2016 Natural Attenuation Assessment Work Plan
Boeing Auburn Facility
Auburn, Washington

June 2, 2016

Prepared for

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LIST OF ABBREVIATIONS AND ACRONYMS

bgs	below ground surface
Boeing	The Boeing Company
cis-1,2-DCE	cis-1,2-dichloroethene
cVOC	chlorinated volatile organic compound
DCE	dichloroethene
DO	dissolved oxygen
Ecology	Washington State Department of Ecology
Facility	Boeing Auburn Fabrication Division Facility
FS	feasibility study
ft	foot/feet
µg/L	micrograms per liter
mg/L	milligrams per liter
MNA	monitored natural attenuation
Order	Agreed Order No. DE 01HWTRNR-3345
ORP	oxygen-reduction potential
QAPP	quality assurance project plan
RI	remedial investigation
TCE	trichloroethene
TOC	total organic carbon
VC	vinyl chloride
VOA	volatile organic analyte
VOC	volatile organic compound

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1.0 INTRODUCTION

This document presents a work plan to assess aquifer conditions as they relate to natural attenuation of the chlorinated hydrocarbon compound trichloroethene (TCE) and its breakdown products. The scope of work outlined in this plan focuses specifically on groundwater at and downgradient of the Boeing Auburn Fabrication Division Facility (Facility), located at 700 15th Street Southwest (SW) in Auburn, Washington. The Boeing Company (Boeing) will complete these activities as part of the feasibility study (FS) underway as a corrective action at the Facility. Corrective action requirements are documented in an Agreed Order (Order; No. DE 01HWTRNR-3345) dated August 14, 2002 and the First Amended Agreed Order dated February 21, 2006, both with the Washington State Department of Ecology (Ecology). The Order includes a requirement to conduct an FS to clean up the Facility contamination impacts both on Boeing property and at downgradient properties (collectively referred to as Site). This work plan includes groundwater natural attenuation assessment on Boeing property and off Boeing property. The location of the Boeing Auburn property is shown on Figure 1.

The following sections provide context for and a description of natural attenuation assessment activities. The objectives and scope of work are defined in Sections 1.1 and 1.2, respectively. Background information is presented in Section 1.3. Section 2.0 presents a description of natural attenuation processes. The assessment approach is presented in Section 3.0 and assessment field procedures are presented in Section 4.0. Data evaluation is discussed in Section 5.0. Schedule and reporting are discussed in Section 6.0.

1.1 Objective

The objective of this assessment is further analysis of natural attenuation resulting from biological and chemical processes at the Site. The results of this assessment will be considered in conjunction with the Algona natural attenuation assessment that was completed in December 2014 (LAI 2015).

Together the two assessments will provide a better understanding of ongoing plume attenuation resulting from natural aquifer conditions throughout the plumes. Results will also inform future remedy selection which could consist of source control, other active treatment, institutional controls, and monitored natural attenuation (MNA).

1.2 Scope of Work

The scope of work consists of collecting additional geochemical groundwater data to evaluate natural attenuation of TCE and its breakdown products. Groundwater samples will be collected at 51 sampling points at 20 locations[1]. A few locations are at the Facility [near the Prologis building, (former Building 17-05) and upgradient of Building 17-07], while the majority of locations are in the downgradient plumes along the groundwater flow paths to the north/northwest. The natural attenuation sampling

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[1] The selected locations typically have well clusters or multi-level wells resulting in more than one sampling point at a given location.

described in this work plan will be performed in conjunction with the regularly scheduled annual volatile organic compound (VOC) sampling in June 2016.

1.3 Background

Boeing has been implementing remedial investigation (RI) activities to characterize the nature and extent of two intermingled groundwater plumes: the Area 1 plume (Plume 1) and the western plume (Plume 2), which occur beneath the northern portion of the Facility and extend off Boeing property to the north and northwest. These plumes consist of TCE and its reductive dechlorination breakdown products cis-1,2-dichloroethene (cis-1,2-DCE) and vinyl chloride (VC). These RI activities are described in the draft RI report (LAI 2016).

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 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, the uppermost aquifer has been subdivided into three groundwater zones based on depth beneath ground surface (bgs):

- A shallow zone, from the water table (approximately 5 ft) to 35 ft bgs. The most shallow 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 Osceola Mudflow, the depth of which may vary based on location.

The current Phase VI groundwater monitoring well network includes 216 wells and 263 active sampling points[2] to monitor the groundwater plumes in all three upper aquifer zones (LAI 2014).

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

2.0 NATURAL ATTENUATION DEGRADATION PROCESSES

Natural attenuation describes a reduction of contaminant toxicity, volume, concentration, mobility, and/or bioavailability through natural physical, chemical, or biological processes that occur without human intervention. For the VOCs that occur in the groundwater plumes associated with the Facility, physical attenuation processes include dispersion, dilution, sorption, and volatilization; these VOCs are also susceptible to chemical and biological degradation. Chemical and biological attenuation processes that destroy or degrade contaminants are preferred over non-destructive physical processes (EPA 1999). Synonyms for natural attenuation include intrinsic remediation, natural recovery, and natural assimilation.

MNA is groundwater treatment technology that involves periodic groundwater monitoring to evaluate the progress of natural attenuation in achieving remediation objectives. MNA is not a “no action” approach, but requires performance monitoring, demonstration that attenuation is occurring, and an understanding of Site-specific and contaminant-specific attenuation mechanisms. MNA is typically appropriate for sites with a low potential for continued contaminant migration (i.e., stable plumes) and where natural attenuation processes will achieve cleanup levels in a reasonable timeframe compared to more active treatment. MNA is typically performed in conjunction with some active remedial measures (e.g., source control) and/or institutional controls (EPA 1999).

This section describes the biologic (biotic) and chemical (abiotic) degradation processes that can result in natural attenuation of the VOCs of concern in the groundwater plumes, required aquifer conditions, and evaluation of parent and degradation products. The VOCs of concern are TCE (parent) and biodegradation breakdown products cis-1,2-DCE and VC. VC can be further biodegraded to the non-toxic end products ethene and ethane, as follows:

TCE→cis-1,2-DCE→VC→Ethene/Ethane

2.1 Required Aquifer Conditions

Anaerobic aquifer conditions are required for biotic reductive dechlorination and for abiotic degradation of TCE and breakdown products. The presence of dissolved oxygen (DO) indicates aerobic, or oxidative, aquifer conditions. In the absence of DO, conditions are anaerobic, or reducing.

Aerobic and anaerobic conditions are characterized by sequential redox reactions, whereby, aquifer micro-organisms (including bacteria and archaea) obtain energy. These redox reactions require an electron donor (i.e., a source of organic carbon, which ferments to volatile fatty acids and hydrogen) and an electron acceptor (e.g., oxygen, nitrate, iron). These redox reactions can be compared to the process whereby humans obtain energy through consumption of food (electron donor) and oxygen (electron acceptor).

Micro-organisms obtain the greatest energy yield by using oxygen as an acceptor as it is highly oxidized and therefore, can be reduced easily and to a large degree. Less oxidized acceptors provide less energy yield and are utilized after available oxygen has been consumed. When oxygen is depleted in an aquifer, anaerobic bacteria use the less oxidized electron acceptors in sequential order: nitrate, manganese (IV), iron (III), sulfate, and carbon dioxide. The redox state of the aquifer is defined by which natural electron acceptors are being used (i.e., reduced) at a given time. Understanding the redox state of the aquifer is important, as biotic and abiotic degradation of TCE and breakdown products requires specific redox conditions, as described below.

2.2 Biotic Degradation

TCE can be biotically degraded in an anaerobic aquifer through either reduction or oxidation processes. TCE and breakdown products are utilized as electron acceptors by specific micro-organisms to obtain energy. The most common process is reductive dechlorination, whereby bacteria sequentially reduce TCE to breakdown products cis-1,2-DCE and VC, and finally to non-toxic end products ethene and/or ethane. Although anaerobic aquifer conditions are required for metabolic degradation of TCE, breakdown products VC and cis-1,2-DCE can also be degraded under aerobic conditions (AFCEE 2004 and EPA 2000). Cis-1,2-DCE and VC can also be oxidized under anaerobic conditions to carbon dioxide although this is typically a minor pathway compared to reductive dechlorination. Anaerobic reductive dechlorination and anaerobic oxidation are described below.

TCE and breakdown products are reductively dechlorinated under different redox conditions. At each step of reductive dechlorination, a chlorine ion present on the chlorinated hydrocarbon molecule (e.g., TCE) is replaced with hydrogen, resulting in the formation of successively less chlorinated (less oxidized) molecules (e.g., cis-1,2-DCE, VC, ethene/ethane). Because TCE is a highly oxidized, it can be reduced under moderately reducing (iron-reducing conditions; Chapelle 1996). Less oxidized cis-1,2-DCE and VC require successively more reduced aquifer conditions for anaerobic degradation; cis-1.2-DCE under sulfate-reducing or methanogenic conditions (Chapelle 1996; Vogel et al. 1987) and VC under highly reducing, methanogenic conditions (Ballapragada et al. 1997; Freedman and Gosset 1989; Maymó-Gatell et al. 1995; and Vogel and McCarthy 1985).

A less well understood degradation pathway is biotic anaerobic oxidation, a minor pathway compared to reductive dechlorination. VC and cis-1,2-DCE are more reduced than TCE and therefore, can be anaerobically oxidized to carbon dioxide. The precise mechanism for anaerobic oxidation of cis-1,2-DCE and VC is not fully understood. It likely involves either a redox reaction or conversion to acetate (i.e., acetogenesis), with further oxidation of acetate through either acetotrophic methanogenesis to methane and carbon dioxide (Bradley and Chapelle 1999a,b and 2000), or through anaerobic oxidation to carbon dioxide (Bradley and Chapelle 2000). Due to the common occurrence of the anaerobic oxidation breakdown products, it is difficult to document degradation by this pathway.

2.3 Abiotic Degradation

TCE and cis-1,2-DCE can also be degraded abiotically through chemical reaction with iron sulfide minerals. This abiotic destruction is complimentary and occurs concurrently with biological reductive dechlorination of TCE. This same destruction mechanism occurs in zero valent iron permeable reactive barriers. Although the destruction of TCE and cis-1,2-DCE by this mechanism is abiotic, the formation of iron sulfide minerals requires biological reduction of iron and sulfate.

The predominant abiotic reaction is known as reductive elimination (or beta-elimination), whereby iron chemically reduces TCE or cis-1,2-DCE, replacing two chlorine atoms with hydrogen atoms. This reaction does not occur with VC. The reduction results in short-lived, non-toxic intermediaries chloroacetylene and acetylene; these compounds are highly reactive and break down quickly to carbon dioxide (Shen and Wilson 2007) and possibly other products. If detected, acetylene indicates reductive elimination of TCE/cis-1,2-DCE is occurring; however, due to its high reactivity, acetylene is detected infrequently or at low concentrations even when reductive elimination is actively occurring.

Hydrogenolysis is a minor abiotic degradation pathway whereby TCE chemically reacts with iron, sequentially replacing one chlorine atom at a time with a hydrogen atom. This sequential reduction produces the same breakdown products as biotic reductive dechlorination (cis-1,2-DCE and VC), which can be degraded further to ethene.

2.4 Evaluation of Molar Fractions

Conversion of groundwater concentrations [unit micrograms per liter (µg/L)] to molar equivalents (unit micromoles per liter) allows evaluation of molar fractions. Converting groundwater concentrations to molar equivalents allows a direct comparison of the number of moles (i.e., number of molecules) of TCE and breakdown products in a given sample. Because TCE and breakdown products have different molecular weights, with the molecular weight decreasing at each dechlorination step (i.e., removal of chloride ion), groundwater concentrations in units of µg/L do not allow a comparison of the relative percentages of TCE, cis-1,2-DCE, and VC in a given sample. For example, full dechlorination of a given concentration of TCE (100 µg/L) results in lower concentrations of cis-1,2-DCE (79 µg/L) and VC (48 µg/L) due to their lower molecular weights. However, conversion to molar equivalents allows direct comparison of the percentage of each compound since 1 mole of TCE would convert sequentially to 1 mole of cis-1,2-DCE, 1 mole of VC, then 1 mole of end products ethene plus ethane.

Molar fractions indicate the relative percentages of TCE, total dichloroethene[3] (DCE), and VC in a given sample. Chlorinated VOC (cVOC) molar fractions are calculated by dividing the individual molar equivalents for TCE, DCE, and VC by the molar equivalent for total cVOCs (i.e., sum of molar

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[3] Although cis-1,2-DCE is known to be the primary isomer resulting from reductive dechlorination, total DCE, consisting of the sum of cis-1,2-DCE, trans-1,2-DCE, and 1,1-DCE isomers, is used as a conservatism in calculating the DCE molar fraction.

equivalents for TCE, DCE, and VC). The compound with the highest molar fraction is considered predominant in that sample. Predominance of TCE, DCE, VC, or ethene/ethane indicates the stage of reductive dechlorination at the sample location.

3.0 ASSESSMENT APPROACH

This section describes natural attenuation monitoring parameters and a description of how sample collection locations were selected.

3.1 Natural Attenuation Parameters

Groundwater monitoring for assessment of natural attenuation includes analysis of TCE, biotic and abiotic degradation products, organic carbon, and aquifer redox parameters. TCE biotic and abiotic degradation products include cis-1,2-DCE, VC, ethene, ethane, and acetylene. Total organic carbon (TOC) results will be used to evaluate the availability of electron donor within the aquifer. Aquifer redox parameters include oxygen, nitrate, ferrous iron, sulfate/sulfide, and methane [produced by carbon dioxide (C02) reduction], which will be used to assess the redox state of the aquifer.

Parameters requiring laboratory analysis are nitrate, sulfate, sulfide, TOC, and the dissolved gases acetylene, methane, ethene, and ethane (AMEE), while field parameters consist of pH, ferrous iron, DO, and oxidation-reduction potential (ORP). The indicated laboratory parameters will be analyzed in addition to the standard Boeing 38 VOCs as listed in the Quality Assurance Project Plan (QAPP; LAI 2013a). Table 1 presents analytical methods, holding times, and sample bottle information. Table 1 also describes the information provided by each field and laboratory parameter for evaluation of natural attenuation. Data evaluation is further described in Section 5.0.

3.2 Selection of Monitoring Locations

There are 51 groundwater monitoring wells at 20 locations proposed for collection of natural attenuation parameters as shown in Table 2. These monitoring wells supplement the Algona natural attenuation assessment monitoring wells that were sampled in December 2014 (LAI 2015). The Algona natural attenuation assessment monitoring wells and the currently proposed 2016 natural attenuation assessment monitoring wells are shown on Figure 2.

The proposed natural attenuation assessment monitoring wells were selected to address the Area 1 plume (beginning at the current Prologis building and extending downgradient to the northwest) and the area where the western plume and Area 1 plume co-mingle in the northern portion of commercial Algona. The focus of the prior Algona natural attenuation assessment was on the western plume (from the Facility at Building 17-07 downgradient to residential Algona).. The proposed assessment addresses the remainder of the plume area (Area1 and western plumes) and includes monitoring wells near the Prologis and YMCA buildings, Fana property, and The Outlet Collection. Monitoring wells were also selected at the distal end of the plume near the west, northwest, and north edges crossgradient of the plume to the east. Additionally, two well locations were selected upgradient of the western plume source to enhance the understanding of the western plume source area derived from the prior Algona natural attenuation Assessment.

Groundwater monitoring wells were selected using the following criteria, all wells were selected in order to provide:

- Spatial distribution across the Site.
- Representation of each groundwater zone, with a preference for multi-level or clustered well locations.
- Different percentages (molar fractions) of TCE and breakdown products. Selected locations include wells that are TCE, DCE, and VC predominant for comparison of other natural attenuation parameters at these locations. Molar fractions for each of the selected sampling points are presented in Table 2.

4.0 FIELD PROCEDURES

The following sections describe procedures for groundwater sampling of both conventional and multi-level wells. Procedures are in accordance with the site Draft Sampling and Analysis Plan (LAI 2013b), and site QAPP (LAI 2013a). A sampling matrix is presented in Table 3. Locations of the select monitoring wells are shown on Figure 2.

4.1 Groundwater Sampling

Groundwater sampling will be conducted using a peristaltic pump and dedicated tubing in accordance with low-flow sampling techniques. Field parameters will be measured at the time of sampling. A multi-parameter probe (YSI 556 MPS) and flow-through cell will be used to measure pH, conductivity, DO, temperature, and ORP. Ferrous iron will be analyzed using a Hach® Model 1R-18C field test kit. Turbidity will also be measured using a turbidity meter.

Samples will be analyzed by Eurofins Lancaster Laboratories, Inc. of Lancaster, Pennsylvania for the parameters indicated in Section 3.1 and summarized in Table 1. Samples will be analyzed on the standard 2-week turnaround time. Analytical methods, sample bottles, preservatives, and holding times are indicated in Table 1.

There will be 9 to 11[4] VOA containers and one 250-milliliter glass bottle will be collected for each sample. All samples will be stored in coolers with ice and transported or shipped using proper chain-of-custody procedures. Nitrate has a short holding time of 48 hours. A trip blank will accompany each cooler of samples. One set of duplicate samples will be collected for each 20 samples.

4.2 Sample Identification

Samples collected from CMT wells will have the following sample numbering scheme: well name-channel number-sample depth- year month day. For example, sample number AGW207-2-30-20160601 indicates a sample collected from well AGW207, channel 2, at a depth of 30 ft (approximate center of screen) on June 1, 2016.

Samples collected from conventional wells will have the following sample numbering scheme: well name-year month day. For example, sample number AGW137-20160601 indicates a sample collected from well AGW137 on June 1, 2016. Duplicate samples will be identified as AGW900, AGW901, etc.

4.3 Waste Management

All decontamination water and purge water will be contained in screw-top buckets and transported to the Boeing Facility drum yard. 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

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[4] Only nine volatile organic analyte (VOA) containers are needed if selected ion monitoring analysis is not being performed.

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.

5.0 DATA EVALUATION

Data will be used to evaluate the occurrence of aquifer conditions conducive to natural attenuation and to identify degradation mechanisms. Groundwater data will be used to evaluate changes in groundwater concentrations of TCE and breakdown products, including biotic and abiotic degradation products and non-toxic end products. Data will support evaluation of organic carbon availability and aquifer redox conditions. The information provided by each field and laboratory groundwater parameter for evaluation of natural attenuation is listed in Table 1 and summarized below.

- Field Parameters:
    - DO: Indicates whether aquifer is anaerobic [concentration less than 1 milligram per liter (mg/L)] or aerobic (concentration greater than 1 mg/L). However, DO measurements can be unreliable and may disagree with more reliable redox indicators listed below.
    - ORP: Negative values indicate reducing conditions. However, ORP measurements can be unreliable and may disagree with more reliable redox indicators listed below.
    - pH: Values between 6 and 8 are optimal for biodegradation.
    - Ferrous iron: Detections indicate iron-reducing conditions.
- Laboratory Parameters:
    - TOC: Detections indicate availability of electron donor. TOC > 10 mg/L is considered adequate for substantial reductive dechlorination (Major et al. 2003). Lower concentrations of < 5 mg/L may be adequate for sustained natural attenuation.
    - Nitrate: Detections above 1.0 mg/L indicate aerobic conditions; low to depleted nitrate concentrations indicate nitrate-reducing conditions.
    - Sulfate: Low concentrations are an indicator of sulfate-reducing conditions.
    - Sulfide: Detections indicate sulfate-reducing conditions. However, sulfide is commonly not detected where sulfate-reducing conditions occur, because it complexes with ferrous iron (if present) and precipitate on the aquifer matrix as iron sulfides.
    - Methane: Detections indicate methanogenic aquifer redox conditions (i.e., CO2 reduction).
    - VOCs: TCE breakdown products are indicative of reductive dechlorination. Breakdown products are also an indicator of aquifer redox, as more-reduced aquifer redox conditions are required for dechlorination of cis-1,2-DCE and VC than for TCE (Section 2.2).
    - Ethene/Ethane: Detection indicates complete reductive dechlorination to these non-toxic end products.
    - Acetylene: Indicates TCE and cis-1,2-DCE destruction through abiotic reductive elimination. However, acetylene is unstable and short-lived, and may not be detected even where reductive elimination is occurring.

Natural attenuation evaluation requires a “weight of evidence” approach, as there is often some disagreement between individual parameters. VOC groundwater data will be plotted on a molar basis for each well to evaluate the relative percentages of TCE and breakdown products.

6.0 SCHEDULE AND REPORTING

Field work is scheduled for the first 2 weeks of June 2016 in conjunction with the 2nd quarter annual groundwater sampling event. Final data packages will undergo data validation and be entered in the Site-wide database for inclusion in a supplemental report. Evaluation of natural attenuation data will be presented in a natural attenuation assessment report to be completed during the 3rd quarter of 2016.

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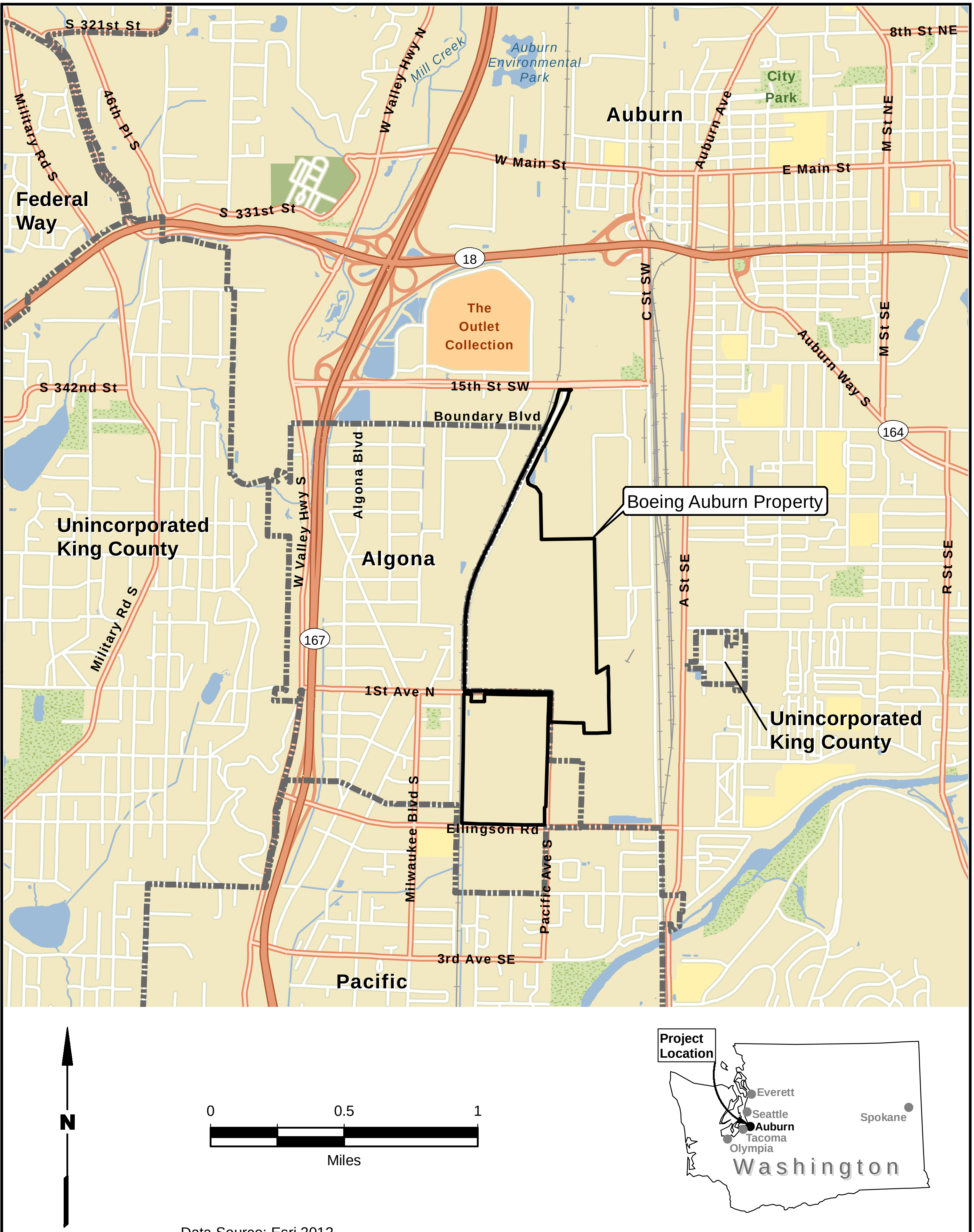

Data Source: Esri 2012

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

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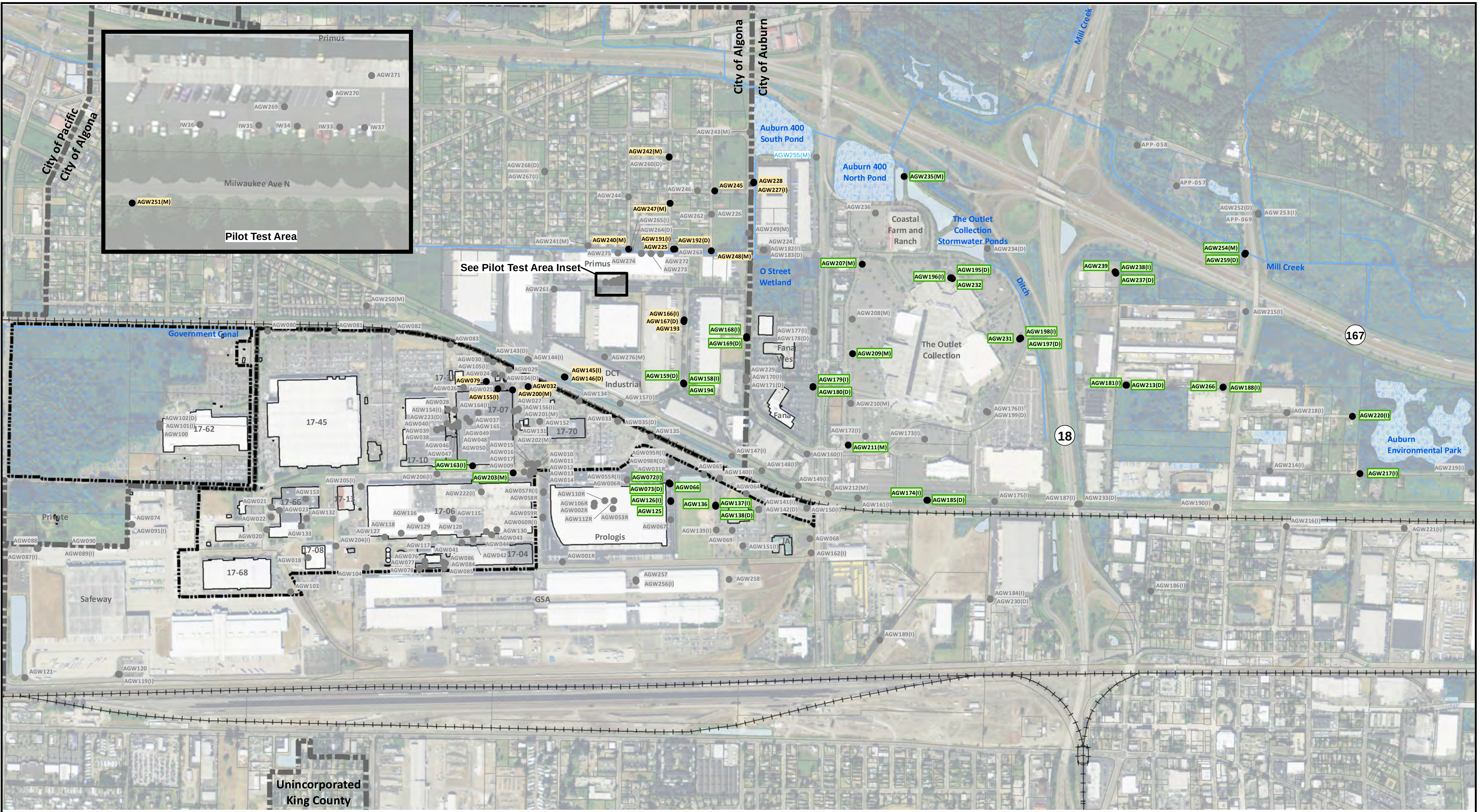

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Notes

1. Groundwater wells are identified by the AGW prefix. The designations behind the indentifications 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. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

● NA Monitoring Well
● Other Monitoring Well
Wetland Areas
Water Bodies
Waterways
AGW032 Algona NA Assessment (December 2014)
AGW266 Proposed Site-Wide NA Assessment

0 1,000 2,000
Scale in Feet

N

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

Landau Associates

Boeing Auburn
Auburn, Washington

Site-Wide Natural Attenuation Assessment Monitoring Locations

Figure
2

Table 1
Natural Attenuation Monitoring Parameters
Boeing Auburn Facility
Auburn, Washington

Field Parameters	Data Collection Method	Units	Information Provided
DO	Field Meter (a)	mg/L	Aquifer is considered anaerobic at DO concentrations less than 1.0 mg/L.
ORP	Field Meter (a)	mV	Negative values indicate reducing conditions.
pH	Field Meter (a)	unitless	Optimal for biodegradation in the 6-8 range
Ferrous Iron	Hach® Kit	mg/L	Detections indicate iron reducing conditions.

Laboratory Analyses	Analytical Method	Bottles	Allowable Holding Time	Information Provided
VOCs (b) (c)	EPA Method 8260C; EPA Method 8260C SIM for VC, PCE	5 40-mL VOA preserved with HCl	14 days	Concentrations of TCE breakdown products are indicative of reductive dechlorination.
TOC	SM 5310 C-2000	2 40-mL VOA preserved with H3PO4	28 days	Indicative of electron donor available to maintain reduced aquifer redox conditions and for reductive dechlorination.
Nitrate/Sulfate	EPA Method 300.0	2 40-mL VOA unpreserved	Nitrate: 48 hours Sulfate: 28 days	Nitrate concentrations below background indicate nitrate reducing conditions. Sulfate concentrations below background indicate sulfate-reducing conditions.
Sulfide	SM 4500-S2 D-2000	1 250-mL glass bottle preserved with ZnAc and NaOH	7 days	Sulfide detections indicate sulfate-reducing conditions.
AMEE (b)	RSKSOP-175 Modified	2 40-mL VOA preserved with HCl	14 days	Concentrations of ethene and ethane are indicative of complete reductive dechlorination to non-toxic end products. Elevated methane concentrations indicate methanogenic aquifer redox conditions. Acetylene indicates the occurrence of abiotic reductive elimination.

AMEE = Acetylene, Methane, Ethene, Ethane
DO = Dissolved Oxygen
EPA = U.S. Environmental Protection Agency
H3PO4 = Phosphoric acid
HCl = Hydrochloric acid
mg/L = milligrams per liter
mL = milliliter
mV = millivolts
NaOH = Sodium hydroxide
ORP = Oxidation Reduction Potential
PCE = Tetrachloroethene
RSKSOP = EPA Method
SIM = Selected Ion Monitoring
SM = Standard Method
TCE = Trichloroethene
TOC = Total Organic Carbon
VC = Vinyl Chloride
VOA = Volatile Organic Analyte
VOCs = Volatile Organic Compounds
ZnAc = Zinc acetate

a. Measured using a flow-through cell.
b. Care to be taken during sample collection to minimize aeration and volatilization. Sample collected with no headspace.
c. Standard Boeing 38 list of VOCs. Locations sampled using Method 8260C SIM for VC are listed on Table 3.

Table 2
Selected Monitoring Locations
Boeing Auburn Facility
Auburn, Washington

Area	Aquifer Zone	Well ID	Predominant Constituent (a)	Molar Fraction (b) December 2015
Near Source Area - Upgradient of 17-07	I	AGW163	TCE	76/23/1
Near Source Area - Upgradient of 17-07	S	AGW203-2	TCE	83/17/0
Near Source Area - Upgradient of 17-07	I	AGW203-4	TCE	100/0/0
Near Source Area - Upgradient of 17-07	D	AGW203-6	TCE	100/0/0
Near Source Area - Prologis Building/YMCA	S	AGW066	TCE	74/26/0
Near Source Area - Prologis Building/YMCA	I	AGW072	TCE	100/0/0
Near Source Area - Prologis Building/YMCA	D	AGW073	TCE	100/0/0
Near Source Area - Prologis Building/YMCA	S	AGW125	TCE	79/20/1
Near Source Area - Prologis Building/YMCA	I	AGW126	TCE	53/45/2
Near Source Area - Prologis Building/YMCA	S	AGW136	TCE	62/38/0
Near Source Area - Prologis Building/YMCA	I	AGW137	TCE	63/37/1
Near Source Area - Prologis Building/YMCA	D	AGW138	TCE	100/0/0
Core of Plume - Merging of Western and Area 1 Plume	S	AGW194	TCE	70/28/2
Core of Plume - Merging of Western and Area 1 Plume	I	AGW158	TCE	75/22/3
Core of Plume - Merging of Western and Area 1 Plume	D	AGW159	TCE	73/22/5
Core of Plume - Merging of Western and Area 1 Plume	I	AGW168	TCE	65/33/2
Core of Plume - Merging of Western and Area 1 Plume	D	AGW169	TCE	72/27/2
Core of Plume - Merging of Western and Area 1 Plume	I	AGW179	DCE	3/95/2
Core of Plume - Merging of Western and Area 1 Plume	D	AGW180	TCE	80/20/0
Core of Plume - Merging of Western and Area 1 Plume	S	AGW211-2	ND	ND
Core of Plume - Merging of Western and Area 1 Plume	I	AGW211-5	TCE	75/25/0
Core of Plume - Merging of Western and Area 1 Plume	D	AGW211-6	DCE	36/64/0
Core of Plume	S	AGW207-2	TCE	56/41/3
Core of Plume	I	AGW207-4	TCE	69/26/5
Core of Plume	D	AGW207-7	TCE	86/14/1
Core of Plume	S	AGW209-2	VC	0/0/100
Core of Plume	I	AGW209-5	VC	29/30/41
Core of Plume	D	AGW209-6	TCE	85/14/1
Core of Plume	S	AGW232	DCE	0/59/41
Core of Plume	I	AGW196	DCE	0/59/41
Core of Plume	D	AGW195	TCE	89/11/0
Core of Plume	S	AGW231	VC	15/24/61
Core of Plume	I	AGW198	TCE	88/12/0
Core of Plume	D	AGW197	TCE	90/10/0
Upgradient - East	I	AGW174	TCE	100/0/0
Upgradient - East	D	AGW185	TCE	100/0/0
Distal End of Plume - West	S	AGW235-2	VC	0/46/54
Distal End of Plume - West	I	AGW235-4	DCE	29/69/2
Distal End of Plume - West	D	AGW235-7	ND	ND
Distal End of Plume - Northwest	I	AGW181	TCE	74/25/2

Table 2
Selected Monitoring Locations
Boeing Auburn Facility
Auburn, Washington

Area	Aquifer Zone	Well ID	Predominant Constituent (a)	Molar Fraction (b) December 2015
Distal End of Plume - Northwest	D	AGW213	VC	0/0/100
Distal End of Plume - Northwest	S	AGW266	DCE	0/100/0
Distal End of Plume - Northwest	I	AGW188	TCE	86/13/1
Distal End of Plume - Northwest	D	AGW237	DCE	47/51/2
Distal End of Plume - Northwest	I	AGW238	ND	ND
Distal End of Plume - Northwest	S	AGW239	DCE	0/86/14
Distal End of Plume - Northwest	S	AGW254-2	VC	0/0/100
Distal End of Plume - Northwest	I	AGW254-5	ND	ND
Distal End of Plume - Northwest	D	AGW259	ND	ND
Distal End of Plume - North	I	AGW217	TCE	85/13/2
Distal End of Plume - North	I	AGW220	TCE	100/0/0

D = Deep
DCE = dichloroethene
I = Intermediate
ND = non-detect
S = Shallow
TCE = trichloroethene
VC = vinyl chloride

a. Based on molar fraction.
b. CVOC molar fractions are shown as percent TCE/percent DCE/percent VC. CVOC molar fractions are calculated by dividing the individual molar equivalents (µmol/L) for TCE, DCE, and VC by the sum of cVOC molar equivalents (i.e., TCE+DCE+VC).

Table 3
Natural Attenuation Assessment Sample Matrix
Boeing Auburn Facility
Auburn, Washington

Well	CMT Channel Depth (ft)	Aquifer Depth	Location	VOCs 8260 (a)	VOCs VC 8260 SIM (b)	NA Parameters (c)
AGW066	--	S	N of Prologis Building	X	X	X
AGW072	--	I	NW of Prologis Building	X	X	X
AGW073	--	D	NW of Prologis Building	X	X	X
AGW125	--	S	N of Prologis Building	X	X	X
AGW126	--	I	N of Prologis Building	X	X	X
AGW136	--	S	S of YMCA	X	X	X
AGW137	--	I	S of YMCA	X	X	X
AGW138	--	D	S of YMCA	X	X	X
AGW158	--	I	10th St SW	X	X	X
AGW159	--	D	10th St SW	X	X	X
AGW163	--	I	E of 17-07	X	X	X
AGW168	--	I	Boundary Blvd	X	X	X
AGW169	--	D	Boundary Blvd	X	X	X
AGW174	--	I	Interurban Trail, N of 15th St SW	X	X	X
AGW179	--	I	Eastern Fana Property	X	X	X
AGW180	--	D	Eastern Fana Property	X	X	X
AGW181	--	I	S end of Lund Rd	X	X	X
AGW185	--	D	Interurban Trail E of Outlet Collection	X	X	X
AGW188	--	I	Lund Rd at Main ST	X	X	X
AGW194	--	S	10th St SW, Algona	X	X	X
AGW195	--	D	Outlet Collection - delivery area, W side	X	X	X
AGW196	--	I	Outlet Collection - delivery area, W side	X		X
AGW197	--	D	Outlet Collection - west of Sam's Club	X	X	X
AGW198	--	I	Outlet Collection - west of Sam's Club	X	X	X
AGW203-2	30	S	Between 17-07 and 17-06	X	X	X
AGW203-4	49	I	Between 17-07 and 17-06	X	X	X
AGW203-6	80	D	Between 17-07 and 17-06	X	X	X
AGW207-2	30	S	Outlet Collection parking lot SW Corner	X	X	X
AGW207-4	49	I	Outlet Collection parking lot SW Corner	X	X	X
AGW207-7	80	D	Outlet Collection parking lot SW Corner	X	X	X
AGW209-2	30	S	Outlet Collection parking lot	X		X
AGW209-5	60	I	Outlet Collection parking lot	X	X	X
AGW209-6	80	D	Outlet Collection parking lot	X	X	X
AGW211-2	30	S	Outlet Collection parking lot	X	X	X
AGW211-5	60	I	Outlet Collection parking lot	X	X	X
AGW211-6	80	D	Outlet Collection parking lot	X	X	X
AGW213	--	D	S end of Lund Rd	X	X	X
AGW217	--	I	Clay St	X	X	X

Table 3
Natural Attenuation Assessment Sample Matrix
Boeing Auburn Facility
Auburn, Washington

Well	CMT Channel Depth (ft)	Aquifer Depth	Location	VOCs 8260 (a)	VOCs VC 8260 SIM (b)	NA Parameters (c)
AGW220	--	I	Western Ave	X	X	X
AGW231	--	S	Outlet Collection parking lot	X		X
AGW232	--	S	Outlet Collection parking lot	X		X
AGW235-2	19	S	Access road to Outlet Collection stormwater ponds	X	X	X
AGW235-4	39	I	Access road to Outlet Collection stormwater ponds	X	X	X
AGW235-7	71	D	Access road to Outlet Collection stormwater ponds	X	X	X
AGW237	--	D	Auburn School District, NW corner of property	X	X	X
AGW238	--	I	Auburn School District, NW corner of property	X	X	X
AGW239	--	S	Auburn School District, NW corner of property	X	X	X
AGW254-2	20	S	S Access Rd, West Main St	X	X	X
AGW254-5	50	I	S Access Rd, West Main St	X	X	X
AGW259	--	D	S Access Rd, West Main St	X	X	X
AGW266	--	S	Lund Rd at Main St	X	X	X

Aquifer Depth
S = Shallow
I = Intermediate
D = Deep

a. Volatile organic compounds by EPA Method 8260; collect three 40-milliliter volatile organic analytes (HCl).
b. Vinyl chloride by selected ion monitoring; collect two 40-milliliter volatile organic analytes (HCl).
c. Natural attenuation parameters include Acetylene/Methane/Ethene/Ethane by Method 8015, Sulfate/Nitrate by IC Method E300, Sulfide by Methoc
TOC by Method 415.1, and DO/ORP/Iron II field measurements.