If it is a non-residential building, do they know if the building is under positive or negative pressure?

i. Water Supply:

Public water   Drilled well   Driven well   Dug well   Other:

j. Sewage Disposal:

Public sewer   Septic tank   Leach field   Dry well   Other:

k. How is roof runoff/storm drainage routed?

Downspouts directly to surface

Directed to the surface away from the building

Infiltrated

Collected and reused

l. Is the basement/lowest level occupied?

Full-time   Occasionally   Seldom   Almost Never

m. Does the garage have a separate heating unit?   Y / N

n. Has the building ever had a fire?   Y / N   When:

o. Is a kerosene or unvented gas space heater present?   Y / N
Where & Type?

p. Is there a workshop or hobby/craft area?   Y / N
Where & Type?

q. Is there smoking in the building? Y / N Frequency?

r. Have cleaning products been used recently? Y / N
When & Type?

s. Have cosmetic products been used recently? Y / N
When & Type?

t. Has painting/staining been done in the last 6 months? Y / N
Where & When?

u. Is there new carpet, drapes or other textiles? Y / N
Where & When?

v. Have air fresheners been used recently? Y / N
When & Type?

w. Is there a clothes dryer? Y / N If yes, is it vented outside? Y / N

x. Has there been a pesticide/herbicide application? Y / N
When, type, & location?

y. Do any of the building occupants use solvents or volatile chemicals at work? (e.g., chemical manufacturing or laboratory, auto mechanic or auto body shop, painting, fuel oil delivery, boiler mechanic, pesticide applicator, cosmetologist, carpet installer) Y / N

If yes, what type of solvents are used?

If yes, are their work clothes stored at or washed at home? Y / N

z. Do any of the building occupants regularly use or work at a **dry-cleaning** service? (circle appropriate response below)

Yes, use dry-cleaning regularly (weekly)

Yes, use dry-cleaning infrequently (monthly or less)

Yes, work at a dry-cleaning service

No

Unknown

aa. Ask them to review the Common Household Chemicals List (page 13) and to point out locations where these items are stored.

List specific locations/items that need further inspection based on responses to these questions:

5. BUILDING TOUR/INSPECTION
    a. General
        i. Review the Occupant/Owner Questionnaire and inspect associated locations of interest (e.g., heaters, HVAC unit, hobby area, etc.)
        ii. Above grade construction:

            Wood frame Concrete Stone Masonry/bricks

        iii. Are there air distribution ducts present? Y / N
        iv. Describe the supply and cold air return ductwork; its condition where visible; whether there is a cold air return and tightness of duct joints. Indicate the locations on the floor plan diagram.
        v. General use of each floor: (e.g., family room, bedroom, laundry, workshop, storage)

            Basement:

            1st Floor:

            2nd Floor:

            3rd Floor:

            4th Floor:

        vi. Please describe any odors in the building:
        vii. Use air current tubes or tracer smoke to evaluate airflow patterns and qualitatively describe:

            Airflow between floors:

            Airflow near a potential preferential pathway:

            Outdoor air infiltration:

            Infiltration into air ducts:

b. Basement (Circle all that apply)

Basement type:	full	slab	crawlspace	other:
Basement floor:	concrete	dirt	stone	other:
Basement floor:	unsealed	sealed	covered with:	
Foundation walls:	poured block	stone	other:	
Foundation walls:	unsealed	sealed	sealed with:	
The basement is:	wet	damp dry	moldy	
The basement is:	finished	unfinished	partially finished	

Is a sump present? Y / N

Is there water in the sump? Y / N

Basement/Lowest level depth below grade: (in feet)

Identify potential soil vapor entry points and approximate size: (e.g., cracks, utility ports, drains)

Note the general condition of the basement/crawlspace floor:

c. Kitchen

- i. Is there an exhaust fan? Y / N If yes, where is it vented?

d. Bathroom(s)

- i. Is there an exhaust fan? Y / N If yes, where is it vented?

e. Garage

- i. Is the garage attached? Y / N
- ii. Are petroleum-powered machines or vehicles stored in the garage? (e.g., lawnmower, ATV, car) Y / N Please specify:

f. Floor plans:

Draw a plan view sketches of the basement & upper floor(s) of the building (**use consistent orientation per plan)**.

Note any potential air sampling locations, preferential pathways, household chemicals, heating and ventilations elements, plumbing, doors, windows, and other items of interest.

i. Basement:

○

Dir.
Arrow

ii. First Floor:

Note any potential air sampling locations, preferential pathways, household chemicals, heating and ventilations elements, plumbing, doors, windows, and other items of interest.

Dir.
Arrow

iii. Second Floor:

Note any potential air sampling locations, preferential pathways, household chemicals, heating and ventilations elements, plumbing, doors, windows, and other items of interest.

Dir.
Arrow

iv. Outdoor Plot

Draw a sketch of the area surrounding the building being sampled. If applicable, provide information on spill locations; potential air contamination sources (industries, gas stations, repair shops, landfills, etc); outdoor air sampling location(s). Also indicate the locations of the well, septic, and drainage systems, if applicable; any known utilities; and a qualifying statement to help locate the site on a topographic map. **Note any standing water within the yard.**

○

Dir.
Arrow

g. Product inventory log

Describe the condition of the product containers as **Unopened (UO)**, **Used (U)**, or **Deteriorated (D)**. Photographs of the front and back of the product containers can replace the hand written list of chemical ingredients; however, the photographs must be of good quality & ingredient labels must be legible.

Location	Product Description	Size (units)	Condition (UO, U, D)	Chemical Ingredients	Field Instrument Reading (units)	Photo Y / N

Additional Notes/Comments:

Attachments: ____

Signed:____

Common Household Chemicals

- Adhesives (automotive, household, craft, plumbing)
- Household cleaners
- Lubricants
- Bonders
- Adhesive removers
- Antistatic aerosols
- Automotive parts cleaners
- Paint strippers
- “Spot removers” for fabrics
- Jewelry polish
- Water repellants
- Spray paints
- Dry-cleaned materials (e.g., clothes)
- Caulks and sealants
- Cosmetics including hair spray, nail polish, nail polish remover, and perfume/cologne
- Air fresheners and odor eliminators
- Inset repellants

Photograph Log

Roll No./Phone No.	Comments

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As-Built
Well Completion Form

Exploration No.: ____________

Well No. (If different than Expl. No.): ____

Client/Owner: ____________ Project No.: ____________

Project Name: ____________

Drilling Co.: ____________

LAI Rep(s): ____________

Installation Start Date: ____________ Hour: ______

Installation Finish Date: ____________ Hour: ______

Well Type: ☐ Single ☐ Nested ☐ Clustered

BORING AND WELL DIMENSIONS AND INSTALLATION DETAILS

DOE Unique Well No.: ____________

Number of Pipes in Boring: ____________

Boring Diameter at Top of Hole: ____________

Does Diameter of Hole Change? ____________

Boring Diameter at First Step Down: ____________

Depth of First Step Down: ____________

Boring Diameter at Second Step Down: ____________

Depth of Second Step Down: ____________

Well Completion Date: ____________

Elevation of Well Cover: ____________

Elevation of Top of Well Pipe: ____________

Depth to Water: ____________

Date: ____________ Time: ____________

MATERIALS USED

______ Sacks of ____________ Sand

______ Sacks of ____________ Concrete/Cement

______ Sacks of ____________ Grout Mix Used

______ Sacks of Bentonite Chips

______ Feet of ____-inch PVC Blank Casing

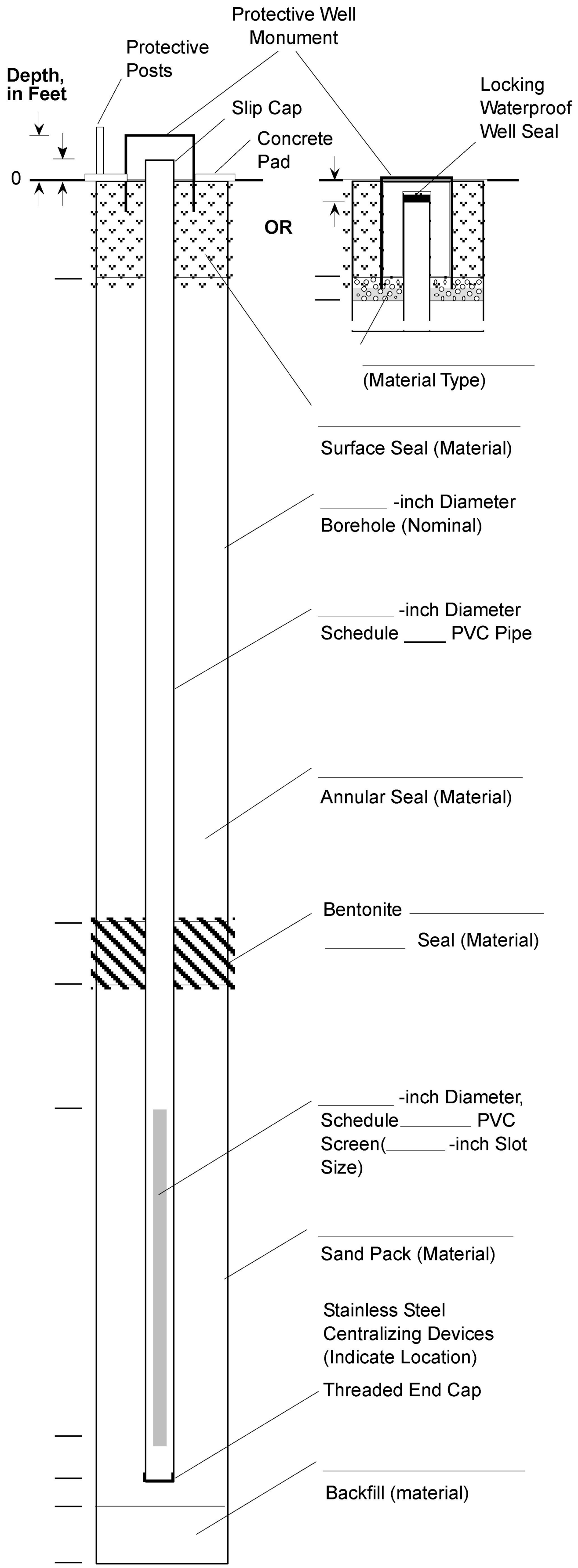
______ Feet of ____-inch PVC Slotted Screen

______ Threaded End Cap

______ Waterproof Well Seal/Slip Cap

______ Flush Mount/Aboveground Protective Monument

______ Protective Posts



\\Edmdata\wproc\000MasterForms\Field\Well As-Built Form.cdr

LANDAU ASSOCIATES

Well Development Record

Project Name: ____________________
Location: ____________________
Client: ____________________

Project No. ____________________
Date: ____________________
Landau Representative: ____________________

Well Number: ____________________

Time: ____________________

Depth to Water: ____________________
Well Depth: ____________________
Casing Diameter: ____________________
Casing Volume: ____________________

Volume of Schedule 40 PVC Pipe

Diameter (inch)	O.D. (inch)	I.D. (inch)	Volume (gal/ln ft)	Wt. Water (lbs/ln ft)
1.25	1.660	1.380	0.08	0.64
2	2.375	2.067	0.17	1.45
4	4.500	4.026	0.66	5.51
6			1.47	12.24

Est. Purge Volume: ____________________

Method of Development: ____________________

Surge Block: Yes ______ No ______

Begin Development: Time:
Finish Development: Time:

Final Volume Purged: ____________________
Water Disposal: ☐ 55-gal drum ☐ Storage Tank ☐ Ground ☐ Other __________

Initial Water Quality: (Turbidity, Color, Odor, Other) ____________________ Initial Yield: ______
pH: ________ Temp: ________ Conductivity: ________ Turbidity: ___
Notes: ____________________

Water Quality Notes: ____________________

Gallons	pH	Temperature	Conductivity	Turbidity	Comments

Final Water Quality: (Turbidity, Color, Odor, Other) ____________________
Final Yield: ____________________
pH: ________ Temperature: ________ Conductivity: ________ Turbidity: ________

Depth to Water After Development: ____________________ Well Depth After Development: ____________

APPENDIX C

Soil Gas Sampling

Appendix C
Soil Gas Sample Collection

Sub-Slab Soil Gas Sampling Procedure

After sample port installation, the sample point will be left undisturbed to equilibrate for a minimum of 30 minutes to 2 hours depending on the type of installation and whether water had to be used during the coring process. To prevent the sample point from being tampered with or damaged, a safety cone will be placed over the sampling assembly during the equilibration period for temporary sample points. Permanent monitoring points will be fitted with a monument or cap that is flush with the floor to prevent tripping hazards.

Each sub-slab sample will be collected in a 1-liter (L) or 6-L Summa (vacuum) canister fitted with a flow controller. The flow controller will be calibrated by the laboratory to a flow rate not to exceed 200 milliliters per minute.

After the equilibration period is complete:

1. Attach sample tubing to the Summa canister. The sample train between the sample tubing and the Summa canister may be configured differently depending on whether leak testing will be performed. Teflon or Nylaflow tubing is acceptable. If using a vapor pin, install new connection tubing (Masterflex® or other acceptable connection tubing) on the barb of the Vapor Pin and connect it to the sample tubing. If using a temporary vapor implant, the sample tubing connected to the porous implant should be long enough to connect it directly to the Summa canister. For permanent vapor implants, connect the sample tubing to the rest of the sampling train with appropriate, air-tight connectors based on the type of installation.
2. If conducting a helium leak test and/or shut-in test, follow the setup diagrams on Figures C-1 and C-2 and procedures outlined in the Helium Leak Test and Shut-In Test Procedure Sections of this Appendix.
3. Following the helium leak test and shut-in test, purge the sample tubing using a calibrated hand pump or graduated syringe. An example purge setup is described in the Purging section of this Appendix. The purge volume should be equal to three times the volume of the sample train and either the void space below the vapor pin or the vapor implant sand pack depending on the construction.
4. Turn on the helium detector and zero-out the instrument to read a helium concentration of 0 parts per million (ppm).
5. If not already in place, install the shroud over the sample point, tubing, and Summa canister. If a shut-in test was conducted, the shroud only needs to be placed over the sample point.
6. Connect the helium tank to the shroud from the exterior of the shroud and ensure that all connections are tight. Place the helium detector inside the shroud. Only ultra-pure helium should be used. Balloon grade helium can contain other contaminants and is not acceptable for use in sampling.
7. Attach the shroud lid to the shroud, if necessary. Release one burst of helium into the shroud.

8. Concentrations should be at least two orders of magnitude above the lower detection limit of the helium detector (for example: if the lower detection limit is 25 ppm, the concentration in the shroud should be at least 2,500 ppm). It is expected that helium concentrations will peak and begin to fall. Maintain concentrations inside the shroud at least two orders of magnitude above the lower detection limit. If concentrations fall near or below that concentration, add another short-burst of helium to maintain the minimum concentration.
9. Open the Summa canister valve to begin collecting the sample. If the summa canister is inside the shroud, use the attached gloves to open the Summa canister valve.
10. Record helium concentration and time at the start of sampling and at the end of sampling. Also, record helium concentrations in the shroud before and after each burst of helium to capture maximum and minimum concentrations within the shroud.
11. Once the vacuum gauge on the Summa canister reaches 0 inches of mercury (in. Hg), remove the shroud lid and close the valve on the Summa canister. Ensure the Summa canister valve is closed prior to disconnecting it from the well to prevent accidental entrance of remnant low-level helium from the shroud into the Summa canister.
12. If the sampling point is temporary, the sample point assembly will be removed and the core hole patched with hydraulic expanding cement to reseal the concrete slab.

Borehole Soil Gas Sampling Procedure

This procedure applies to deeper soil gas sampling points installed outside of a building. After sample port installation, the sample point will be left undisturbed to equilibrate for a minimum of 30 minutes. To prevent the sample point from being tampered with or damaged, a safety cone will be placed over the sampling assembly during the equilibration period for temporary sample points. Permanent monitoring points will be fitted with an appropriate protective monument. Depending on the location, flush traffic-rated or stick-up monuments may be appropriate.

Each soil gas sample will be collected in a 1-liter (L) or 6-L Summa (vacuum) canister fitted with a flow controller. In some instances, a smaller Summa canister may be acceptable, if appropriate, analytical reporting limits can be achieved. The flow controller will be calibrated by the laboratory to a flow rate not to exceed 200 milliliters per minute.

After the equilibration period is complete:

1. Select the appropriate height shroud to fully encapsulate the aboveground portion of the sample port and, if using, drill tooling. Teflon® or Nylaflow tubing should be used throughout the sample train; avoid use of polyethylene tubing. Place the shroud over the sample port and extend the sample tubing through the outlet at the top of the shroud.
2. Hydrated bentonite or bentonite clay can be used around the base of the shroud if an uneven ground surface is present. Though this is usually not necessary in order to maintain adequate helium levels inside the shroud.
3. If conducting a helium leak test and/or shut-in test, follow the setup diagrams on Figures C-1 and C-2 and procedures outlined in the Helium Leak Test and Shut-In Test Procedure Sections of this Appendix.

4. Following the helium leak test and shut-in test, purge the sample tubing using a calibrated hand pump or graduated syringe. An example purge setup is described in the Purging section of this Appendix. The purge volume should be equal to three times the volume of the sample tubing, the vapor implant, and sand pack (if using).
5. If a shut-in test was conducted, the shroud only needs to be placed over the sample point.
6. Connect the helium tank to the shroud from the exterior of the shroud, and ensure that all connections are tight.
7. Insert the probe of the meter or the entire meter inside the shroud depending on the type of shroud being used.
8. Release helium into the shroud. Concentrations should be at least two orders of magnitude above the lower detection limit of the helium detector (for example: if the lower detection limit is 25 ppm, the concentration in the shroud should be at least 2500 ppm). It is expected that helium concentrations will peak and begin to fall. Maintain concentrations inside the shroud at least two orders of magnitude above the lower detection limit. If concentrations fall near or below that concentration, add another short-burst of helium to maintain the minimum concentration.
9. Open the Summa canister valve to begin collecting the sample. If the summa canister is inside the shroud, use the attached gloves to open the Summa canister valve.
10. Record helium concentration and time at the start of sampling and at the end of sampling. Also, record helium concentrations in the shroud before and after each burst of helium to capture maximum and minimum concentrations within the shroud.
11. Once the vacuum gauge on the Summa canister reaches 0 in. Hg, close the valve on the Summa canister. Ensure the Summa canister valve is closed prior to disconnecting it from the well to prevent accidental entrance of remnant low-level helium from the shroud into the Summa canister.
12. If the sampling point is temporary, the sample point assembly will be removed and the bore hole will be decommissioned, in accordance with appropriate regulations, and patched with like material to the surrounding surface.

Helium Leak Test Procedure

The helium leak test setup is shown on the attached Figure C-1. Select the appropriate height shroud to fully encapsulate the aboveground portion of the sample port and tooling. Teflon® or Nylaflow tubing should be used throughout the sample train; avoid use of polyethylene tubing.

1. Place the shroud over the sample port and extend the sample tubing through the outlet at the top of the shroud.
2. Hydrated bentonite or bentonite clay can be used around the base of the shroud if an uneven ground surface is present. Though this is usually not necessary in order to maintain adequate helium levels inside the shroud.
3. Connect the helium tank to the shroud from the exterior of the shroud, and ensure that all connections are tight.
4. Turn on the helium detector and zero-out the instrument in ambient air to read a helium concentration of 0 percent and/or 0 ppm. Insert the probe of the meter inside the shroud.

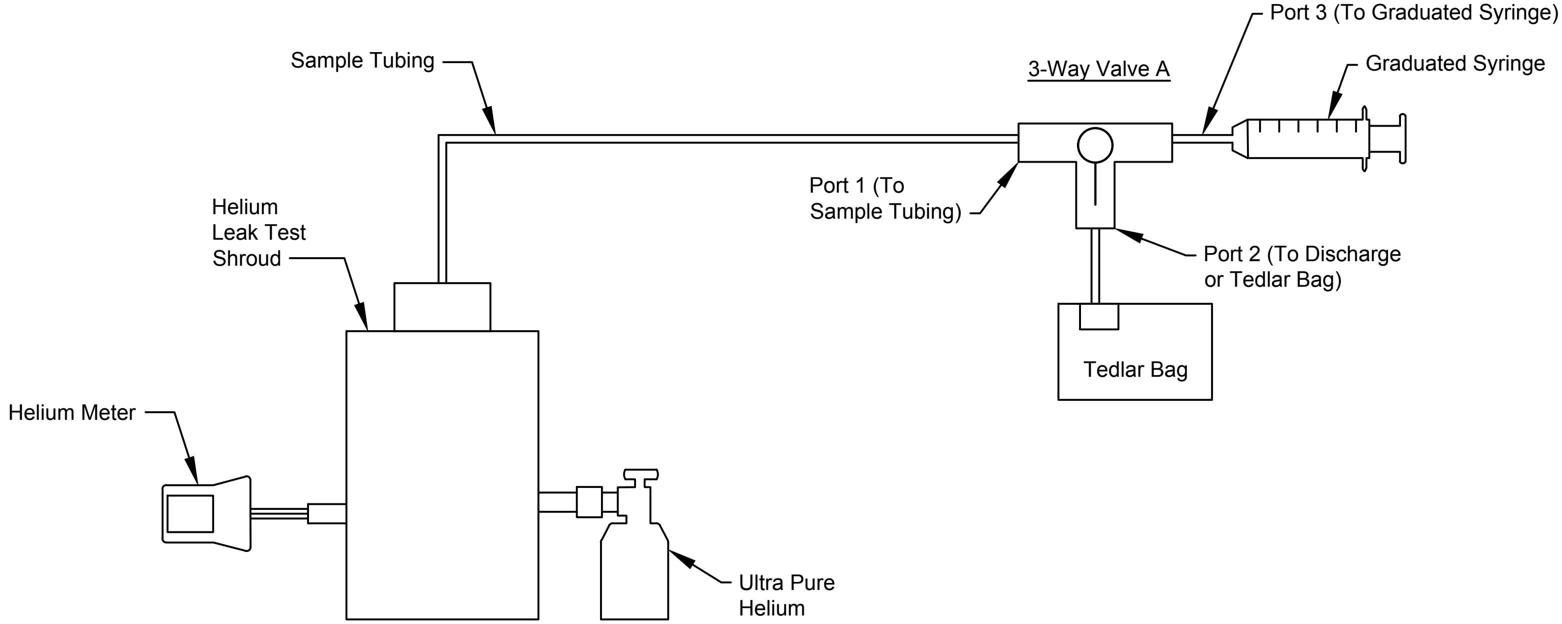
5. Release helium into the shroud until the helium detector indicates the air inside the shroud contains at least 50 percent helium. Record the highest concentration of helium in ppm.
6. Purge the sample train: Connect the end of the sample tubing to port 1 of a 3-way valve (3-way valve A on Figure C-1) and connect a large graduated syringe to port 3 of the 3-way valve A (port 2 is left open for discharge). Purge 1 volume of air from the sample train by placing the valve so that port 2 (discharge) is closed and extracting the required volume of air with the graduated syringe; turn the valve so port 1 (sample tubing) is closed, and push the extracted air out of the syringe through port 2.
7. Collect soil gas for leak testing: Connect a Tedlar bag to port 2 of the 3-way valve A. Turn the valve so port 2 is closed. Collect a sample of air from the tubing using the graduated syringe. Turn the valve so port 1 is closed and empty the syringe into a Tedlar bag. Repeat the process until approximately 400 milliliters (mL) of soil gas has been purged into the Tedlar bag. Turn the valve so port 1 is closed. Leave the valve in this position until the shut-in test has been completed and the sample is ready to be collected. Close the Tedlar bag and remove it from the valve. Remove the syringe from Port 3 of the 3-way valve A. Leave the sample tubing connected to the 3-way valve A.
8. Remove the helium detector from the sample shroud. Zero-out the instrument to read helium concentration of 0 ppm and 0 percent.
9. Insert the helium detector into the Tedlar bag to measure the helium concentration in the extracted soil gas. Concentrations of helium in the sample should be zero.
   a. If concentrations of helium are detected in the Tedlar bag sample, a leak may be present in the surface seal, allowing ambient air to enter the well. Double-check surface seal, tightness of fittings and other possibilities for leaks and repeat the test.

Shut-In Test Procedure

1. The shut-in test procedure is shown on the attached Figure C-2. Attach the Summa canister portion of the sample train to port 2 of the 3-way valve A. The Summa canister portion of the sample train consists of the Summa canister, a vacuum gauge, and inline flow controller. To port 3 of the 3-way valve A, attach an inline vacuum gauge, a second 3-Way Valve (3-way valve B), and a large graduated syringe; on 3-way valve B, connect port 1 to the syringe, port 2 to the inline vacuum gauge and 3-way valve A, and leave port 3 open for discharge of purge air. The same syringe may be used for the helium leak test and shut-in test unless there are concerns about helium contamination in the syringe.
2. Turn 3-way valve A so that port 1 (sample tubing) is closed. Turn 3-way valve B so that port 3 (discharge) is closed. At this point, the sample train between the Summa canister and the syringe will be open. Use the syringe to pull a vacuum on the sample train. Both vacuum gauges should indicate a vacuum has been applied. Record the shut-in test starting vacuum pressure. Hold the vacuum for 2 minutes. Record the shut-in test ending vacuum. If the vacuum holds steady, this indicates there are no leaks in the sample train between the sample tubing and the summa canister. At this point, the entire sample train has been tested for leaks.
   a. If the vacuum pressure drops during the shut-in test period, a leak is present. Double-check tightness of fittings, examine tubing and other equipment for defects or other possible leaks and repeat the test.

Purging

1. The purge set-up is shown on the attached Figure C-2. Turn valve B so that port 3 (discharge) is closed. Turn 3-way valve A so that port 2 (Summa canister) is closed. At this point, the sample train will be open between the sample tubing and the syringe. Use the syringe to purge 3 volumes from the sample train (approximately 6 mL per ft of ¼- inch sample tubing) by filling the syringe, turning 3-way valve B so port 2 is closed, and discharge the air from the syringe through port 3. Repeat the process if the required purge volume is greater than the capacity of the syringe. Record the purge volume.
2. Once purging is complete, turn 3-way valve A so that port 1 (syringe) is closed. The sample train will then be open between the Summa canister and the sample tubing.

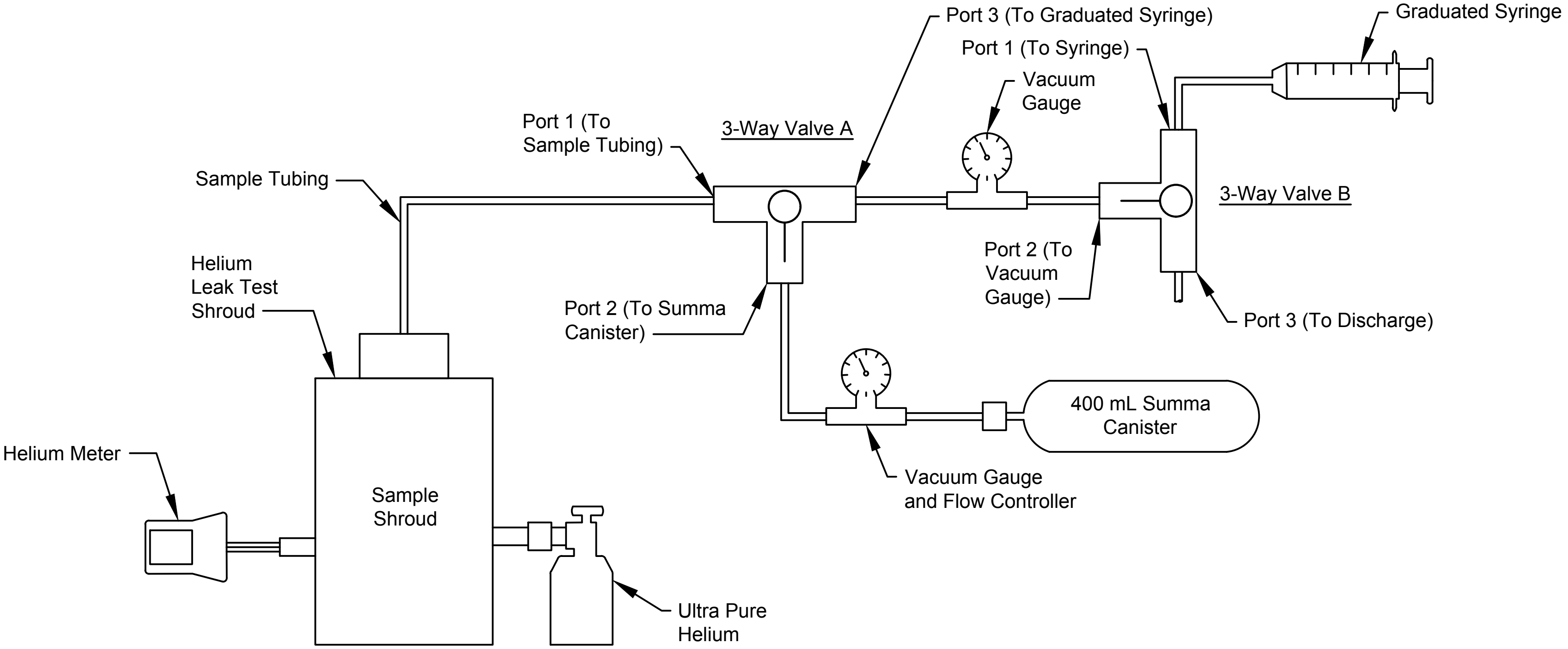


LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

Helium Leak Test

Figure
C-1



LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

Shut-in Test, Purge and Sample Collection Set-up

Figure
C-2

APPENDIX E

Quality Assurance Project Plan

Quality Assurance Project Plan
Boeing Auburn Facility
Auburn, Washington

October 23, 2017

Prepared for

The Boeing Company
Seattle, Washington

LANDAU ASSOCIATES

950 Pacific Avenue, Suite 515
Tacoma, WA 98402
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Quality and Assurance Project Plan
Boeing Auburn Facility
Auburn, Washington

This document was prepared by, or under the direct supervision of, the technical professionals noted below.

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Project Manager

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Project Coordinator:	Juliann Cooley

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LIST OF ABBREVIATIONS AND ACRONYMS

Boeing	The Boeing Company
COC	chain of custody
DQO	data quality objective
Ecology	Washington State Department of Ecology
EDD	electronic data deliverable
EIM	Ecology’s Environmental Information Management database
EPA	US Environmental Protection Agency
LAI	Landau Associates, Inc.
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LOQ	limits of quantitation
MQO	measurement quality objective
MS	matrix spike
MSD	matrix spike duplicate
QA	quality assurance
QC	quality control
QAPP	Quality Assurance Project Plan
RI	remedial investigation
RPD	relative percent difference
SAP	Sampling Analysis Plan
TOC	total organic carbon
TPH-D	diesel-range total petroleum hydrocarbon
TPH-G	gasoline-range total petroleum hydrocarbon
TPH-O	motor oil-range total petroleum hydrocarbon
VOC	volatile organic compound

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1.0 INTRODUCTION

The Boeing Company (Boeing) is currently undergoing corrective action at their Auburn Fabrication Division facility (facility) located at 700 15th Street Southwest in Auburn, Washington (Figure 1). The facility is used to manufacture airplane parts. Corrective action requirements are documented in an Agreed Order (No. DE 01HWTRNR-3345) dated August 14, 2002 and the First Amended Agreed Order dated February 21, 2006, both with Washington State Department of Ecology (Ecology). This quality assurance project plan (QAPP) presents the project quality assurance objectives, laboratory analytical methods, quality assurance/quality control (QA/QC) requirements, and data management procedures in support of corrective actions taking place at the facility and at downgradient properties (Site). This QAPP was prepared using the Ecology Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies (Ecology 2004). This QAPP is intended to be used in conjunction with the project Sampling and Analysis Plan (SAP; LAI 2017). Specific work plans provide additional details related to Site setting and specific investigative work to be conducted.

2.0 PROJECT TEAM ORGANIZATION AND RESPONSIBILITIES

The project team organizational structure was developed based on the requirements of the field and laboratory activities. The key positions/contractors and associated responsibilities are described below:

- Boeing Project Manager — Responsible for overseeing the implementation of the Agreed Order and feasibility study (FS) at the Facility and communicating status and issues related to the RI to the Ecology Project Manager. The Boeing Project Manager is the contact for the Landau Associates, Inc. (LAI) Project Manager.
- LAI Project Manager — Responsible for implementation of all aspects of the FS Work Plans, SAP, and QAPP. Specific responsibilities include review and approval of revisions to FS documentation, overseeing that all technical procedures are followed, reporting of deviations from the Ecology-approved FS Work Plans, SAP, and QAPP to the Boeing Project Manager, and overseeing that data collected will satisfy the QA objectives discussed in Section 3.0.
- LAI QA Manager – Responsible for insuring that data is of sufficient quality to achieve the Data Quality Objectives (DQOs) presented in this QAPP.
- Ecology Project Managers — Responsible for overseeing the implementation of the Agreed Order and the First Amended Agreed Order dated February 21, 2006, both with Boeing.
- Analytical Laboratory Project Manager — Responsible for providing sample bottles, performing chemical analyses per the QAPP and reporting of data as required by the QAPP. Boeing’s contracted laboratories at the date of this report are Eurofins Lancaster Laboratories, Inc., located in Lancaster, Pennsylvania; Analytical Resources, Inc., located in Tukwila, Washington; TestAmerica Laboratories, located in Tacoma, Washington; and Apex Laboratories, located in Tigard, Oregon

3.0 QUALITY ASSURANCE OBJECTIVES

QA objectives consist of DQOs and Measurement Quality Objectives (MQOs). DQOs are established when the data will be used to make a critical decision, such as selecting between two alternative conditions or to determine compliance with a standard. MQOs specify how good the data must be in order to fulfill the project's objectives; they are the acceptance thresholds for data quality indicators. Data quality indicators are precision, bias, and sensitivity.

3.1 Representativeness

Representativeness expresses the degree to which data accurately and precisely represent an actual condition or characteristic of a population. Representativeness can be evaluated using replicate samples, representative sampling locations, and blanks. Representativeness for the FS sampling will be accomplished using appropriate selection of sampling locations for each media of potential concern (groundwater, surface water, soil, soil vapor, and air). To determine that the analytical results are representative of the sampled item and not influenced by cross-contamination, method blanks will be analyzed with each analysis as described in Section 5.5.6.

3.2 Comparability

Comparability expresses the confidence with which one data set can be evaluated in relation to another data set. For this work, comparability of data will be established through the use of standard analytical methodologies with analytical limits of quantitation (LOQs) that can meet screening level criteria to the extent practicable, standard reporting formats, and common traceable calibration and reference materials. Methods to be used for analysis of groundwater, surface water, soil, soil vapor, and air samples are discussed in Section 4.0.

3.3 Measurement Quality Objectives

MQOs for the project specify how good the data must be in order to meet the objectives of the project and are based on precision and accuracy, as described in this section.

3.3.1 Precision

Precision measures the reproducibility of measurements under a given set of conditions. Specifically, it is a quantitative measure of the variability of a group of measurements compared to their average values. Analytical precision is measured through matrix spike/matrix spike duplicate (MS/MSD) and/or through laboratory control sample/laboratory control sample duplicate (LCS/LCSD) for organic analysis and through laboratory duplicate samples for inorganic analyses.

Analytical precision measurements will be carried out on project-specific samples when possible as described in Section 5.0. Laboratory precision will be evaluated against quantitative relative percent difference (RPD) performance criteria provided by the laboratory.

Field precision will be evaluated by the collection of blind field duplicate samples as described in Section 5.0. Control limits for the groundwater field duplicates will be 20 percent unless the duplicate sample values are within five times the LOQ, in which case the control limit interval will be plus or minus the LOQ.

Precision measurements can be affected by the nearness of a chemical concentration to the method detection limit, where the percent error (expressed as RPD) increases. The equation used to express precision is as follows:

$$RPD = \left| \frac{C_1 - C_2}{(C_1 + C_2)/2} \right| x\,100$$

Where: C1 = first sample value

C2 = second sample value (duplicate)

RPD = relative percent difference.

3.3.2 Accuracy

Accuracy is an expression of the degree to which a measured or computed value represents the true value. Field accuracy is controlled by adherence to sample collection procedures as outlined in the SAP.

Analytical accuracy may be assessed by analyzing “spiked” samples with known standards (surrogates, LCS, and/or MS) and measuring the percent recovery. Accuracy measurements on MS samples will be carried out as described in Section 5.0. Because MS/MSDs measure the effects of potential matrix interferences of a specific matrix, the laboratory will perform MS/MSDs only on samples from this investigation and not from other projects. Surrogate recoveries will be determined for every sample analyzed for organics.

Laboratory accuracy will be evaluated against quantitative MS and surrogate spike recovery performance criteria provided by the laboratory. Accuracy can be expressed as a percentage of the true or reference value, or as a percent recovery in those analyses where reference materials are not available and spiked samples are analyzed. The equation used to express accuracy is as follows:

$$\begin{matrix}\text{Percent} \\ \text{Recovery}\end{matrix} = \frac{(\text{Spiked Sample Result} - \text{Unspiked Sample Result})}{\text{Amount of Spike Added}} \; x \;\, 100$$

Control limits for percent recovery for groundwater, soil, and vapor samples will be laboratory acceptance limits generated according to U.S. Environmental Protection Agency (EPA) guidelines.

3.3.3 Bias

Bias is the systematic or persistent distortion of a measured process that causes errors in one direction. Bias of the laboratory results will be evaluated based on analysis of method blanks and MS samples as described in Section 5.0.

3.3.4 Sensitivity

Sensitivity is the ability to discern the difference between very small amounts of a substance. For the purposes of this project, sensitivity is the lowest concentration that can be accurately detected by the analytical method. The analytical method will be considered sufficiently sensitive if the LOQs are below project screening levels. Proposed analytical methods and LOQs are discussed in Section 4.0.

3.3.5 Completeness

Completeness is a measure of the proportion of data obtained from a task sampling plan that is determined to be valid. It is calculated as the number of valid data points divided by the total number of data points requested. The QA objective for completeness during this project will be 95 percent. Completeness will be routinely determined and compared to this control criterion.

4.0 LABORATORY METHODS

Groundwater samples are routinely analyzed for volatile organic compounds (VOCs), dissolved metals (arsenic, cadmium, and nickel), total organic carbon (TOC), sulfate, ethane, ethene, methane, and diesel-range and motor oil-range petroleum hydrocarbons (TPH-D and TPH-O, respectively). Surface water and sediment pore water samples are routinely analyzed for VOCs and occasionally sampled for natural attenuation parameters (TOC, sulfate, ethane, ethene, and methane). Soil samples may be analyzed for VOCs, semi-volatile organic compounds, metals (arsenic, lead, cadmium, chromium, and nickel), polychlorinated biphenyls, TPH-D, TPH-O, and gasoline-range petroleum hydrocarbons (TPH-G). Soil vapor and air samples will be analyzed for VOCs only.

Laboratory methods, laboratory target LOQs, and screening levels for the analysis of the above constituents and select constituents that may be analyzed in water (groundwater and surface water[1]), soil, soil vapor, and air samples are summarized in Tables 1, 2, 3, and 4, respectively. For all groundwater analyses except dissolved metals, any suspended material in the sample will be allowed to settle and the sample will not be agitated prior to analysis of the supernatant. For the dissolved metals analyses, the samples will be filtered in the field to remove any suspended material. A silica gel cleanup will be applied to all soil and water samples analyzed for TPH-D and TPH-O. Sample containers, preservation, and holding times are provided in Table 5.

Analytes where laboratory target LOQs exceed screening levels are presented in Table 6. If new or modified analytical procedures become available that result in the reporting limits meeting the respective screening levels, Boeing will submit a technical memorandum and a revised Table 6 to Ecology (Ecology 2012).

---

[1] Only groundwater screening levels for constituents in water are shown as they are typically more conservative than surface water screening levels.

5.0 QUALITY ASSURANCE/QUALITY CONTROL REQUIREMENTS

This section describes the procedures that will be implemented to:

1. Ensure sample integrity from the time of sample collection to the time of analysis in the laboratory;
2. Obtain the appropriate chemical and physical data;
3. Collect field and laboratory QC samples;
4. Monitor performance of the laboratory and field measurement systems;
5. Correct any deviations from the methods or QA requirements established in this QAPP; and
6. Report and validate the data.

5.1 Laboratory Instrument Calibration

The Analytical Laboratory Project Manager is responsible for maintaining laboratory instruments in proper working order including routine maintenance and calibration, and training of personnel in maintenance and calibration procedures. Laboratory instruments will be properly calibrated with appropriate check standards and calibration blanks for each parameter before beginning each analysis. Instrument performance check standards, where required, and calibration blank results will be recorded in a laboratory logbook dedicated to each instrument. At a minimum, the preventive maintenance schedules contained in the EPA methods and in the equipment manufacturer's instructions will be followed. Laboratory calibration procedures and schedules will be as described in the laboratory QAPP.

5.2 Field Equipment Calibration

Field meters, including pH, conductivity, dissolved oxygen, temperature probes, and photoionization detector will be calibrated and maintained in accordance with the manufacturer’s specifications. All routine maintenance will be recorded in the field equipment logs.

5.3 Field Documentation

A complete record of all field activities will be maintained for the duration of the field phase of the work. Documentation will include the following:

- Daily recordkeeping by field personnel of all field activities
- Recordkeeping of all samples collected for analysis (field sampling forms)
- Use of sample labels and tracking forms for all samples collected for analysis.

The field logs will provide a description of all sampling activities, sampling personnel, weather conditions, and a record of all modifications to the procedures and plans identified in the SAP. The field logs are intended to provide sufficient data and observations to enable participants to reconstruct events that occurred during the sampling period.

Sample possession and handling will also be documented so that it is traceable from the time of sample collection to the laboratory and data analysis. All field logs, sample collection forms, and chain-of-custody (COC) forms will be electronically scanned and copies placed in the electronic project file.

5.4 Sample Handling Procedures and Transfer of Custody

Samples submitted to the analytical laboratories will be collected in the appropriate sample containers and preserved as specified in Table 5. The storage temperatures and maximum holding times for physical/chemical analyses are also presented in Table 5.

The transportation and handling of samples will be accomplished in a manner that not only protects the integrity of the sample, but also prevents any detrimental effects due to release of samples. Samples will be logged on a COC form and will be kept in coolers on ice until delivery to the analytical laboratory. The laboratory will provide appropriate packing material for shipping the samples so that damage to the samples is avoided. Samples will be sent to the project analytical laboratory in batches. The COC will accompany each cooler in a shipment of samples to the laboratory. Each cooler will also have custody seals placed on the outside to indicate if tampering has taken place during shipment. Cooler receipt forms will be filled out by the laboratory. Upon receipt by the laboratory, custody seals will be inspected and the COC form signed and dated by laboratory personnel. Laboratory personnel will verify sample numbers and the condition of each sample. Shipping manifests and COC forms signed and dated by laboratory personnel will be considered sufficient documentation of sample custody transfer from the sampler, through the shipping agent, to the analysts at the laboratory. A copy of each COC form will be retained by the sampling team for the project file and the duplicate copies will be sent with the samples. Bills of lading will also be retained as part of the documentation for the COC records. In conjunction with data reporting, the laboratory will return the original COC forms to the LAI Project Manager for inclusion into the central project file.

5.5 Field and Laboratory Quality Control Samples

Field and analytical laboratory QC samples will be collected to evaluate data precision, accuracy, representativeness, completeness, bias, and comparability of the analytical results for the FS. The QC samples and the frequency at which they will be collected and/or analyzed are described in the following sections. Quality control criteria are provided in Appendix A.

5.5.1 Blind Field Duplicates

A blind field duplicate will be collected at a frequency of at least one sample per 20 groundwater samples per chemical analysis, not including laboratory and field QC samples, but not less than one field duplicate per sampling event (any continuous sampling period not interrupted by more than 2 days). The blind field duplicate will consist of a split sample collected at a single sample location. Groundwater blind field duplicates will be collected by alternately filling sample containers for both the original and the corresponding duplicate sample at the same location to decrease variability between the duplicates. No soil blind field duplicate samples will be collected due to the inherent heterogeneity of the samples. Soil vapor and air blind field duplicates will be collected at a frequency of at least 1 per 20 samples, but no less than one field duplicate per sampling event. The blind field duplicate will be collected by concurrently filling a second Summa canister at the same location. Blind field duplicate sample results will be used to evaluate data precision.

5.5.2 Field Trip Blanks

Field trip blanks will consist of de-ionized or distilled water sealed in a sample container provided by the analytical laboratory. The trip blank will accompany samples collected for the analysis of VOCs and TPH-G during transportation to and from the field, and then will be returned to the laboratory with each shipment. The trip blank will remain unopened until submitted to the laboratory for analysis. One trip blank per cooler containing water and/or soil samples for VOCs and TPH-G analysis will be evaluated to determine possible sample contamination during transport.

5.5.3 Laboratory Matrix Spike

A minimum of one project sample per 20 samples per analyses will be spiked by the laboratory to evaluate potential matrix interference. These analyses will be performed to provide information on accuracy and to verify that extraction and concentration levels are acceptable. The laboratory spikes will follow EPA guidance for MS and MSDs.

5.5.4 Laboratory Matrix Spike Duplicate

A minimum of one project sample per 20 samples per analyses will be spiked by the laboratory as a MSD. The analysis of MSD samples will be performed to provide information on the precision of chemical analyses. The laboratory spikes will follow EPA guidance for MS and MSDs.

5.5.5 Laboratory Duplicates

A minimum of one laboratory duplicate per 20 samples, or one laboratory duplicate sample per batch of samples if fewer than 20 samples are contained in a batch, will be analyzed for metals. These analyses will be performed to provide information on the precision of chemical analyses. The laboratory duplicate will follow EPA guidance in the method.

5.5.6 Laboratory Method Blanks

A minimum of one laboratory method blank per 20 samples, one every 12 hours, or one per batch of samples analyzed (if fewer than 20 samples are contained in a batch) will be analyzed for all parameters to assess possible laboratory contamination. Dilution water will be used whenever possible. Method blanks will contain all reagents used for analysis. The generation and analysis of additional method, reagent, and glassware blanks may be necessary to verify that laboratory procedures do not contaminate samples.

5.5.7 Laboratory Control Sample

A minimum of one LCS per 20 samples, or one LCS per sample batch if fewer than 20 samples are contained in a batch, will be analyzed for all parameters.

5.5.8 Surrogate Spikes

All project samples analyzed for organic compounds will be spiked with appropriate surrogate compounds as defined by the analytical methods.

5.6 Laboratory Quality Assurance/Quality Control

QA/QC for chemical testing includes laboratory instrument and analytical method QA/QC. Instrument QA/QC monitors the performance of the instrument and method QA/QC monitors the performance of sample preparation procedures. The analytical laboratory will be responsible for instrument and method QA/QC. QA/QC procedures to be performed by the laboratory for analysis of water, soil, soil vapor, and air samples will be in accordance with methods specified in Tables 1, 2, 3, and 4, respectively.

When an instrument or method control limit is exceeded, the Analytical Laboratory Project Manager will contact the LAI Project Manager immediately. The laboratory will be responsible for correcting the problem and will re-analyze the samples within the sample holding time if sample re-analysis is appropriate. Corrective actions are described further in Section 6.0.

6.0 CORRECTIVE ACTIONS

Corrective actions will be needed for two categories of non-conformance:

- Deviations from the methods or QA requirements established in this QAPP
- Equipment or analytical malfunctions.

Corrective action procedures to be implemented based on detection of unacceptable data are developed on a case-by-case basis. Such actions may include one or more of the following:

- Altering procedures in the field
- Using a different batch of sample containers
- Performing an audit of field or laboratory procedures
- Re-analyzing samples (if holding times allow)
- Resampling and analyzing
- Evaluating sampling and analytical procedures to determine possible causes of the discrepancies
- Accepting the data without action, acknowledging the level of uncertainty
- Rejecting the data as unusable.

During field operations and sampling procedures, the field personnel will be responsible for conducting and reporting required corrective actions. A description of any action taken will be entered in the daily field notebook. The project manager will be consulted immediately if field conditions are such that conformance with this QAPP is not possible. The field coordinator will consult with the LAI Project Manager, who may authorize changes or exceptions to the QA/QC portion of the QAPP, as necessary and appropriate.

During laboratory analysis, the Laboratory QA Officer will be responsible for taking required corrective actions in response to equipment malfunctions. If an analysis does not meet DQOs outlined in this QAPP, corrective action will follow the guidelines in the noted EPA analytical methods and the EPA guidelines for data validation for organics and inorganics analyses (EPA 1999, 2004, respectively). At a minimum, the laboratory will be responsible for monitoring the following:

- Calibration check compounds must be within performance criteria specified in the EPA method or corrective action must be taken prior to initiation of sample analysis. No analyses may be performed until these criteria are met.
- Before processing any samples, the analyst should demonstrate, through analysis of a reagent blank that interferences from the analytical system, glassware, and reagents are within acceptable limits. Each time a set of samples is extracted or there is a change in reagents, a reagent blank should be processed as a safeguard against chronic laboratory contamination. The blank samples should be carried through all stages of the sample preparation and measurement steps.

- Generally, method blanks should be below instrument detection limits. If contaminants are present, then the source of contamination must be investigated, corrective action taken and documented, and all samples associated with a contaminated blank re-analyzed. If, upon re-analysis, blanks do not meet these requirements, the LAI Project Manager will be notified immediately to discuss whether analyses may proceed.
- Surrogate spike analysis must be within the specified range for recovery limits for each analytical method utilized or corrective action must be taken and documented. Corrective action includes: 1) reviewing calculations, 2) checking surrogate solutions, 3) checking internal standards, and 4) checking instrument performance. Subsequent action could include recalculating the data and/or re-analyzing the sample if any of the above checks reveal a problem. If the problem is determined to be caused by matrix interference, re-analysis may be waived, if so directed, following consultation with the LAI Project Manager. If the problem cannot be corrected through re-analysis, the laboratory will notify the LAI Project Manager prior to data submittal so that additional corrective action can be taken, if appropriate.
- If the recovery of a surrogate compound in the method blank is outside the recovery limits, the blank will be re-analyzed along with all samples associated with that blank. If the surrogate recovery is still outside the limits, the LAI Project Manager will be notified immediately to discuss whether analyses may proceed.
- If quantitation limits or MS control limits cannot be met for a sample, the LAI Project Manager will be notified immediately to discuss corrective action required.
- If holding times are exceeded, all positive and undetected results may need to be qualified as estimated concentrations. If holding times are grossly exceeded, the LAI Project Manager may determine the data to be unusable.

If analytical conditions are such that nonconformance with this QAPP is indicated, the LAI Project Manager will be notified as soon as possible so that any additional corrective actions can be taken. The laboratory project manager will then document the corrective action by a memorandum submitted to the LAI Project Manager. A narrative describing the anomaly; the steps taken to identify and correct the anomaly; and any recalculation, re-analyses, or re-extractions will be submitted with the data package in the form of a cover letter.

7.0 DATA VERIFICATION AND VALIDATION

All data will be verified and validated to determine the results are acceptable and meet the quality objectives described in Section 3.0. Prior to submitting a laboratory report, the laboratory will verify that all the data are consistent, correct, and complete, with no errors or omissions.

LAI will perform an EPA Level IIa equivalent validation, following the guidelines in the appropriate sections of the EPA Contract Laboratory Program National Functional Guidelines for Organic and Inorganic Data Review (EPA 1999, 2004, respectively). The Level IIa equivalent data validation will include evaluations of the following:

- COC records
- Holding times
- Laboratory method blanks
- Surrogate recoveries
- MS/MSD
- LCS/LCSD
- Laboratory duplicates
- Corrective action records
- Completeness
- Overall assessment of data quality.

In the event that a portion of the data is outside the DQO limits or the EPA guidance (EPA 1999, 2004), or sample collection and/or documentation practices are deficient, corrective action(s) will be initiated. Corrective action, as described in Section 6.0, will be determined by the field coordinator and LAI's QA Manager in consultation with the LAI Project Manager and may include any of the following:

- Rejection of the data and resampling
- Qualification of the data
- Modified field and/or laboratory procedures.

Data qualification arising from data validation activities will be described in the data validation report, rather than in individual corrective action reports. The Boeing Project Manager will notify the Ecology Project Manager of all variances of the QAPP and applicable project plans through status reports, data reports, quarterly reports, or other written correspondences, so that the variances are communicated to Ecology as quickly as possible (Ecology 2012).

8.0 DATA MANAGEMENT PROCEDURES

All laboratory analytical results, including QC data, will be submitted electronically to LAI. Electronic format will include a scanned PDF of the original laboratory data package and an EQuIS 4-file format electronic data deliverable (EDD), which will be uploaded to the project database. Following validation of the data, any qualifiers will be imported to the project database. All survey data will be provided electronically in a format that can be downloaded into an Excel spreadsheet. All field data (groundwater field parameter data and water levels measurements) will be entered into an Excel spreadsheet and verified to determine all entered data is correct and without omissions and errors. Analytical results will be formatted electronically and uploaded once a year to Ecology's Environmental Information Management (EIM) system.

9.0 REFERENCES

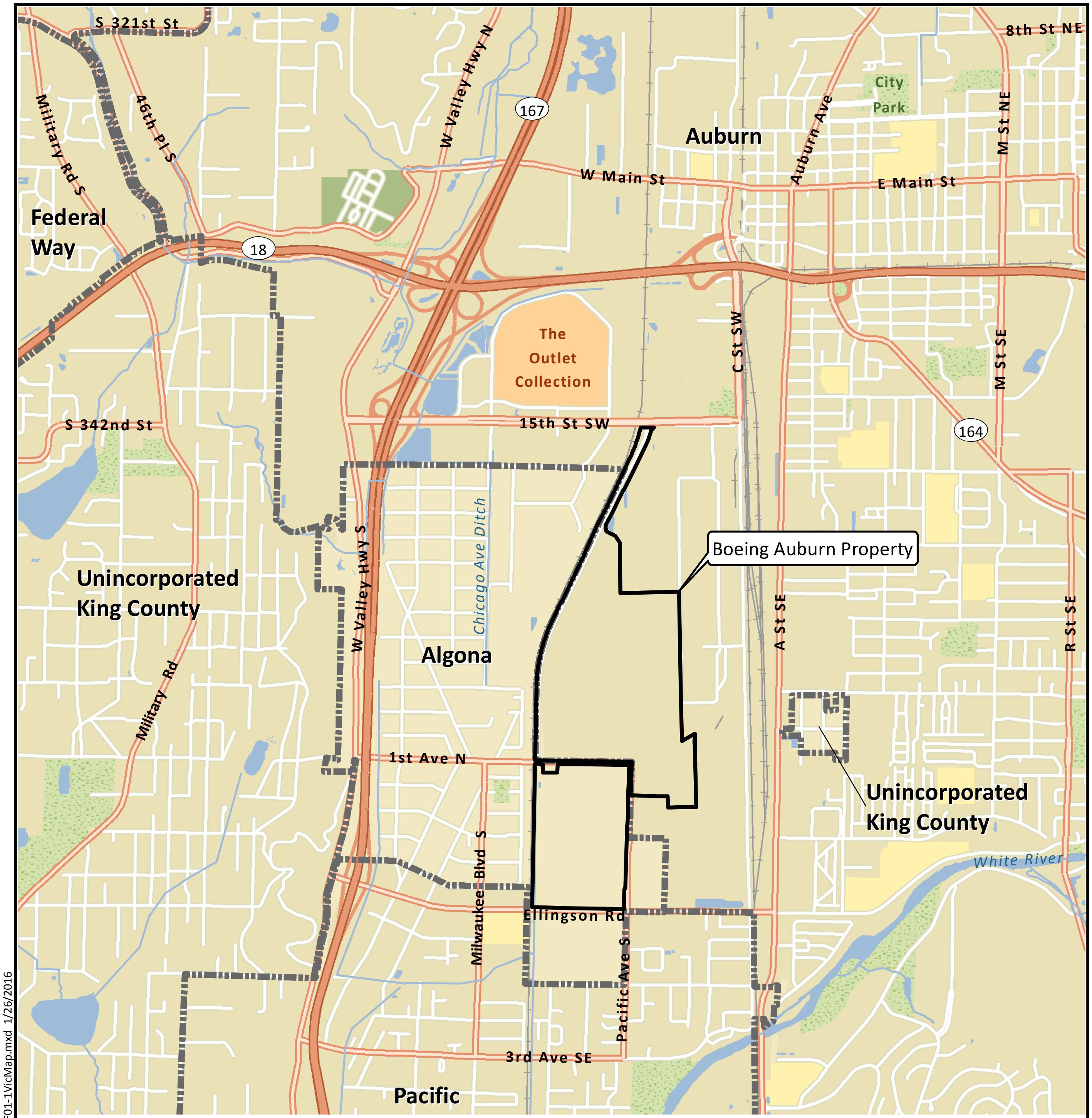
Ecology. 2004. Guidelines for Preparating Quality Assurance Project Plans for Environmental Studies. Olympia, WA: Washington State Department of Ecology.

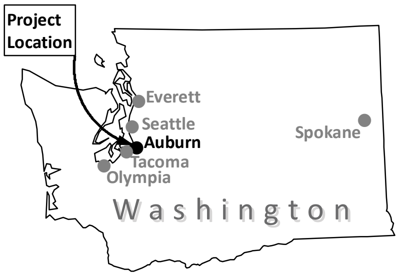
Ecology. 2012. Ecology Contingent Approval of the Revised Quality Assurance Project Plan (QAPP), Boeing Auburn, dated February 27, 2012. edited by Dean Yasuda. Bellevue, WA.

EPA. 1999. USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review. edited by Office of Emergency and Remedial Response. Washington, DC: US Environmental Protection Agency.

EPA. 2004. USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review. Washington, DC: US Environmental Protection Agency.

LAI. 2017. Sampling Analysis Plan. Tacoma, WA: Landau Associates, Inc.





Data Source: Esri 2012

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LANDAU ASSOCIATES

Boeing Auburn Auburn, Washington	**Vicinity Map**	Figure 1

Table 1
Water Sample Laboratory Analytical Methods and Target Limits of Quantitation
Boeing Auburn Facility
Auburn, Washington

Analyte	Analytical Method (a)	Target LOQs ARI (b)	Target LOQs LLI (b)	Target LOQs TA (b)	Target LOQs Apex	Groundwater Screening Level
Volatile Organic Compounds (VOCs) (µg/L)						
1,1,1-Trichloroethane	EPA 8260C	0.2	0.5	0.5	N/A	2.00E+02 µg/L
1,1,2,2-Tetrachloroethane	EPA 8260C	0.2	0.2	0.2	N/A	2.19E-01 µg/L
1,1,2-Trichloro-1,2,2-trifluoroethane	EPA 8260C	0.2	0.5	0.5	N/A	2.40E+05 µg/L
1,1,2-Trichloroethane	EPA 8260C	0.2	0.2	0.2	N/A	7.68E-01 µg/L
1,1-Dichloroethane	EPA 8260C	0.2	0.5	0.5	N/A	7.68E+00 µg/L
1,1-Dichloroethene	EPA 8260C	0.2	0.2	0.2	N/A	7.00E+00 µg/L
1,2-Dichloroethane	EPA 8260C	0.2	0.2	0.2	N/A	4.81E-01 µg/L
1,2-Dichloropropane	EPA 8260C	0.2	0.5	0.5	N/A	1.22E+00 µg/L
2-Butanone	EPA 8260C	5.0	5.0	5.0	N/A	4.80E+03 µg/L
2-Hexanone	EPA 8260C	5.0	5.0	5.0	N/A	---
4-Methyl-2-Pentanone (MIBK)	EPA 8260C	5.0	5.0	5.0	N/A	6.40E+02 µg/L
Acetone	EPA 8260C	5.0	5.0	5.0	N/A	7.20E+03 µg/L
Benzene	EPA 8260C	0.2	0.2	0.2	N/A	7.95E-01 µg/L
Bromodichloromethane	EPA 8260C	0.2	0.5	0.5	N/A	8.00E-02 µg/L
Bromoform	EPA 8260C	0.2	0.5	0.5	N/A	5.54E+00 µg/L
Bromomethane	EPA 8260C	1.0	0.5	0.5	N/A	1.12E+01 µg/L
Carbon Disulfide	EPA 8260C	0.2	0.5	0.5	N/A	8.00E+02 µg/L
Carbon Tetrachloride	EPA 8260C	0.2	0.2	0.2	N/A	6.25E-01 µg/L
Chlorobenzene	EPA 8260C	0.2	0.5	0.5	N/A	1.00E+02 µg/L
Chloroethane	EPA 8260C	0.2	0.5	0.5	N/A	---
Chloroform	EPA 8260C	0.2	0.2	0.2	N/A	1.41E+00 µg/L
Chloromethane	EPA 8260C	0.5	0.5	0.5	N/A	---
cis-1,2-Dichloroethene	EPA 8260C	0.2	0.2	0.2	N/A	1.60E+01 µg/L
cis-1,3-Dichloropropene	EPA 8260C	0.2	0.2	0.2	N/A	---
Dibromochloromethane	EPA 8260C	0.2	0.5	0.5	N/A	5.21E-01 µg/L
Ethylbenzene	EPA 8260C	0.2	0.5	0.5	N/A	7.00E+02 µg/L
m,p-Xylene	EPA 8260C	0.4	0.5	0.5	N/A	1.60E+03 (d) µg/L
Methylene Chloride	EPA 8260C	1.0	0.5	0.5	N/A	5.00E+00 µg/L
o-Xylene	EPA 8260C	0.2	0.5	0.5	N/A	1.60E+03 (d) µg/L
Styrene	EPA 8260C	0.2	0.5	0.5	N/A	1.00E+02 µg/L
Tetrachloroethene	EPA 8260C	0.2	0.2	0.2	N/A	5.00E+00 µg/L
Toluene	EPA 8260C	0.2	0.2	0.2	N/A	6.40E+02 µg/L
trans-1,2-Dichloroethene	EPA 8260C	0.2	0.2	0.2	N/A	1.00E+02 µg/L
trans-1,3-Dichloropropene	EPA 8260C	0.2	0.2	0.2	N/A	---
Trichloroethene	EPA 8260C	0.2	0.2	0.2	N/A	5.40E-01 µg/L
Trichlorofluoromethane	EPA 8260C	0.2	0.5	0.5	N/A	2.40E+03 µg/L
Vinyl Acetate	EPA 8260C	0.2	0.5	1.0	N/A	8.00E+03 µg/L
Vinyl Chloride (c)	EPA 8260C	0.2	0.2	0.02	N/A	2.90E-02 µg/L
Low-Level VOCs						
Tetrachloroethene	EPA 8260C-SIM	0.020	0.020	(k)	N/A	5.00E+00 µg/L
Trichloroethene	EPA 8260C-SIM	0.020	0.020	(k)	N/A	5.40E-01 µg/L
Vinyl Chloride	EPA 8260C-SIM	0.020	0.020	(k)	N/A	2.90E-02 µg/L
Total Petroleum Hydrocarbons (mg/L)						
Gasoline Range	NWTPH-Gx (f)	0.10	0.25	0.25	N/A	8.00E-01 (g) (h) mg/L
Diesel Range	NWTPH-Dx (f)	0.10	0.10	0.1	N/A	5.00E-01 (g) mg/L
Oil Range	NWTPH-Dx (f)	0.20	0.25	0.25	N/A	5.00E-01 (g) mg/L

Table 1
Water Sample Laboratory Analytical Methods and Target Limits of Quantitation
Boeing Auburn Facility
Auburn, Washington

Analyte	Analytical Method (a)	Target LOQs ARI (b)	Target LOQs LLI (b)	Target LOQs TA (b)	Target LOQs Apex	Groundwater Screening Level
Dissolved Gases (µg/L)						
Acetylene	RSK-175	1.06	1 (i)	0.732 (i)	N/A	---
Methane	RSK-175	0.654	3 (i)	0.218 (i)	N/A	---
Ethane	RSK-175	1.23	1 (i)	0.573 (i)	N/A	---
Ethene	RSK-175	1.14	1 (i)	0.398 (i)	N/A	---
Metals, Dissolved and Total (mg/L)						
Arsenic	EPA 6010C	(e)	0.02		N/A	8.00E-03 mg/L
	EPA 6020A/200.8	0.0002	0.02	0.005		
Cadmium	EPA 6010C	0.002	0.005	0.02	N/A	5.00E-03 mg/L
	EPA 6020A/200.8	0.0001	0.0005	0.002		
Nickel (soluble salts)	EPA 6010C	0.01	0.01	0.02	N/A	1.00E-01 mg/L
	EPA 6020A/200.8	0.0005	0.002			
Copper	EPA 6020A/200.8	0.0005	0.002	0.01	N/A	6.40E-01 mg/L
Conventional Parameters (mg/L)						
Nitrate	EPA 300.0	0.1	0.1	0.2	N/A	---
Sulfate	EPA 300.0	0.1	1.0	1.2	N/A	---
Sulfide	SM 4500-S2-D	0.05	0.16	0.05	N/A	---
Total Organic Carbon	SM 5310 C-2000	0.5	1.0	1.0	N/A	---
Total Cyanide	ASTM D-7511	(j)	0.006	(j)	0.0050	9.60E-03 mg/L

Notes:

--- = Screening level not established

(a) Analytical methods are from SW-846 (EPA 1986) and updates, unless otherwise noted.

(b) Target LOQs are based on current laboratory data and may be modified during the investigation process as methodology is refined. Instances may arise where high sample concentrations, nonhomogeneity of samples or matrix interferences preclude achieving the laboratory LOQs.

(c) LLI LOQ exceeds SL; therefore,analyte will be run as low-level VOC by USEPA 8260C-SIM to achieve SL. See "Low Level VOCs" section of this table.

(d) Screening level is for total xylenes.

(e) Analyte or method not included in previous QAPP; therefore, ARI reporting limit is not relevant.

(f) Methods NWTPH-Gx and NWTPH-Dx as described in Ecology's Analytical Methods for Petroleum Hydrocarbons, Publication ECY97-602, June 1997. A silica gel cleanup will be performed for all NWTPH-Dx and NWTPH-Gx analyses. (Ecology 1997).

(g) MTCA Method A groundwater cleanup levels are used for TPH-D, TPH-O, and TPH-G.

(h) If benzene is present, the cleanup level for groundwater is 0.8 mg/L. If there is no detectable benzene, cleanup level for groundwater is 1.0 mg/L.

(i) Laboratories will report to the method detection limit (MDL) for all dissolved gases analyzed by method RSK-175.

(j) Laboratory does not use the preferred analytical method, so reporting limits are not provided.

(k) TA runs 8260 low-level method, which does not require using method 8260 SIM to meet screening levels.

Abbreviations/Acronyms:

ARI = Analytical Resources, Inc.
ASTM = ASTM International
Ecology = Washington State Department of Ecology
EPA = U.S. Environmental Protection Agency
LLI = Eurofins Lancaster Laboratories, Inc.
LOQ = limit of quantitation
µg/L = microgram per liter (parts per billion)
mg/L = milligram per liter (parts per million)
MTCA = Model Toxics Control Act
N/A = not applicable
NWTPH-Dx = Method Northwest diesel-range total petroleum hydrocarbon extended (Ecology 1997).
NWTPH-Gx = Method Northwest gasoline-range total petroleum hydrocarbon extended
QAPP = quality assurance project plan
SIM = selected ion monitoring
SL = screening level
SM = standard method
SW = solid waste
TPH-D = diesel-range total petroleum hydrocarbon
TPH-G = gasoline-range total petroleum hydrocarbon
TPH-O = motor oil-range total petroleum hydrocarbon
VOC = volatile organic compound

Table 2
Soil Sample Laboratory Analytical Methods and Target Limits of Quantitation
Boeing Auburn Facility
Auburn, Washington

Analyte	Analytical Method (a)	Target LOQs ARI (b)	Target LOQs LLI (b)	Target LOQs TA (b)	Soil Screening Levels (c)
Volatile Organic Compounds (µg/kg)					
1,1,1-Trichloroethane	EPA 8260C	1.0	5.0	2.0	1.58E+03 µg/kg
1,1,2,2-Tetrachloroethane	EPA 8260C	1.0	5.0	4.0	1.23E+00 µg/kg
1,1,2-Trichloro-1,2,2-trifluoroethane	EPA 8260C	2.0	10.0	3.0	1.05E+07 µg/kg
1,1,2-Trichloroethane	EPA 8260C	1.0	5.0	2.0	4.27E+00 µg/kg
1,1-Dichloroethane	EPA 8260C	1.0	5.0	1.0	4.19E+01 µg/kg
1,1-Dichloroethene	EPA 8260C	1.0	5.0	5.0	5.01E+01 µg/kg
1,2-Dichloroethane	EPA 8260C	1.0	5.0	1.0	2.32E+00 µg/kg
1,2-Dichloropropane	EPA 8260C	1.0	5.0	2.0	6.25E+00 µg/kg
2-Butanone	EPA 8260C	5.0	10.0	40.0	1.96E+04 µg/kg
2-Hexanone	EPA 8260C	5.0	10.0	20.0	---
4-Methyl-2-Pentanone (MIBK)	EPA 8260C	5.0	10.0	10.0	4.23E+03 µg/kg
Acetone	EPA 8260C	5.0	20.0	15.0	2.89E+04 µg/kg
Benzene	EPA 8260C	1.0	5.0	2.0	4.48E+00 µg/kg
Bromodichloromethane	EPA 8260C	1.0	5.0	1.0	4.17E-01 µg/kg
Bromoform	EPA 8260C	1.0	5.0	2.0	3.63E+01 µg/kg
Bromomethane	EPA 8260C	1.0	5.0	1.0	5.18E+01 µg/kg
Carbon Disulfide	EPA 8260C	1.0	5.0	1.0	5.65E+03 µg/kg
Carbon Tetrachloride	EPA 8260C	1.0	5.0	2.0	5.75E+00 µg/kg
Chlorobenzene	EPA 8260C	1.0	5.0	2.0	8.74E+02 µg/kg
Chloroethane	EPA 8260C	1.0	5.0	2.0	---
Chloroform	EPA 8260C	1.0	5.0	2.0	7.51E+00 µg/kg
Chloromethane	EPA 8260C	1.0	5.0	1.0	--- µg/kg
cis-1,2-Dichloroethene	EPA 8260C	1.0	5.0	2.0	8.00E+01 µg/kg
cis-1,3-Dichloropropene	EPA 8260C	1.0	5.0	1.0	---
Dibromochloromethane	EPA 8260C	1.0	5.0	2.0	2.77E+00 µg/kg
Ethylbenzene	EPA 8260C	1.0	5.0	2.0	6.05E+03 µg/kg
m,p-Xylene	EPA 8260C	2.0	5.0	2.0	1.46E+04 µg/kg
Methylene Chloride	EPA 8260C	2.0	5.0	15.0	2.18E+01 µg/kg
o-Xylene	EPA 8260C	1.0	5.0	2.0	1.46E+04 µg/kg
Styrene	EPA 8260C	1.0	5.0	2.0	2.24E+03 µg/kg
Tetrachloroethene	EPA 8260C	1.0	5.0	2.0	5.30E+01 µg/kg
Toluene	EPA 8260C	1.0	5.0	2.0	4.65E+03 µg/kg
trans-1,2-Dichloroethene	EPA 8260C	1.0	5.0	2.0	5.43E+02 µg/kg
trans-1,3-Dichloropropene	EPA 8260C	1.0	5.0	10.0	---
Trichloroethene	EPA 8260C	1.0	5.0	2.0	3.57E+00 µg/kg
Trichlorofluoromethane	EPA 8260C	1.0	5.0	2.0	3.39E+04 µg/kg
Vinyl Acetate	EPA 8260C	5.0	10.0	5.0	3.31E+04 µg/kg
Vinyl Chloride	EPA 8260C	1.0	5.0	2.0	1.83E-01 µg/kg
Semi-Volatile Organic Compounds (µg/kg)					
1,2,4-Trichlorobenzene	EPA 8270D	67.0	33	50	5.62E+01 µg/kg
1,2-Dichlorobenzene	EPA 8270D	67.0	33	50	7.03E+03 µg/kg
1,3-Dichlorobenzene	EPA 8270D	67.0	33	50	---
1,4-Dichlorobenzene	EPA 8270D	67.0	33	50	1.34E+02 µg/kg
1-Methylnaphthalene	EPA 8270D	67.0	17	30	3.45E+04 µg/kg

Table 2
Soil Sample Laboratory Analytical Methods and Target Limits of Quantitation
Boeing Auburn Facility
Auburn, Washington

Analyte	Analytical Method (a)	Target LOQs ARI (b)	Target LOQs LLI (b)	Target LOQs TA (b)	Soil Screening Levels (c)
2,2'-oxybis(1-Chloropropane)	EPA 8270D	67.0	33	250	3.27E+00 µg/kg
2,4,5-Trichlorophenol	EPA 8270D	330	33	200	2.88E+04 µg/kg
2,4,6-Trichlorophenol	EPA 8270D	330	33	150	4.62E+01 µg/kg
2,4-Dichlorophenol	EPA 8270D	330	33	100	1.67E+02 µg/kg
2,4-Dimethylphenol	EPA 8270D	67.0	33	100	1.31E+03 µg/kg
2,4-Dinitrophenol	EPA 8270D	670	1,000	1,000	1.28E+02 µg/kg
2,4-Dinitrotoluene	EPA 8270D	330	170	200	1.67E+00 µg/kg
2,6-Dinitrotoluene	EPA 8270D	330	33	150	3.14E-01 µg/kg
2-Chloronaphthalene	EPA 8270D	67.0	33	25	2.31E+04 µg/kg
2-Chlorophenol	EPA 8270D	67.0	33	200	4.72E+02 µg/kg
2-Methylnaphthalene	EPA 8270D	67.0	17	50	3.20E+05 µg/kg
2-Methylphenol (o-Cresol)	EPA 8270D	67.0	33	150	2.33E+03 µg/kg
2-Nitroaniline	EPA 8270D	330	33	100	---
2-Nitrophenol	EPA 8270D	67.0	33	200	---
3,3'-Dichlorobenzidine	EPA 8270D	330	330	400	3.59E+00 µg/kg
3-Nitroaniline	EPA 8270D	330	170	200	---
4,6-Dinitro-2-methylphenol	EPA 8270D	670	500	1,000	---
4-Bromophenyl-phenylether	EPA 8270D	67.0	33	200	---
4-Chloro-3-methylphenol	EPA 8270D	330	33	150	---
4-Chloroaniline (p-Chloroaniline)	EPA 8270D	330	33	1,500	1.16E+00 µg/kg
4-Chlorophenyl-phenylether	EPA 8270D	67.0	33	200	---
4-Methylphenol (p-Cresol)	EPA 8270D	67.0	33	200	3.94E+03 µg/kg
4-Nitroaniline	EPA 8270D	330	170	100	---
4-Nitrophenol	EPA 8270D	330	500	1,500	---
Acenaphthylene	EPA 8270D	67.0	17	25	---
Acenaphthene	EPA 8270D	67.0	17	25	9.79E+04 µg/kg
Anthracene	EPA 8270D	67.0	17	25	2.27E+06 µg/kg
Benzo(b)fluoranthene	EPA 8270D	67.0	17	25	(e) µg/kg
Benzo(g,h,i)perylene	EPA 8270D	67.0	17	60	---
Benzo(k)fluoranthene	EPA 8270D	67.0	17	60	(e) µg/kg
Benzo[a]anthracene	EPA 8270D	67.0	17	25	(e) µg/kg
Benzo[a]pyrene	EPA 8270D	67.0	17	60	137 (e) µg/kg
Benzoic Acid	EPA 8270D	670	500	2,500	2.57E+05 µg/kg
Benzyl Alcohol	EPA 8270D	330	500	4,000	3.36E+03 µg/kg
bis(2-Chloroethoxy)methane	EPA 8270D	67.0	33	200	---
bis(2-Chloroethyl)ether	EPA 8270D	67.0	33	200	2.20E-01 µg/kg
bis(2-Ethylhexyl) phthalate	EPA 8270D	67.0	170	600	1.34E+04 µg/kg
Butylbenzylphthalate	EPA 8270D	67.0	170	200	1.28E+04 µg/kg
Carbazole	EPA 8270D	67.0	33	150	--- µg/kg
Chrysene	EPA 8270D	67.0	17	60	(e) µg/kg
Dibenz[a,h]anthracene	EPA 8270D	67.0	17	50	(e) µg/kg
Dibenzofuran	EPA 8270D	67.0	33	150	---
Diethyl Phthalate	EPA 8270D	67.0	170	550	7.22E+04 µg/kg
Dimethyl phthalate	EPA 8270D	67.0	170	150	---
di-n-Butyl Phthalate	EPA 8270D	67.0	170	500	5.65E+04 µg/kg

Table 2
Soil Sample Laboratory Analytical Methods and Target Limits of Quantitation
Boeing Auburn Facility
Auburn, Washington

Analyte	Analytical Method (a)	Target LOQs ARI (b)	Target LOQs LLI (b)	Target LOQs TA (b)	Soil Screening Levels (c)
di-n-Octyl Phthalate	EPA 8270D	67.0	170	1,000	8.00E+05 µg/kg
Fluoranthene	EPA 8270D	67.0	17	25	6.31E+05 µg/kg
Fluorene	EPA 8270D	67.0	17	25	1.01E+05 µg/kg
Hexachlorobenzene	EPA 8270D	67.0	17	50	8.77E+01 µg/kg
Hexachlorobutadiene	EPA 8270D	67.0	33	50	---
Hexachlorocyclopentadiene	EPA 8270D	330	500	100	1.92E+05 µg/kg
Hexachloroethane	EPA 8270D	67.0	170	150	4.36E+01 µg/kg
Indeno[1,2,3-cd]pyrene	EPA 8270D	67.0	17	40	(e) µg/kg
Isophorone	EPA 8270D	67.0	33	150	2.27E+02 µg/kg
Naphthalene	EPA 8270D	67.0	17	25	---
Nitrobenzene	EPA 8270D	67.0	33	200	1.02E+02 µg/kg
n-Nitroso-di-n-propylamine	EPA 8270D	67.0	33	200	5.60E-02 µg/kg
n-Nitrosodiphenylamine	EPA 8270D	67.0	33	60	5.32E+02 µg/kg
Pentachlorophenol	EPA 8270D	330	170	400	3.47E+00 µg/kg
Phenanthrene	EPA 8270D	67.0	17	60	--- µg/kg
Phenol	EPA 8270D	67.0	33	150	1.10E+04 µg/kg
Pyrene	EPA 8270D	67.0	17	60	6.55E+05 µg/kg
Polychlorinated Biphenyls (PCBs) (µg/kg)					
Aroclor 1016	EPA 8082A (Standard)	20.0	17	25	5.60E+03 µg/kg
Aroclor 1221	EPA 8082A (Standard)	20.0	17	11	(f) µg/kg
Aroclor 1232	EPA 8082A (Standard)	20.0	17	11	(f) µg/kg
Aroclor 1242	EPA 8082A (Standard)	20.0	17	10	(f) µg/kg
Aroclor 1248	EPA 8082A (Standard)	20.0	17	11	(f) µg/kg
Aroclor 1254	EPA 8082A (Standard)	20.0	17	10	5.00E+02 µg/kg
Aroclor 1260	EPA 8082A (Standard)	20.0	17	10	5.00E+02 µg/kg
Total PCBs	EPA 8082A (Standard)		--	25	2.71E+02 µg/kg
Total Petroleum Hydrocarbons (mg/kg)					
Gasoline Range	NWTPH-Gx (c)	5	5.0	4	2.00E+03 (g,h) mg/kg
Diesel Range	NWTPH-Dx (c,i)	50.0	7.0	50	1.00E+02 (g) mg/kg
Oil Range	NWTPH-Dx (c,i)	100	30	50	2.00E+03 (g) mg/kg
Total Metals (mg/kg)					
Arsenic	EPA 6010C	5.0	4	3	7.00E+00 mg/kg
	EPA 6020A	0.200	0.8		
Cadmium	EPA 6010C	(d)	1	1	1.00E+00 mg/kg
	EPA 6020A	0.100	0.2		
Chromium	EPA 6010C	(d)	3	1.3	1.20E+05 mg/kg
	EPA 6020A	0.500	0.8		

Table 2
Soil Sample Laboratory Analytical Methods and Target Limits of Quantitation
Boeing Auburn Facility
Auburn, Washington

Analyte	Analytical Method (a)	Target LOQs ARI (b)	Target LOQs LLI (b)	Target LOQs TA (b)	Soil Screening Levels (c)
Lead	EPA 6010C	(d)	3	1.5	2.50E+02 mg/kg
	EPA 6020A	0.100	0.4		
Nickel	EPA 6010C	(d)	2	1	1.30E+02 mg/kg
	EPA 6020A	0.500	0.8		
Conventionals (mg/kg)					
TOC	EPA 9060A			2,000	NA

Notes:

--- = Screening level not established

(a) Analytical methods are from SW-846 (EPA 2014) and updates, unless otherwise noted.

(b) Target LOQs are based on current laboratory data and may be modified during the investigation process as methodology is refined. Instances may arise where high sample concentrations, nonhomogeneity of samples or matrix interferences preclude achieving the laboratory LOQs.

(c) Methods NWTPH-G and NWTPH-Dx as described in Ecology's Analytical Methods for Petroleum Hydrocarbons, Publication ECY97-602, June 1997.

(d) Analyte or method not included in previous QAPP; therefore, ARI reporting limit not relevant.

(e) Evaluated using TEQ based on benzo(a)pyrene.

(f) Evaluated using screening level for total PCBs.

(g) MTCA Method A soil cleanup levels are used for lead, TPH-D, TPH-O, and TPH-G.

(h) The cleanup level for TPH-G is 100 mg/kg where benzene is not present and the total concentration of ethylbenzene, toluene, and xyelene are less than 1 percent of the gasoline mixture. The cleanup level for all other gasoline mixtures is 30 mg/kg.

(i) A silica gel cleanup will be performed for all NWTPH-Dx analyses.

Abbreviations/Acronyms:

ARI = Analytical Resources, Inc.
Ecology = Washington State Department of Ecology
EPA = U.S. Environmental Protection Agency
LLI = Eurofins Lancaster Laboratories, Inc.
LOQ = Limit of Quantitation
µg/kg = microgram per kilogram
mg/kg = milligram per kilogram
MTCA = Model Toxics Control Act
NA = not applicable
NWTPH-Dx = Method Northwest Total Petroleum Hydrocarbon Diesel Extended
NWTPH-Gx - Method Northwest Total Petroleum Hydrocarbon Gasoline Extended
PCB = polychlorinated biphenyl
QAPP = quality assurance project plan
SW = Solid Waste
TEQ = toxicity equivalency quotient
TPH-D = diesel-range total petroleum hydrocarbon
TPH-G = gasoline-range total petroleum hydrocarbon
TPH-O = motor oil-range total petroleum hydrocarbon

Table 3
Soil Vapor Sample Laboratory Analytical Methods and Target Limits of Quantitation
Boeing Auburn Facility
Auburn, Washington

Analyte	Analytical Method	Target LOQs Air Toxics (a,b)		Target LOQs TestAmerica (a)		Sub-Slab Soil Gas Screening Levels (c)
Volatile Organic Compounds		**µg/m³**	**ppbV**	**µg/m³**	**ppbV**	**µg/m³**
1,1-Dichloroethene (d)	EPA Method TO-15	2.0	0.5	3.17	0.800	3,000
cis-1,2-Dichloroethene	EPA Method TO-15	2.0	0.5	1.59	0.400	--- (e)
Tetrachloroethene	EPA Method TO-15	3.4	0.5	2.71	0.400	320
Trichloroethene	EPA Method TO-15	2.7	0.5	2.15	0.105	12
trans-1,2-Dichloroethene (d)	EPA Method TO-15	2.0	2.0	1.59	0.100	900
Vinyl Chloride	EPA Method TO-15	1.3	0.5	1.02	0.120	9.5

Notes:

--- = Screening level not established

(a) Target LOQs are based on current laboratory data and may be modified during the investigation process as methodology is refined.

(b) Air Toxics LOQs provided are for the low-level TO-15 Method. The low-level method must be specified on the chain of custody.

(c) Soil gas SLs have been developed in accordance with methods recommended by Ecology (Ecology 2012a; Jones, E. 2012). Soil gas SLs have been calculated by applying a vapor attenuation factor of 0.03 to Standard Method B air cleanup levels from the CLARC database, which is applicable to shallow soil gas samples.

(d) Ecology has requested that Boeing screen for tDCE and 1,1-DCE in air if it is present in groundwater (Ecology 2013).

(e) Air cleanup levels, the basis for calculating soil gas SLs, are not calculated under MTCA for cDCE due to insufficient data (Ecology 2010). Analysis of cDCE is conducted to provide information regarding the distribution of chlorinated solvent degradation products.

Abbreviations/Acronyms:

1,1-DCE = 1,1-dichloroethene
cDCE = cis-1,2-dichloroethene
CLARC = Ecology's Cleanup Levels and Risk Calculation
EPA = U.S. Environmental Protection Agency
LOQ = Limit of Quantitation
µg/m³ = micrograms per cubic meter
MTCA = Model Toxics Control Act
ppbV = parts per billion by volume
SL = screening level
tDCE = trans-1,2-dichloroethene
VOC = Volatile Organic Compound

Table 4
Air Sample Laboratory Analytical Methods and Target Limits Quantitation
Boeing Auburn Facility
Auburn, Washington

Analytes	Analytical Method	Target LOQs Air Toxics (a)		Target LOQs TestAmerica		Residential Air Screening Levels (b)
Volatile Organic Compounds		µg/m³	ppbV	µg/m³	ppbV	µg/m³
cis-1,2-Dichloroethene	EPA Method TO-15 SIM	0.079	0.010	0.0793	0.0200	--- (c)
Tetrachloroethene	EPA Method TO-15 SIM	0.14	0.020	0.136	0.0200	9.6
Trichloroethene	EPA Method TO-15 SIM	0.11	0.020	0.107	0.0200	0.37
trans-1,2-Dichloroethene (d)	EPA Method TO-15 SIM	0.40	0.10	0.0793	0.0200	27
1,1-Dichloroethene (d)	EPA Method TO-15 SIM	0.040	0.10	0.0793	0.0200	91
Vinyl Chloride	EPA Method TO-15 SIM	0.026	0.05	0.0511	0.0200	0.28

Notes:

--- = Screening level not established

(a) Target LOQs are based on current laboratory data and may be modified during the investigation process as methodology is refined.

(b) Residential air SLs are the most conservative air SLs. Air SLs are standard Method B air cleanup levels from the CLARC database. Residential air SLs are applied to indoor air, crawl spaces/basement, and ambient air samples.

(c) Air cleanup levels, the basis for calculating soil gas SLs, are not calculated under MTCA for cDCE due to insufficient data (Ecology 2010). Analysis of cDCE is conducted to provide information regarding the distribution of chlorinated solvent degradation products.

(d) Ecology requested that Boeing screen for tDCE and 1,1-DCE in air if it is present in groundwater (Ecology 2013).

Abbreviations/Acronyms:

1,1-DCE = 1,1-dichloroethene
cDCE = cis-1,2-dichloroethene
EPA = U.S. Environmental Protection Agency
LLI = Eurofins Lancaster Laboratories, Inc.
LOQ = limit of quantitation
µg/m³ = micrograms per cubic meter
MTCA = Model Toxics Control Act
ppbV = parts per billion by volume
SIM = selected ion monitoring
SL = screening level
tDCE = trans-1,2-dichloroethene

Table 5
Sample Containers, Preservatives, and Holding Times
Boeing Auburn Facility
Auburn, Washington

Matrix/Analysis	Analytical Method	Minimum Sample Amount	Container	Preservation	Extraction Holding Time	Analysis Holding Time
Water						
TPH-G	NWTPH-Gx	5 mL	Three, 40-mL VOA glass vials with teflon septum (no headspace)	HCl pH<2, cool to 4°C +/- 2°C	NA	14 days
TPH-D and TPH-O	NWTPH-Dx	1 L	Two, 250-mL amber glass, teflon lined cap	HCl pH<2, cool to 4°C +/- 2°C	7 days	40 days (a)
VOCs	EPA 8260C/8260C Low-level/8260C SIM	25 mL	Three, 40-mL VOA glass vials with teflon septum (no headspace) (b)	HCl pH<2, cool to 4°C +/- 2°C	NA	14 days
Metals (Dissolved and Total) (c)	EPA 6000 Series/200.8	250 mL	One-250 mL HDPE - total metals; one-250 mL HDPE- dissolved metals	HNO3 to pH <2, cool to 4°C +/- 2°C	NA	6 months
TOC	SM 5310 C-2000	40 mL	One, 250-mL amber glass	H2SO4 pH <2, Cool to 4°C +/- 2°C	NA	28 days
Nitrate (d)	EPA 300.0	40 mL	One, 250-mL poly	Cool to 4°C +/- 2°C	NA	48 hours
Sulfate (d)	EPA 300.0	40 mL	one, 250-mL poly	Cool to 4°C +/- 2°C	NA	28 days
Sulfide	SM 4500-S2-D	50 mL	One, 125-mL poly	NaOH and ZnAc, Cool to 4°C +/- 2°C	NA	7 days
Dissolved Gases (AMEE)	RSKSOP-175	5 mL	Two, 40-mL VOA glass vials with teflon septum (no headspace)	HCl pH<2, cool to 4°C +/- 2°C	14 days	14 days
Total Cyanide	ASTM D-7511	50 mL	Two, 250-mL amber poly	NaOH and C6H8O6, Cool to 4°C +/- 2°C	NA	14 days
Soil						
TPH-D and TPH-O	NWTPH-Dx	30 g	8-oz glass jar with teflon-lined lid	Cool to 4°C +/- 2°C	14 days	40 days (a)
TPH-G	NWTPH-Gx	10 g	Two, 40-mL VOA vials w/methanol (from Easy-Draw Syringe); one, 2-oz glass jar with teflon-lined lid (minimize headspace)	Methanol (for VOA vial); no headspace (for 2-oz glass jar); cool to 4°C +/- 2°C (5 g of sample to 5 mL of preservative)	NA	14 days
VOCs	EPA 8260C	5 g	Two, 40-mL VOA vials with sodium bisulfate (from Easy-Draw Syringe); one, 40-mL VOA vial with methanol (from Easy-Draw Syringe); and one, 2-oz glass jar with teflon-lined lid (minimize headspace)	Sodium bisulfate (for VOA vial); methanol (for VOA vial); no headspace (for 2-oz glass jar); cool to 4°C +/- 2°C (5 g of sample for 5 mL of preservative)	NA	14 days
Total Metals	EPA 6000 Series/200.8	5 g	4-oz glass jar with teflon-lined lid	Cool to 4°C +/- 2°C	NA	6 months
SVOCs	EPA 8270D	30 g	8-oz glass jar with teflon-lined lid	Cool to 4°C +/- 2°C	14 days	40 days (a)
PCBs	EPA 8082A (Standard)	30 g	8-oz glass jar with teflon-lined lid	Cool to 4°C +/- 2°C	14 days	40 days (a)
Soil Gas						
VOCs	EPA Method TO-15/ EPA Method TO-15 Low Level (e)	1 L	200 mL, 1-L, 6-L Summa canister	None	NA	30 days
Indoor Air						
Low-Level VOCs	EPA Method TO-15 SIM (f)	1 L	1-L or 6-L Summa canister	None	NA	30 days

Notes:

(a) Days from extraction date.

(b) If analysis for VOCs and low-level VOCs or SIM are required on the same sample, collect five, 40-mL vials.

(c) Samples for dissolved metals analysis will be preserved by the laboratory after filtration, or pre-preserved containers will be used for samples filtered in the field.

(d) Sample volume for nitrate and sulfate can be combined into one sample bottle; however, nitrate analysis must be performed within the 48-hour holding time.

(e) Low-level methods (provided by AirToxics) will be utilized when necessary to meet screening levels.

(f) Summa canisters used for TO-15 SIM analyses will be individidually certified by the analytical laboratory prior to sample collection.

Abbreviations/Acronyms:

AMEE = acetylene, methane, ethane, ethene
ASTM = American Society for Testing and Materials
C6H8O6 = ascorbic acid
°C = degrees Celsius
EPA = U.S. Environmental Protection Agency
g = gram
H3P04 = phosphoric acid
HCl = hydrochloric acid
HDPE = High-density polyethylene
HN03 = nitric acid
L = liter
mL = milliliter
NA = not application
NWTPH-Dx = Method Northwest diesel-range total petroleum hydrocarbon extended
NWTPH-Gx = Method Northwest gasoline-range total petroleum hydrocarbon extended
oz = ounce
PCB = Polychlorinated Biphenyls
SIM = Selected Ion Monitoring
SM = Standard Method
SVOC = Semivolatile Organic Compounds
TOC = total organic carbon
TPH-D = diesel-range total petroleum hydrocarbon
TPH-G = gasoline-range total petroleum hydrocarbon
TPH-O = oil-range total petroleum hydrocarbon
VOA = Volatile Organic Analyte
VOC = Volatile Organic Compounds
ZnAc = zinc acetate

Table 6
Analytes Where Laboratory Target Limits of Quantitation Exceed Screening Levels
Boeing Auburn Facility
Auburn, Washington

Analytes where LOQ Exceeds Screening Level	Analytical Method (a)	Target LOQs - ARI (b)	Target LOQs - LLI (b)	Target LOQs - TA (b)	Screening Levels (c)
Soil Volatile Organic Compounds					
1,1,2,2-Tetrachloroethane	EPA 8260C	1.0 µg/kg	5.0 µg/kg	4.0 µg/kg	1.23E+00 µg/kg
1,1,2-Trichloroethane	EPA 8260C	1.0 µg/kg	5.0 µg/kg	2.0 µg/kg	4.27E+00 µg/kg
1,2-Dichloroethane	EPA 8260C	1.0 µg/kg	5.0 µg/kg	1.0 µg/kg	2.32E+00 µg/kg
Benzene	EPA 8260C	1.0 µg/kg	5.0 µg/kg	2.0 µg/kg	4.48E+00 µg/kg
Bromodichloromethane	EPA 8260C	1.0 µg/kg	5.0 µg/kg	1.0 µg/kg	4.17E-01 µg/kg
Dibromochloromethane	EPA 8260C	1.0 µg/kg	5.0 µg/kg	2.0 µg/kg	2.77E+00 µg/kg
Trichloroethene	EPA 8260C	1.0 µg/kg	5.0 µg/kg	2.0 µg/kg	3.57E+00 µg/kg
Vinyl Chloride	EPA 8260C	1.0 µg/kg	5.0 µg/kg	2.0 µg/kg	1.83E-01 µg/kg
Soil Semi-Volatile Organic Compounds					
2,2'-oxybis(1-Chloropropane)	EPA 8270D	20 µg/kg	33 µg/kg	250 µg/kg	3.27E+00 µg/kg
2,4-Dinitrophenol	EPA 8270D	200 µg/kg	1,000 µg/kg	1,000 µg/kg	1.28E+02 µg/kg
2,4-Dinitrotoluene	EPA 8270D	100 µg/kg	170 µg/kg	200 µg/kg	1.67E+00 µg/kg
2,6-Dinitrotoluene	EPA 8270D	100 µg/kg	33 µg/kg	150 µg/kg	3.14E-01 µg/kg
3,3'-Dichlorobenzidine	EPA 8270D	100 µg/kg	330 µg/kg	400 µg/kg	3.59E+00 µg/kg
4-Chloroaniline (p-Chloroaniline)	EPA 8270D	100 µg/kg	33 µg/kg	1,500 µg/kg	1.16E+00 µg/kg
Benzyl Alcohol	EPA 8270D	330 µg/kg	500 µg/kg	4,000 µg/kg	3.36E+03 µg/kg
bis(2-Chloroethyl)ether	EPA 8270D	20 µg/kg	33 µg/kg	200 µg/kg	2.20E-01 µg/kg
Hexachloroethane	EPA 8270D	20 µg/kg	170 µg/kg	150 µg/kg	4.36E+01 µg/kg
Nitrobenzene	EPA 8270D	67 µg/kg	33 µg/kg	200 µg/kg	1.02E+02 µg/kg
n-Nitroso-di-n-propylamine	EPA 8270D	100 µg/kg	33 µg/kg	200 µg/kg	5.60E-02 µg/kg
Pentachlorophenol	EPA 8270D	100 µg/kg	170 µg/kg	400 µg/kg	3.47E+00 µg/kg
Groundwater Volatile Organic Compounds					
Bromodichloromethane	EPA 8260C	0.2 µg/L	0.5 µg/L	0.5 µg/L	8.00E-02 µg/L
Groundwater Metals (Dissolved and Total)					
Arsenic	EPA 6010/ 6020/200.8	(d)	0.02 mg/L	0.005 mg/L	8.00E-03 mg/L

Notes:

(a) Analytical methods are from SW-846 and updates.

(b) Target LOQs are based on current laboratory data and may be modified during the investigation process as methodology is refined. Instances may arise where high sample concentrations, nonhomogeneity of samples or matrix interferences preclude achieving the LOQs.

(c) Screening levels are defined in LAI 2009a,b.

(d) Analyte or method not formerly analyzed by this laboratory; therefore, LOQs are not relevant

Abbreviations/Acronyms:

ARI = Analytical Resources, Inc.
EPA = U.S. Environmental Protection Agency
LAI = Landau Associates, Inc.
LLI = Eurofins Lancaster Laboratories, Inc.
LOQ = Limit of Quantitation
µg/L = microgram per liter
µg/kg = microgram per kilogram
mg/L = milligram per liter
SL = Screening Level
SW = Solid Waste

APPENDIX A

Quality Control Criteria for Data Quality Assessment

Table A-1
Quality Control Criteria for Data Quality Assessment
Volatile Organic Compounds (EPA 8260C)
Boeing Auburn Facility
Auburn, Washington

Analyte	Water			Soil		
	LCS/LCSD %	**MS/MSD %**	**RPD %**	**LCS/LCSD %**	**MS/MSD %**	**RPD %**
Precision and Accuracy						
Acetone	73-135	57-163	30	18-197	31-195	30
Benzene	80-120	87-126	30	80-120	55-143	30
Bromodichloromethane	80-120	82-133	30	75-114	53-136	30
Bromoform	63-132	60-138	30	70-120	38-124	30
Bromomethane	38-146	41-145	30	32-162	42-168	30
2-Butanone (MEK)	70-130	63-146	30	38-146	37-163	30
Carbon Disulfide	80-128	84-141	30	59-129	48-146	30
Carbon Tetrachloride	74-133	81-148	30	69-122	45-153	30
Chlorobenzene	80-120	78-133	30	80-120	49-135	30
Chloroethane	67-124	70-139	30	37-154	39-152	30
Chloroform	80-120	86-136	30	80-120	61-142	30
Chloromethane	55-135	55-152	30	56-120	36-143	30
Dibromochloromethane	80-126	79-125	30	77-120	51-128	30
1,1-Dichloroethane	80-120	88-136	30	80-120	63-142	30
1,2-Dichloroethane	80-127	82-135	30	72-126	49-150	30
1,1-Dichloroethene	80-123	83-150	30	73-129	61-149	30
cis-1,2-Dichloroethene	80-120	82-129	30	74-120	49-153	30
trans-1,2-Dichloroethene	80-120	88-127	30	79-120	51-153	30
1,2-Dichloropropane	80-120	91-126	30	80-120	48-145	30
cis-1,3-Dichloropropene	74-120	74-132	30	74-120	35-151	30
trans-1,3-Dichloropropene	73-126	71-128	30	77-120	30-149	30
Ethylbenzene	80-120	80-140	30	80-120	44-141	30
2-Hexanone	80-129	59-169	30	40-129	32-160	30
4-Methyl-2-Pentanone (MIBK)	69-135	69-149	30	52-125	46-139	30
Methylene Chloride	80-120	84-122	30	76-124	49-160	30
Styrene	80-120	63-151	30	76-120	35-134	30
1,1,2,2-Tetrachloroethane	80-125	75-131	30	71-123	40-152	30
Tetrachloroethene	80-120	75-129	30	78-126	42-149	30
Toluene	80-120	83-127	30	80-120	50-146	30
Freon 113 (1,1,2-Trichloro-1,2,2-trifluoroethane)	78-132	87-158	30	64-137	56-156	30
1,1,1-Trichloroethane	79-127	85-140	30	71-125	43-150	30
1,1,2-Trichloroethane	80-120	85-129	30	80-120	47-161	30
Trichloroethene	80-120	85-131	30	80-120	53-144	30
Trichlorofluoromethane	77-132	67-161	30	58-133	47-163	30
Vinyl Acetate	40-137	38-115	30	29-111	21-139	30
Vinyl Chloride	65-127	65-151	30	53-120	50-154	30
m,p-Xylene	80-120	81-137	30	80-120	44-137	30

Table A-1
Quality Control Criteria for Data Quality Assessment
Volatile Organic Compounds (EPA 8260C)
Boeing Auburn Facility
Auburn, Washington

Analyte	Water			Soil		
	LCS/LCSD %	MS/MSD %	RPD %	LCS/LCSD %	MS/MSD %	RPD %
o-Xylene	80-120	81-137	30	80-120	42-137	30
Cyclohexanone	58-125	50-126	30	57-133	27-162	30
Surrogate Recoveries						
Dibromofluoromethane	77-114		--	50-141		--
1,2-Dichloroethane-d4	74-113		--	54-135		--
Toluene-d8	77-110		--	52-141		--
4-Bromofluorobenzene	78-110		--	50-131		--

Notes:

-- = not applicable

1. Quality control criteria presented are typical criteria provided by Eurofins Lancaster Laboratories, Inc. on April 24, 2013. Actual quality control criteria are subject to change due to periodic updating of laboratory control limits, but will adhere to laboratory accreditation standards.

Abbreviations/Acronyms:

EPA = U.S. Environmental Protection Agency
LCS = laboratory control sample
LCSD = laboratory control sample duplicate
MS = matrix spike
MSD = matrix spike duplicate
% = percent
RPD = relative percent difference

Table A-2
Quality Control Criteria for Data Quality Assessment Low-Level Volatile Organic Compounds (EPA 8260C-SIM)
Boeing Auburn Facility
Auburn, Washington

Analyte	Water		
	LCS/LCSD %	MS/MSD %	RPD %
Precision and Accuracy			
Tetrachloroethene	70-130	70-130	30
Trichloroethene	70-130 *	70-130 *	30
Trichloroethene	70-130	70-130	30
Vinyl Chloride	70-130	70-130	30
Surrogate Recoveries			
Toluene-d8	80-120		--
1,4-Difluorobenzene	80-120		--

Notes:

-- = not applicable

1. Quality control criteria presented are typical criteria provided by Eurofins Lancaster Laboratories, Inc. on April 24, 2013. Actual quality control criteria are subject to change due to periodic updating of laboratory control limits, but will adhere to laboratory accreditation standards.

Abbreviations/Acronyms:

EPA = U.S. Environmental Protection Agency
LCS = laboratory control sample
LCSD = laboratory control sample duplicate
MS = matrix spike
MSD = matrix spike duplicate
% = percentage
RPD = relative percent difference
SIM = selected ion method

Table A-3
Quality Control Criteria for Data Quality Assessment
Semivolatile Organic Compounds (EPA 8270D)
Boeing Auburn Facility
Auburn, Washington

Analyte	Soil		
	LCS/LCSD %	MS/MSD %	RPD %
Precision and Accuracy			
1,2,4-Trichlorobenzene	73-108	72-115	30
1,2-Dichlorobenzene	74-99	61-107	30
1,3-Dichlorobenzene	74-97	62-101	30
1,4-Dichlorobenzene	74-100	58-108	30
1-Methylnaphthalene	74-105	64-122	30
2,2'-oxybis(1-Chloropropane)	56-123	60-134	30
2,4,5-Trichlorophenol	76-113	69-114	30
2,4,6-Trichlorophenol	82-115	72-123	30
2,4-Dichlorophenol	69-123	69-117	30
2,4-Dimethylphenol	75-120	60-129	30
2,4-Dinitrophenol	10-117	20-143	30
2,4-Dinitrotoluene	79-114	69-115	30
2,6-Dinitrotoluene	71-122	71-118	30
2-Chloronaphthalene	55-134	50-141	30
2-Chlorophenol	69-118	65-116	30
2-Methylnaphthalene	71-119	68-119	30
2-Methylphenol	69-120	63-126	30
2-Nitroaniline	78-116	67-125	30
2-Nitrophenol	71-118	69-118	30
3,3'-Dichlorobenzidine	25-100	10-112	30
3-Nitroaniline	62-109	59-122	30
4,6-Dinitro-2-methylphenol	46-120	11-126	30
4-Bromophenyl-phenylether	73-114	68-118	30
4-Chloro-3-methylphenol	74-119	62-122	30
4-Chloroaniline	10-99	10-107	30
4-Chlorophenyl-phenylether	74-115	80-109	30
4-Methylphenol	63-125	58-128	30
4-Nitroaniline	49-98	41-109	30
4-Nitrophenol	56-118	52-123	30
Acenaphthylene	82-121	73-125	30
Acenaphthene	76-111	72-110	30
Anthracene	73-121	58-129	30
Benzo(a)anthracene	72-120	65-122	30
Benzo(a)pyrene	82-117	57-126	30
Benzo(g,h,i)perylene	69-118	59-127	30
Benzo(b)fluoranthene	81-121	59-125	30
Benzo(k)fluoranthene	78-119	70-125	30
Benzoic acid	19-135	10-114	30
Benzyl alcohol	68-111	67-115	30
bis(2-Chloroethoxy)methane	65-110	63-109	30
bis(2-Chloroethyl)ether	60-108	54-111	30
bis(2-Ethylhexyl)phthalate	75-117	74-117	30
Butylbenzylphthalate	75-115	61-127	30
Carbazole	77-113	64-120	30

Table A-3
Quality Control Criteria for Data Quality Assessment
Semivolatile Organic Compounds (EPA 8270D)
Boeing Auburn Facility
Auburn, Washington

Analyte	Soil		
	LCS/LCSD %	MS/MSD %	RPD %
Chrysene	62-120	62-128	30
Di-n-butylphthalate	79-112	75-116	30
Di-n-octylphthalate	77-128	60-146	30
Dibenz(a,h)anthracene	79-118	65-125	30
Dibenzofuran	81-107	64-117	30
Diethylphthalate	80-113	66-118	30
Dimethylphthalate	77-109	75-111	30
Fluoranthene	78-116	73-112	30
Fluorene	75-116	68-116	30
Hexachlorobenzene	63-118	65-116	30
Hexachlorobutadiene	65-110	60-111	30
Hexachlorocyclopentadiene	58-118	10-153	30
Hexachloroethane	55-107	39-110	30
Indeno(1,2,3-cd)pyrene	79-116	61-126	30
Isophorone	69-110	73-102	30
N-Nitroso-di-n-propylamine	70-113	60-116	30
N-Nitrosodiphenylamine	67-141	71-122	30
Naphthalene	73-106	66-108	30
Nitrobenzene	67-104	69-102	30
Pentachlorophenol	44-111	13-138	30
Phenanthrene	70-116	60-120	30
Phenol	62-122	46-135	30
Pyrene	79-113	60-131	30
Surrogate Recoveries			
Phenol-d6	54-116		--
2-Fluorophenol	59-117		--
2,4,6-Tribromophenol	41-137		--
Nitrobenzene-d5	61-112		--
2-Fluorobiphenyl	60-120		--
Terphenyl-d14	45-158		--

Notes:

-- = not applicable

1. Quality control criteria presented are typical criteria provided by Eurofins Lancaster Laboratories, Inc. on April 24, 2013. Actual quality control criteria are subject to change due to periodic updating of laboratory control limits, but will adhere to laboratory accreditation standards.

Abbreviations/Acronyms:

EPA = U.S. Environmental Protection Agency
LCS = laboratory control sample
LCSD = laboratory control sample duplicate
MS = matrix spike
MSD = matrix spike duplicate
% = percent
RPD - Relative percent difference

Table A-4
Quality Control Criteria for Data Quality Assessment
Polychlorinated Biphenyls (EPA 8082)
Boeing Auburn Facility
Auburn, Washington

Analyte	Soil		
	LCS/LCSD %	MS/MSD %	RPD %
Precision and Accuracy			
Aroclor 1016	77-121	19-146	50
Aroclor 1221	--	--	--
Aroclor 1232	--	--	--
Aroclor 1242	--	--	--
Aroclor 1248	--	--	--
Aroclor 1254	--	--	--
Aroclor 1260	72-127	29-141	50
Surrogate Recoveries			
Tetrachlorometaxylene (TCMX)	41-146		--
Decachlorobiphenyl (DCBP)	39-151		--

Notes:

-- = not applicable

1. Quality control criteria presented are typical criteria provided by Eurofins Lancaster Laboratories, Inc. on April 24, 2013. Actual quality control criteria are subject to change due to periodic updating of laboratory control limits, but will adhere to laboratory accreditation standards.

Abbreviations/Acronyms:

EPA = U.S. Environmental Protection Agency
LCS = laboratory control sample
LCSD = laboratory control sample duplicate
MS = matrix spike
MSD = matrix spike duplicate
% = percent
RPD = relative percent difference

Table A-5
Quality Control Criteria for Data Quality Assessment
Northwest Total Petroleum Hydrocarbons (NWTPH)
Boeing Auburn Facility
Auburn, Washington

Analyte	Water			Soil		
	LCS/LCSD %	MS/MSD %	RPD %	LCS/LCSD %	MS/MSD %	RPD %
Precision and Accuracy						
Gasoline	75-135	75-135	30	67-119	39-118	30
Diesel	60-120	60-120	20	60-120	60-120	20
Oil	60-120	--	20	60-120	--	20
Surrogate Recoveries						
Trifluorotoluene-F (NWTPH-Gx)	63-135		--	61-122		--
Chlorobenzene (NWTPH-Dx)	50-150		--	50-150		--
o-Terphenyl (NWTPH-Dx)	50-150		--	50-150		--

Notes:

-- = not applicable

1. Quality control criteria presented are typical criteria provided by Eurofins Lancaster Laboratories, Inc. on April 24, 2013. Actual quality control criteria are subject to change due to periodic updating of laboratory control limits, but will adhere to laboratory accreditation standards.

Abbreviations/Acronyms:

LCS = laboratory control sample
LCSD = laboratory control sample duplicate
MS = matrix spike
MSD = matrix spike duplicate
NWTPH - Northwest Total Petroleum Hydrocarbon Methods (Ecology 1997).
NWTPH-Dx = Method northwest diesel-range total petroleum hydrocarbon extended
NWTPH-Gx = Method northwest gasoline-range total petroleum hydrocarbon extended
% = percent
RPD = relative percent difference

Table A-6
Quality Control Criteria for Data Quality Assessment
Dissolved Gases (RSK-175)
Boeing Auburn Facility
Auburn, Washington

Analyte	Water		
	LCS/LCSD %	MS/MSD %	RPD %
Precision and Accuracy			
Ethane	80-120	32-129	20
Ethene	75-130	35-162	20
Methane	80-120	35-157	20
Surrogate Recoveries			
Propene	42-131		--

Notes:

-- = not applicable

1. Quality control criteria presented are typical criteria provided by Eurofins Lancaster Laboratories, Inc. on April 24, 2013. Actual quality control criteria are subject to change due to periodic updating of laboratory control limits, but will adhere to laboratory accreditation standards.

Abbreviations/Acronyms:

LCS = laboratory control sample
LCSD = laboratory control sample duplicate
MS = matrix spike
MSD = matrix spike duplicate
% = percent
RPD = relative percent difference

Table A-7
Quality Control Criteria for Data Quality Assessment
Total and Dissolved Metals (EPA 6000 Series and 200.8)
Boeing Auburn Facility
Auburn, Washington

Analyte	Water								
	EPA Method 6020A			EPA Method 200.8			EPA Method 6010C		
	LCS/LCSD %	MS/MSD %	RPD %	LCS/LCSD %	MS/MSD %	RPD %	LCS/LCSD %	MS/MSD %	RPD %
Arsenic	80-120	75-125	20	80-115	70-130	20	80-120	81-123	20
Cadmium	90-114	79-118	20	85-115	79-118	20	90-112	83-116	20
Nickel	90-113	85-117	20	85-115	85-117	20	90-111	86-115	20

Analyte	Soil / Sediment								
	EPA Method 6020A			EPA Method 200.8			EPA Method 6010C		
	LCS/LCSD %	MS/MSD %	RPD %	LCS/LCSD %	MS/MSD %	RPD %	LCS/LCSD %	MS/MSD %	RPD %
Arsenic	80-120	75-125	20	--	--	--	80-120	75-125	20
Cadmium	80-120	75-125	20	--	--	--	90-112	75-125	20
Chromium	80-120	75-125	20	--	--	--	90-110	75-125	20
Lead	80-120	75-125	20	--	--	--	88-110	75-125	20
Nickel	80-120	75-125	20	--	--	--	90-111	75-125	20

Notes:

-- = not applicable

1. Quality control criteria presented are typical criteria provided by Eurofins Lancaster Laboratories, Inc. on April 24, 2013. Actual quality control criteria are subject to change due to periodic updating of laboratory control limits, but will adhere to laboratory accreditation standards.

Abbreviations/Acronyms:

EPA = U.S. Environmental Protection Agency
LCS = laboratory control sample
LCSD = laboratory control sample duplicate
MS = matrix spike
MSD = matrix spike duplicate
% = percent
RPD = relative percent difference

Table A-8
Quality Control Criteria for Data Quality Assessment
Conventional Parameters
Boeing Auburn Facility
Auburn, Washington

Analyte	Method	Water		
		LCS/LCSD %	MS/MSD %	RPD %
Precision and Accuracy				
Nitrate	EPA 300.0	90-110	90-110	20
Sulfate	EPA 300.0	90-110	90-110	20
Total Cyanide	EPA 300.0	90-110	90-110	20
Total Organic Carbon	SM20 5310C	91-113	63-142	3

Notes:

-- = not applicable

1. Quality control criteria presented are typical criteria provided by Eurofins Lancaster Laboratories, Inc. on April 24, 2013. Actual quality control criteria are subject to change due to periodic updating of laboratory control limits, but will adhere to laboratory accreditation standards.

Abbreviations/Acronyms:

EPA = U.S. Environmental Protection Agency
LCS = laboratory control sample
LCSD = laboratory control sample duplicate
MS = matrix spike
MSD = matrix spike duplicate
% = percent
RPD = relative percent difference
SM = standard method

Table A-9
Quality Control Criteria for Data Quality Assessment
Volatile Organic Compounds in Soil Vapor/Air (EPA TO-15)
Boeing Auburn Facility
Auburn, Washington

Analyte	EPA Method TO-15 Low Level			EPA Method TO-15 SIM		
	LCS/LCSD %	MS/MSD %	RPD %	LCS/LCSD %	MS/MSD %	RPD %
Precision and Accuracy						
1,1-Dichloroethane	70-130	--	25	70-130	--	25
1,1-Dichloroethene	70-130	--	25	70-130	--	25
cis-1,2-Dichloroethene	70-130	--	25	70-130	--	25
Tetrachloroethene	70-130	--	25	70-130	--	25
1,1,1-Trichloroethane	70-130	--	25	70-130	--	25
Trichloroethene	70-130	--	25	70-130	--	25
Vinyl Chloride	70-130	--	25	70-130	--	25
Surrogate Recoveries						
1,2-Dichloroethane-d4	70-130		--	70-130		--
Toluene-d8	70-130		--	70-130		--
4-Bromofluorobenzene	70-130		--	70-130		--

Notes:

-- = not applicable

1. Quality control criteria presented are from the primary air lab, Eurofins-Lancaster California Air Toxics branch.
2. Quality control criteria presented are typical criteria provided by Eurofins-Lancaster California Air Toxics on May 8, 2013. Actual quality control criteria are subject to change due to periodic updating of laboratory control limits, but will adhere to laboratory accreditation standards.

Abbreviations/Acronyms:

EPA = U.S. Environmental Protection Agency
LCS = laboratory control sample
LCSD = laboratory control sample duplicate
MS = matrix spike
MSD = matrix spike duplicate
% = percent
RPD = relative percent difference
SIM = selected ion method