Vapor Intrusion Evaluation and Assessment Approach
Boeing Auburn Facility
Auburn, Washington

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Prepared for

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LIST OF ABBREVIATIONS AND ACRONYMS

bgs ..... below ground surface
Boeing ..... The Boeing Company
CSIA ..... compound specific isotope analysis
CUL ..... cleanup level
Ecology ..... Washington State Department of Ecology
EPA ..... U.S. Environmental Protection Agency
Facility ..... Boeing Auburn Fabrication Division Facility
ft ..... foot/feet
HI ..... hazard index
HVAC ..... heating, ventilating, and air conditioning
IAAL ..... indoor air action levels
JEM ..... Johnson & Ettinger Model
LAI ..... Landau Associates, Inc.
µg/L ..... micrograms per liter
µg/m^3 ..... micrograms per cubic meter
MTCA ..... Model Toxics Control Act
PCE ..... tetrachloroethene
PCL ..... preliminary concern level
QAPP ..... quality assurance project plan
RI ..... remedial investigation
SIM ..... selected ion monitoring
SL ..... screening level
SWMU ..... solid waste management unit
TCE ..... trichloroethene
VAF ..... vapor attenuation factor
VC ..... vinyl chloride
VOC ..... volatile organic compound
WDOH ..... Washington State Department of Health

1.0 INTRODUCTION

This document presents the Boeing Auburn Vapor Intrusion Evaluation and Assessment Approach based on current remedial investigation (RI) data related to The Boeing Company's (Boeing's) Auburn Fabrication Division Facility (Facility) located at 700 15th Street Southwest in Auburn, Washington (Figure 1). The document also provides an updated vapor intrusion assessment using current Site conditions (through July 2014) based on the approach outlined in this document. Boeing is currently undergoing corrective action at the Facility. Corrective action requirements are documented in an Agreed Order (No. DE 01HWTRNR-3345) dated August 14, 2002 and a First Amended Agreed Order dated February 21, 2006, both with Washington State Department of Ecology (Ecology). The Agreed Order includes a requirement to conduct an RI of Facility contamination impacts both within the Facility (on Boeing property) and at downgradient properties (off Boeing property).

Boeing has been implementing RI activities in phases to characterize the nature and extent of two low-concentration trichloroethene (TCE) groundwater plumes (the Area 1 plume and the western plume). Both plumes appear to originate on Boeing property and have migrated off Boeing property. The source of the Area 1 plume is associated with a historical release from a TCE degreaser that operated in former Facility Building 17-05[1] (LAI 2009). The source of the western plume has not been identified but appears to be in the vicinity of Building 17-07 and may be associated with a former TCE vapor degreaser[2] that was operated in that building (LAI 2010).

As part of the RI, risks associated with the vapor intrusion migration pathway (i.e., movement of contaminated vapors from the subsurface into indoor air) for volatile organic compounds (VOCs) are being evaluated. The primary VOCs of concern are TCE and the TCE breakdown product vinyl chloride (VC). This document presents an assessment of current Site conditions as they relate to vapor intrusion and outlines a systematic approach to evaluate the need for additional vapor intrusion assessments where TCE and VC are detected in shallow groundwater.

1.1 Background

In 2011, Ecology requested that Washington State Department of Health (WDOH) conduct a health consultation pertaining to VOC impacts. The purpose of the health consultation was to evaluate potential human health effects that could result from exposure to VOCs associated with impacted groundwater (WDOH 2012). The health consultation discussed exposure to VOCs by the vapor intrusion pathway. Although the vapor intrusion pathway was previously evaluated between 2003 and 2006 near the Area 1 TCE plume source (LAI 2012a), the health consultation re-evaluated the vapor intrusion exposure pathway for two reasons: 1) the extent of shallow groundwater VOC contamination was larger than previously documented, and 2) procedures for vapor intrusion

[1] Building 17-05 was demolished and the property was annexed from the Facility; the AMB building has since been constructed on that property (the AMB building is now occupied by Prologis).
[2] The solid waste management unit (SWMU) for this degreaser is SWMU S-13.

characterization have changed based on the publication of Ecology's draft vapor intrusion guidance document in 2009 (Ecology 2009).

While WDOH identified the need to re-evaluate the vapor intrusion exposure pathway, the health consultation recognizes Ecology as the agency responsible for facilitating further assessment of the vapor intrusion pathway with WDOH review support (WDOH 2012). Upon identifying the need for a re-assessment of the vapor intrusion exposure pathway in late 2011, WDOH and Ecology jointly requested that Boeing conduct a vapor intrusion assessment using Ecology's draft vapor intrusion guidance. Boeing worked collaboratively with WDOH and Ecology to conduct an initial vapor intrusion assessment in 2012. The 2012 vapor intrusion assessment identified the VOCs tetrachloroethene (PCE)[3], TCE, and VC in groundwater and soil gas near or under occupied commercial and industrial buildings both on Boeing property and off Boeing property.

As a result, a draft work plan proposed additional vapor intrusion investigation at five building locations[4] (LAI 2012a). The work plan presented an assessment of available shallow groundwater and soil gas data collected near or under the five buildings and surveys of each building to evaluate routes of potential vapor intrusion and potential sampling locations. Additional soil gas and indoor air sampling were proposed based on the existing data and building survey information. Ecology approved the draft vapor intrusion work plan (Ecology 2012a) and WDOH included parts of the draft vapor intrusion work plan (i.e., the scope of work and relevant available groundwater and soil gas data) in the final health consultation (WDOH 2012).

Activities proposed in the vapor intrusion work plan were executed in February 2012. The data results and associated building vapor intrusion assessments were presented in a 2012 vapor intrusion assessment report (LAI 2012b). The vapor intrusion assessment report documented that the vapor intrusion pathway was not of concern at the assessed buildings but that a follow-up assessment should be conducted at the Fana West building where a background indoor air PCE source appeared to have caused exceedances of the indoor air CUL for PCE. The follow-up data collection activities were approved by Ecology for the Fana West building and were conducted in August 2012. The results indicated that the vapor intrusion pathway was not of concern at the Fana West building (LAI 2012c). The buildings assessed during the 2012 vapor intrusion assessments are shown on Figure 2.

Ecology provided comments on the 2012 vapor intrusion assessment report in a two-part letter (Ecology 2012a,b). The first part of the comment letter pertained to resampling the Fana West

[3] PCE is present at very low concentrations in soil, shallow soil gas, and shallow groundwater on Boeing property. It is also present at low concentrations in shallow groundwater off Boeing property. Detections of PCE in groundwater are below cleanup levels (CULs) and below vapor intrusion screening levels (SLs). Additionally, PCE concentrations in soil gas are below soil gas SLs protective of Model Toxics Control Act (MTCA) Method B Air CULs.

[4] Buildings of potential concern included Building 17-07 on Boeing property and AMB (now Prologis), YMCA, Junior Achievement, and Fana West off Boeing property.

building; this was addressed in a July 2012 response letter (LAI 2012d) and by completing the August 2012 resampling activities mentioned above.

The second part of the comment letter acknowledged that the 2012 vapor intrusion assessments were focused and did not constitute completion of a Site-wide vapor intrusion assessment. Ecology concluded that a Site-wide vapor intrusion assessment of shallow groundwater RI data was needed to determine where additional vapor intrusion assessment may be required. Ecology's specific requests in the second part of the comment letter (Ecology 2012b) were:

- Request 1: Submittal of a systematic approach to evaluate the need for future vapor intrusion assessments
- Request 2: Final confirmation of indoor air sampling at Building 17-07
- Request 3[5]: Submittal of proposed vapor intrusion screening criteria (CULs and SLs) to be used during future vapor intrusion assessments.

This document addresses Request 1. The initial draft of this document (LAI 2014a) was provided to Ecology in February 2013. When the initial draft of this document was released, the need for a residential vapor intrusion assessment study in a neighborhood within Algona, Washington was identified. Ecology and Boeing agreed to focus resources on the completing the residential vapor intrusion assessment study prior to finalization of this document. The residential Algona vapor intrusion assessment study (2013/2014 residential vapor intrusion assessment) began during the summer of 2013 and was completed in April 2014, and was conducted in accordance with a residential vapor intrusion work plan (LAI 2013a). A final technical summary report of the residential Algona vapor intrusion assessment study was completed (LAI 2014b) and the location of the residential study area is presented on Figure 2.

In Request 2, Ecology requested that confirmation indoor air sampling be conducted at Boeing's Building 17-07 even though VOCs were not detected in the initial indoor air samples. Request 2 was completed in April 2013 and the results were presented in a status report (LAI 2013b).

The third request regarding development of vapor intrusion screening criteria was a critical path to addressing Request 1; therefore, Request 3 was addressed first via submittal of a September 2012 technical memorandum (LAI 2012e). The technical memorandum proposed indoor air CULs, soil gas SLs, and shallow groundwater SLs for vapor intrusion constituents which included PCE[6], TCE, and VC. Ecology approved the proposed CULs and SLs with revisions to the TCE CULs and SLs in November 2012 (Ecology 2012c). The final CULs and SLs are summarized in Section 2.1.1. Boeing's response to Ecology comments on the Draft Vapor Intrusion Evaluation and Assessment Approach is provided in Appendix A.

[5] This third request was not labeled "Request 3" in the comments but was listed as a unique third request following Requests 1 and 2.

[6] PCE was subsequently removed as a constituent of concern, which is discussed further in Section 2.1.2.

1.2 Report Organization

The remainder of this document is organized in two parts. Section 2.0 describes the proposed tiered approach to vapor intrusion assessment including the vapor intrusion screening criteria and data evaluation and assessment for each tier of the evaluation. Section 3.0 presents a vapor intrusion assessment of current Site conditions and proposes next steps in the vapor intrusion assessment process.

2.0 SITE-WIDE VAPOR INTRUSION ASSESSMENT APPROACH

This section presents a vapor intrusion assessment approach for the RI. This approach is generally consistent with Ecology's draft vapor intrusion guidance (Ecology 2009). This approach also includes documentation of vapor intrusion screening criteria and constituents of concern.

2.1 Site Vapor Intrusion Assessment Approach Overview

This assessment approach is based on the tiered approach presented in Ecology's draft vapor intrusion guidance document (Ecology 2009). The assessment process consists of two[7] stages of assessment:

- Tier I assessment – Focuses on determining which buildings may be at risk for vapor intrusion using shallow groundwater and/or soil gas data
- Tier II assessment – Focuses on evaluating a particular building or group of buildings of potential concern using indoor air (which may include crawlspace or basement air), ambient air, and sub-slab soil gas data[8].

The Tier I assessment evaluates whether VOCs in shallow groundwater or soil gas occur at concentrations that could pose a vapor intrusion threat to indoor air quality. The Tier II assessment evaluates specific buildings to determine if VOCs of potential concern are present in indoor air above MTCA CULs and if the VOCs are related to vapor intrusion (Ecology 2009).

RI groundwater characterization activities are ongoing. As additional shallow wells are installed or shallow borehole samples are collected as part of the RI activities, new Tier I shallow groundwater data will be compared to vapor intrusion SLs. Locations where SL exceedances occur will be identified and the need for additional Tier I data collection (or the need to move to Tier II data collection) will be evaluated in accordance with this vapor intrusion assessment approach. Section 3.2.1 provides such an evaluation for new well data gathered in summer of 2014.

2.1.1 Vapor Intrusion Screening Criteria

Vapor intrusion screening criteria have been developed for shallow groundwater [SLs and preliminary concern levels (PCLs)], shallow soil gas (SLs), and indoor air[9] [CULs, SLs, and indoor air action levels (IAALs)]. The shallow[10] soil gas SLs are used to screen soil gas (less than 15 ft bgs) collected outside of a building footprint or to screen sub-slab soil gas data collected beneath a building of potential concern. The shallow groundwater SLs are used to screen shallow groundwater (less than 35 ft bgs[11]) data from Site-wide shallow monitoring wells and shallow borehole samples during Tier I assessments.

[7] Ecology's guidance presents an additional stage of assessment call a "preliminary assessment". The preliminary assessment for the RI was completed in 2012 and therefore, is not discussed in this document.
[8] The type and combination of samples varies based on building type and conditions. See Section 2.3.1.
[9] Indoor air screening criteria are used for indoor air, crawlspace air, and basement air.
[10] Groundwater is typically shallower than 15 feet (ft) below ground surface (bgs); therefore, deep soil gas (defined as deeper than 15 ft bgs) is not anticipated to be collected.
[11] The bottom of the deepest shallow zone well screen is approximately 35 ft bgs.

Due to very shallow groundwater (less than 5 ft bgs) in northeastern residential Algona, more conservative PCLs were used to screen shallow groundwater data for the 2013/2014 residential vapor intrusion assessment. MTCA indoor air CULs (Methods B and C[12]) and SLs (Modified Method B[13]) are used in making long-term Site cleanup decisions and general screening. IAALs are used in making interim action decisions such as mitigation.

The proceeding sections present screening criteria for TCE and VC. Initially, during the 2012 vapor intrusion study, screening criteria were also developed for PCE; however, PCE has since been eliminated from the list of vapor intrusion analytes due to the low concentrations in groundwater and soil gas and the potential for background source detections. A more thorough discussion of the elimination of PCE as a contaminant of concern in the vapor intrusion pathway is presented in Section 2.1.2. Screening criteria for other VOCs besides TCE and VC may be calculated during development of area-specific vapor intrusion work plans if additional VOCs are present at significant concentrations in Tier I data (i.e., soil gas or shallow groundwater).

VOCs have been identified in shallow groundwater in residential, commercial, and industrial areas. Therefore, vapor intrusion screening criteria have been developed for the three land-use based exposure scenarios. The vapor intrusion screening criteria are presented by exposure scenario in Table 1 (residential), Table 2 (commercial), and Table 3 (industrial). Land use areas[14] are delineated on Figure 2. These land use areas generally define where the corresponding screening criteria will apply for vapor intrusion screening and assessments. Shallow groundwater and soil gas SLs, indoor air CULs and SLs were previously reviewed and approved for the project in November 2012 (LAI 2012e; Ecology 2012c). In 2012, the U.S. Environmental Protection Agency (EPA) announced new subchronic TCE air concentration values that have been adopted herein as short-term IAALs. The following subsections present further details on 1) shallow groundwater and soil gas SLs (Section 2.1.1.1. and Section 2.1.1.2, respectively), 2) MTCA long-term exposure indoor air CULs and SLs (Section 2.1.1.3), and 3) IAALs (Section 2.1.1.4).

2.1.1.1 Shallow Groundwater Criteria

In the absence of Site-specific data regarding the relationship between groundwater concentrations and the potential for a complete and significant vapor intrusion pathway, a conservative approach is used to calculate shallow groundwater SLs where the shallow groundwater SLs are derived using a ratio of the MTCA indoor air CULs and SLs to a vapor attenuation factor (VAF) and Henry's Law

[12] The MTCA Method C values may be applied when the receptors of concern are industrial workers. Application of Method C as part of the Site cleanup action is conditional and requires imposition of institutional controls per Washington Administrative Code 173-340-706.

[13] Modified MTCA Method B SLs for commercial properties may only apply as long as all receptors of concern for that building or area remain "commercial" workers. Additionally, MTCA Method B CULs for commercial property will be developed during the feasibility study, since the current modified MTCA Method B values are only screening values.

[14] The extent of land use areas defined represents the area of the shallow VOC plumes with some upgradient, crossgradient, and downgradient buffer. Land use designations were determined using field observation and King County's mapping tool (iMAP).

Constant[15] in accordance with Ecology's draft vapor intrusion guidance document (Ecology 2009). In shallow groundwater SL calculations, the VAF takes into account attenuation across both the soil column and across a building's foundation. If conditions differ from the assumptions used in identifying the VAF (for example very shallow groundwater) the standard VAF may require further consideration. Using the standard VAFs, the calculated initial shallow groundwater screening criteria (and associated indoor air values) are presented in Table 4.

In residential Algona, groundwater is typically very shallow (often 5 ft or less bgs). Ecology recommended using a more conservative VAF of 1/667 (unitless) to calculate shallow groundwater PCLs in residential Algona (Ecology 2013). In the 2013/2014 residential vapor intrusion assessment, the shallow groundwater PCLs were used instead of the initial shallow groundwater SLs to define the area for Tier II indoor air assessment; however, use of the PCLs did not result in any additional residences being included in the Tier II assessment beyond those that would have been included if the initial SLs had been used. The shallow groundwater PCLs were presented in the Algona residential vapor intrusion work plan (LAI 2013a).

Analysis of the data from the 2013/2014 residential vapor intrusion assessment indicates that the PCLs previously developed were conservative in their approach. Ecology has approved SLs for groundwater in residential areas and PCLs are no longer in use (Ecology 2014). SLs for residential Algona are presented in Table 4.

2.1.1.2 Shallow Soil Gas Screening Levels

Similar to shallow groundwater SLs, shallow soil gas SLs are derived using a ratio of the MTCA indoor air CULs and SLs to a VAF. However, in shallow soil gas SL calculations, the VAF takes into account only attenuation across a building's foundation. Shallow soil gas SLs are presented in Table 4.

2.1.1.3 Indoor Air Cleanup Levels and Screening Levels

MTCA vapor intrusion screening criteria were established and approved by Ecology in November 2012. The indoor air screening criteria were developed using standard MTCA Method B (residential CULs) and Method C (industrial CULs) formula values and modified MTCA Method B (commercial SLs[16]) values (LAI 2012e). Development of the screening criteria involved reviewing both carcinogenic and non-carcinogenic values for each of the three exposure scenarios. To evaluate potential carcinogenic effects, an excess cancer risk of 1 in 1 million (1x10-6) was used in the cleanup and screening level evaluation. For the residential and commercial scenarios, the carcinogenic values were the most conservative (and thus adopted for use) for TCE and VC. For the industrial scenario, non-carcinogenic values were the most conservative for TCE, and carcinogenic values were the most

[15] Henry's Law constant defines the steady-state relationship between liquid and vapor phase concentrations of volatile chemicals.

[16] Modified MTCA Method B values for commercial areas are considered SLs because MTCA does not contain a provision for use of commercial CULs.

conservative for VC. The carcinogenic and non-carcinogenic indoor air values for all land use types, including the values adopted as CULs and SLs, are provided in Table 5.

2.1.1.4 Indoor Air Action Levels

IAALs are SLs used to make decisions about interim actions such as mitigation or additional sampling. There are two types of IAALs: short-term exposure, which are concentration-based IAALs, and long-term exposure, which are risk-based IAALs.

A short-term exposure IAAL was developed for only one compound, TCE, based on an EPA Region 10 publication (EPA 2012) that identified potential non-carcinogenic risk to a developing fetus; short-term exposure IAALs are not derived from MTCA. The short-term exposure IAAL for TCE is 2.0 micrograms per cubic meter (µg/m^3), and is applicable to residential, commercial, and industrial land use scenarios where women of childbearing age reside or work.

A process for developing long-term (i.e., chronic) exposure IAALs was established for and implemented during the recent residential vapor intrusion assessment program in Algona (LAI 2013a). The same process may be utilized for other vapor intrusion assessments. Using this process, the chronic exposure IAALs have a cumulative potential cancer risk of 1 in 100,000 (1x10-5) or a non-cancer hazard index (HI) of 1 (whichever is less). A cumulative potential cancer risk is calculated for each Tier II sample by summing the potential cancer risk of each detected chemical with carcinogenic effects (e.g., TCE and VC). The calculated cumulative potential cancer risk is compared to the IAAL of 1x10-5. For each sample, a cumulative potential non-cancer HI is also calculated for each non-cancer health effect and compared to the IAAL of 1.0. Additional discussion on the role of IAALs in evaluating Tier II data is presented in Section 2.3.3.

2.1.2 Vapor Intrusion Constituents of Concern

During the 2012 vapor intrusion assessment, constituents of potential concern were identified as PCE, TCE, and VC. Since the 2012 assessment, groundwater and soil gas SLs have been developed and approved based on indoor air CULs. As mentioned in Section 2.1.1, screening criteria for other VOCs may be calculated as part of area-specific vapor intrusion work plans if present in Tier I data (i.e., soil gas or shallow groundwater).

While PCE has been detected at low concentrations in groundwater both on Boeing property and off Boeing property, the concentrations are well below shallow groundwater SLs. The maximum PCE detection in the most recent shallow groundwater samples on Boeing property was 0.81 micrograms per liter (µg/L), which is significantly lower than the industrial vapor intrusion groundwater SL of 100 µg/L (LAI 2012e). The maximum PCE detection in the most recent shallow groundwater samples off Boeing property was less than 0.5 µg/L, which is significantly less than the most conservative approved vapor intrusion groundwater SL (the residential exposure scenario) of 24 µg/L. Additionally, PCE has not exceeded soil gas SLs either on or off Boeing property. The maximum detection of PCE in

soil gas on Boeing property (at Building 17-07) was 220 µg/m^3, which is significantly less than the approved industrial soil gas SL of 1,300 µg/m3 (LAI 2012a). PCE was not detected in soil gas off Boeing property during the 2012 vapor intrusion assessments. The most recent shallow groundwater PCE concentrations are presented on Figure 3.

In addition to recent PCE data, historical PCE data from 1990 to present were evaluated. The maximum shallow groundwater PCE concentration detected was 2.2 µg/L (in on Boeing property well AGW078 on May 21, 2001), which is still less than the residential PCE vapor intrusion SL of 24 µg/L.

Based on the data presented above, PCE is not considered a constituent of concern in groundwater for vapor intrusion assessments; TCE and VC are the primary chemicals that will continue to be evaluated as constituents of concern in vapor intrusion assessments. Although there are presently no MTCA air CULs (and thus no vapor intrusion groundwater or soil gas SLs) for cis-1,2-dichloroethene, it will continue to be included as an analyte in future vapor intrusion work if it is detected in shallow groundwater or soil gas.

2.2 Tier I Assessment Process

The Tier I assessment process evaluates shallow groundwater data from RI monitoring wells and borehole samples and shallow soil gas data as a conservative indicator to identify areas where further vapor intrusion investigation is warranted. The first step in the process is to conduct a Tier I assessment of TCE and VC data from shallow RI wells. If the initial assessment of Tier I groundwater data indicates the need for further investigation, the next step may be additional Tier I data collection or potentially Tier II data collection at buildings of potential concern (see Section 2.3). Collection of additional Tier I data may consist of either shallow soil gas sampling [if adequate vadose zone is present[17]] or shallow groundwater borehole sampling (if the depth to groundwater is very shallow) with the intent of refining the area where groundwater or soil gas exceeds SLs.

This Section consists of three subsections that address each of the three types of Tier I data. The first section (Section 2.2.1) presents the Tier I assessment process using shallow RI groundwater well data. The second section (Section 2.2.2) presents the Tier I assessment process for sample collection and use of shallow soil gas data. The third section (Section 2.2.3) presents the Tier I assessment process for sample collection and use of shallow groundwater borehole data.

2.2.1 Tier I Shallow Groundwater Data Assessment

Assessment of shallow groundwater data at the Site is complex because samples from various well types contribute to the shallow groundwater data set. Much of the data used in the Tier I assessment will come from shallow zone monitoring wells. A total of 108[18] shallow RI groundwater wells are part

[17] Per Ecology's draft vapor intrusion guidance (2009) "due to the possibility of diluting the collected soil gas with atmospheric air, samples should not be collected from depths shallower than 5 ft bgs (unless located sub-slab)".

[18] In multi-level wells, each separate screened interval is considered an individual well for sampling purposes.

of the current RI groundwater sampling program; 48 are screened across the top of the water table (i.e., water table wells), 60 are screened beneath the water table surface (i.e., other shallow wells). Water table data will be used whenever it is available; however, in some areas shallow well data will be used if no water table data is available. The current shallow RI groundwater wells are screened between 1.25 ft bgs and 35 ft bgs with screen lengths ranging from 0.5 ft to 20 ft. The current shallow RI monitoring well network is shown on Figure 4. Well construction details are presented in Table 6.

As mentioned previously, 20 multi-level wells have been installed as part of the RI; each multi-level well has two or three channels screened in the shallow zone[19]. Although the shallowest channel (channel 1) may not be part of the ongoing groundwater monitoring program, channel 1 data from previous sampling events may be used in Tier I assessments because it is the closest to the water table surface. Likewise, borehole water samples are sometimes collected at the water table surface during well installation or direct-push probe investigations. When available, data representative of the water table surface will be used instead of deeper shallow zone samples when conducting Tier I assessments. Actual data used in the Tier I assessment presented in this document are further discussed in Section 3.1.3.

In the Site-wide Tier I assessment, the most recent data from shallow RI wells are compared to appropriate SLs for TCE and VC. If water table data or shallower groundwater data is available at or very near a particular location, the shallower data will be used instead of the deeper well data. The following procedure is used to screen the shallow groundwater data:

1. Delineate a shallow groundwater contour equal to the associated exposure scenario SL (i.e., residential, commercial, or industrial) based on current data.
2. Consistent with the draft vapor intrusion guidance “100 ft rule” (Ecology 2009), identify the areas within 100 ft of the contour; the combined area within the SL contour and the 100 ft radius represents the area where further vapor intrusion assessment should be conducted.
3. Note the presence of existing buildings within the identified area.
4. Use the nearest shallow groundwater depth-to-water data to assess the average water table depth. If the average depth to water is greater than or equal to 5 ft bgs, shallow soil gas will be investigated in accordance with Section 2.2.2; if the average depth to water is less than 5 ft bgs, shallow groundwater may be investigated instead of soil gas in accordance with Section 2.2.3.

The first Site-wide Tier I shallow groundwater assessment was presented in the residential vapor intrusion work plan (LAI 2013a). Since the first assessment, additional shallow wells have been installed, additional shallow borehole samples have been collected, and SLs have been updated and approved by Ecology (Ecology 2014). A second updated Site-wide Tier I shallow groundwater assessment using data through July 2014 is presented in Section 3.0 of this document. For the

[19] Newly installed (i.e., July 2014) multi-level wells AGW240 through AGW243 and AGW 247 through AGW251 have a 2.5 ft water table screen installed in channel 1 to intersect shallow groundwater during seasonal fluctuations. Water level measurements from channel 1 in these multi-level wells will be interpreted similarly to data from water table wells.

duration of the RI, future Site-wide Tier I shallow groundwater assessments will typically occur on an annual basis.

2.2.2 Tier I Shallow Soil Gas Data

This section is split into three subsections. Section 2.2.2.1 discusses shallow soil gas sample collection. Section 2.2.2.2 discusses how shallow soil gas data will be used. Section 2.2.2.3 discusses use of the Johnson & Ettinger Model (JEM) for modeling vapor intrusion when shallow soil gas concentration data are collected.

2.2.2.1 Shallow Soil Gas Data Collection

In areas that require further Tier I assessment, shallow soil gas data will be collected where adequate vadose zone is present. Soil gas samples should be located to evaluate:

1. Concentrations directly above the subsurface vapor intrusion source (i.e., shallow groundwater; Ecology 2009)
2. Concentrations near lateral gas-phase VOC preferential pathways such as utility pipe bedding corridors located in the vadose zone.

The minimum sample depth of a shallow soil gas sample is typically 5 ft bgs[20]; the maximum depth of a shallow soil gas sample is 15 ft bgs[21]. In the case of collecting soil gas to evaluate concentrations along preferential pathways, some utility corridors may be shallower than 5 ft bgs, as defined by the top of the associated utility line(s). If this is the case, shallower samples may be collected but closer spacing of shallow soil gas collection points along the preferential pathway may be needed. Also, shallow soil gas samples should not be collected in areas that are not covered by impervious surface after significant rain events (Ecology 2009). Soil gas sample locations will be evaluated for each applicable area and a work plan will be submitted to Ecology for approval.

Soil gas samples may be collected using either a direct-push probe or a rotohammer and a gas vapor probe kit. Soil gas sampling procedures will be presented in future work plans. Soil gas samples will be analyzed for vapor intrusion constituents of concern (i.e., TCE and VC) by EPA Method TO-15, EPA Method TO-15 low-level, or EPA Method TO-15 selected ion monitoring (SIM) using Summa vacuum canisters in accordance with the RI quality assurance project plan (QAPP; LAI 2013c).

2.2.2.2 Assessment of Shallow Soil Gas Concentration Data

Assessment of soil gas requires a comparison of soil gas data with appropriate SLs based on land use. If the data does not exceed the SL then there may be no need to assess the vapor intrusion pathway further; however, if the soil gas data exceeds the SL, then additional vapor intrusion assessment may be needed. Also, if soil gas data indicates that the area of soil gas contamination above the SL has not

[20] Sampling may be considered at shallower depths if less permeable surfaces such as asphalt are present.

[21] For the purposes of calculating SLs, shallow soil gas is defined as less than 15 ft bgs; deep soil gas is defined as 15 ft bgs or deeper (Ecology 2009). Depth to water is generally less than 15 ft bgs (with the exception of some locations on Boeing property).

been adequately bounded, then additional soil gas data may need to be collected. If the soil gas data exceeds SLs, the next step is to identify buildings for assessment within 100 ft[22] of areas exceeding SLs. There are two options for assessing these buildings:

1. Conduct JEM evaluation to further assess the potential for vapor intrusion at the existing building(s) using the shallow soil gas data and other parameters; see Section 2.2.2.3; or
2. Commence the Tier II assessment process at existing building(s); see Section 2.3.

Option 1 requires collection of building-specific information, which typically requires a building survey (Section 2.3.1). Additional soil gas investigation (if any) and the proposed use of option 1 (JEM) or option 2 (Tier II data collection) will be recommended in a Tier I assessment report and supplemental work plans, as needed. These work plans will be submitted to Ecology for approval. The Tier I soil gas data assessment process is summarized on the decision tree presented on Figure 5.

2.2.2.3 Johnson & Ettinger Model Evaluation

The JEM is a model that may be used to evaluate the vapor intrusion pathway for existing or future buildings. Ecology considers the JEM a Tier I assessment tool that may be used to estimate indoor air VOC concentrations due to vapor intrusion at sites regulated by Ecology. The vapor intrusion guidance states that Ecology believes that one outcome from using the JEM properly is to screen out buildings where vapor intrusion is very unlikely to pose unacceptable risks to indoor receptors (Ecology 2009).

Components of the vapor intrusion conceptual model that might make a building very unlikely to be susceptible to vapor intrusion include: 1) having a layer of fine-grained soils between the top of the contaminated soil gas and the foundation, 2) ground surface features (such as landscaped open spaces) between the location of detected soil gas above the SL and buildings to which soil gas would preferentially flow and discharge to the atmosphere (soil aeration) rather than into nearby building foundations, or 3) the building construction has vapor barrier components.

For this vapor intrusion assessment approach, the JEM will primarily be used to estimate indoor air concentrations or attenuation factors at buildings of potential concern within 100 ft of areas exceeding soil gas SLs. When using Tier I soil gas data with the JEM, the EPA's JEM worksheet "SG-ADV" will be used. The JEM will not be used if concentrations are more than 100 times the SL per Ecology's draft guidance. Application of the JEM will be in general accordance with Appendix D of the draft vapor intrusion guidance[23] (Ecology 2009).

Per the draft vapor intrusion guidance, if the JEM predicts that indoor air concentrations would be at or below applicable CULs then the vapor intrusion assessment for that building would be terminated. However, Ecology has requested that Boeing not base building screen-out decisions solely on JEM

[22] The buffer for including buildings in a Tier II assessment may be expanded in some cases such as the presence of significant known utility corridors or other known subsurface conditions that promote the migration of VOCs in the vapor phase.

[23] Per the draft vapor intrusion guidance, Ecology adopts the use of the EPA JEM worksheets. The primary JEM worksheet anticipated to be used for this Site is the EPA's SG-ADV where SG is soil gas and ADV is advanced.

calculated indoor air concentration from EPA's JEM worksheet "SG-ADV". Screen-out decisions will be made by using shallow soil gas data as primary data and JEM results as secondary or supportive information.

Specifically, the shallow soil gas results, other available Site-specific variables (soil type; building information), and default variables (when Site specific are not available) will be plugged into "SG-ADV" to obtain the "infinite source indoor attenuation coefficient" representative of vapor attenuation from shallow soil gas to indoor air. The attenuation factor (e.g., coefficient) will then be derived by considering the cumulative effect of the vadose zone attenuation factor and the standard sub-slab attenuation factor (0.03); the cumulative attenuation factor is derived by multiplying the two individual attenuation factors. The combined attenuation factor would then be multiplied by the closest shallow soil gas concentration data that exceeded SLs to obtain a theoretical indoor air concentration for the building in question. If the resulting calculated indoor air concentration is below the applicable indoor air CULs (or SLs, in the case of commercial land use), then Boeing will propose to screen-out the respective building(s). However, if the calculated indoor air concentration is at or above the applicable indoor air CULs and SLs and there are no features that make a building very unlikely to be susceptible to vapor intrusion (described above), a Tier II assessment will be conducted (Section 2.3). An example of how this data analysis and screening-out process would work for a hypothetical soil gas sample collected near AGW209 (commercial area in Auburn) is provided in Appendix B. A decision tree for use of the JEM is presented on Figure 6.

2.2.3 Tier I Shallow Groundwater Borehole Data

The intent of collecting additional Tier I shallow groundwater data is to refine the area where groundwater exceeds SLs. Shallow groundwater borehole data will be collected at time of drilling using a direct-push probe or other drilling technology (e.g., sonic or hollow-stem auger). Samples will be collected within 2 ft of the water table encountered at time of drilling. Shallow groundwater borehole data will be analyzed by EPA Method 8260 for TCE and VC in accordance with the RI QAPP (LAI 2013c). The number and location of shallow groundwater borehole data samples will be presented in a work plan submitted to Ecology for approval.

Once a shallow groundwater borehole sample collection plan for a given area has been implemented, the shallow groundwater borehole data will be evaluated to determine if adequate groundwater data has been collected to address data gaps. Assessment of borehole groundwater data requires a comparison of the data with appropriate groundwater SLs based on land use. If the data does not exceed the SL then there is no need to assess the vapor intrusion pathway further, but if the borehole groundwater data exceeds the SL, then an additional assessment would be triggered. Also, if borehole groundwater data indicate that the area of groundwater contamination above the SL has not been adequately bounded, then additional data may need to be collected.

If borehole groundwater data exceeds the SLs, and there is no opportunity to collect additional Tier I soil gas data, it will be necessary to identify existing buildings within 100 ft of the defined area of exceedance. For existing buildings that are within 100 ft of areas exceeding SLs, a Tier II assessment process may be required (see Section 2.3). Additional borehole groundwater investigation (if any) and implementation of Tier II assessment (if any) will be recommended in a Tier I assessment report and supplemental work plan, as needed. The supplemental work plan will be submitted to Ecology for approval. The borehole groundwater data assessment process is summarized on the decision tree presented on Figure 7.

2.3 Tier II Assessment Process

The Tier II assessment process evaluates what impact (if any) vapor intrusion has on indoor air for an existing building of potential concern. The type of Tier II data to be collected at a given building may include indoor air (includes crawlspace and basement air), ambient air, and co-located sub-slab soil gas samples. This section presents the assessment process for buildings of potential concern, how Tier II sampling locations are selected (Section 2.3.1), types of Tier II analyses and sampling procedures (Section 2.3.2), and how Tier II data results will be evaluated (Section 2.3.3).

2.3.1 Building Surveys and Conceptual Models

Prior to Tier II data collection, building surveys will be conducted and conceptual models for buildings of potential concern will be developed. Information gathered during building surveys will also help to evaluate appropriate and feasible sampling locations. The conceptual model will provide a conceptual understanding of the potential pathways for vapor intrusion at each building.

Depending on access, buildings of potential concern requiring Tier II data collection may be surveyed. The initial step of the building survey is to establish a point of contact at the building of potential concern and arrange a time to conduct the building survey. For industrial or commercial properties the point of contact may be the property manager or owner, and for residential properties it will likely be the property owner. Prior to or at the beginning of the building survey visit, Boeing will attempt to obtain construction or relevant utility plans that may be available from the building contact or municipal public works organizations. The building survey will focus on gathering the information outlined below:

- Construction and structural details: the foundation type and characteristics (slab-on-grade, footings and crawlspace, or basement), barriers, and features that could be potential preferential pathways (e.g., utility trenches, cracks in the slab, sumps, floor drains, elevators, or other likely soil vapor routes into the building).
- Air circulation in the building: the heating, ventilation, and air conditioning (HVAC) system layout and typical operation; pressure gradients induced by the HVAC system can cause vapors to migrate indoors.

- Receptor details: for documentation purposes, interview the building contact or owner to obtain typical receptor population and exposure frequency data (e.g., hours occupied on a daily basis, age of occupants, and spaces typically occupied within the building).
- Background indoor air source inventory: document potential indoor air VOC sources (e.g., chemicals used indoors that contain VOCs, dry cleaning chemicals, etc.); notes regarding typical use of potential indoor air VOC sources (e.g., solvents used in machining) will be documented and photos of potential indoor air sources will be taken (if permission is granted by the building owner). Material safety data sheets will be obtained (if available) and reviewed for identified potential background indoor air sources.

The results of the building survey may determine that the building does not require further vapor intrusion assessment; therefore, it would not be necessary to conduct Tier II sampling. An example would be if the HVAC system creates a continuous positive pressure in the building preventing soil gas vapor from moving into the building. The determination that a building would not need further Tier II assessment would be proposed in a technical memorandum and submitted to Ecology for approval.

When Tier II sampling is deemed necessary for a given building, it will include indoor air (which will also include crawlspace or basement air, if these features are present), ambient air, and co-located sub-slab soil gas sampling whenever possible. However, sub-slab soil gas samples cannot be collected at buildings with the following conditions:

- Earthen crawlspaces, with no slab
- Wetted slabs (basement or slab-on-grade) where shallow groundwater is immediately beneath the slab.

At locations with the above conditions, only indoor air and ambient air samples can be collected. Such conditions (construction and structural details) will be documented during the building survey.

Once the available construction and utility information have been obtained and the building survey has taken place, the building-specific conceptual model will be developed. The conceptual model will consider the building's spatial relationship to subsurface contamination, evaluate preferential pathways for vapor migration, and consider potential receptor exposure. The conceptual model will contain applicable elements in accordance with Section 3.2 of Ecology's draft vapor intrusion guidance (Ecology 2009). Once the building survey and conceptual model are completed, a Tier II work plan will be compiled and submitted to Ecology for approval. Sample locations will be determined based on preferential pathways, air circulation, and spaces occupied most by receptors.

2.3.2 Tier II Sampling Analyses and Procedures

Tier II data collection consists of air samples (soil gas and indoor/ambient/crawlspace/basement air). The VOC air analyses to be run include EPA Method TO-15 SIM, EPA Method TO-15 low-level, and EPA Method TO-15 (standard). The primary constituents of concern to be reported include TCE and VC[24];

[24] If additional Tier II data collection is conducted in residential Algona, samples will be analyzed for TCE only, based on the results of the 2013/2014 sampling where VC was not detected in any of the 189 samples.

additional chemicals may be analyzed depending on the VOCs detected in nearby shallow groundwater samples. VOC air samples are typically collected using Summa vacuum canisters.

Analytical standards for indoor air (includes crawlspace and basement air), ambient air, and sub-slab soil gas samples are presented in the RI QAPP (LAI 2013c) and air data collection procedures are presented in the RI Sampling and Analysis Plan (LAI 2013d). A revised shroud procedure for sub-slab collection of soil gas was submitted to Ecology for review in December 2013 (Wynkoop, J. 2013); Ecology approved the revised procedure in January 2014 (Harrover, R. 2014). Analytical reporting limits will be below the associated vapor intrusion SLs to which the samples will be compared.

If VOCs are detected in indoor air, the potential sources are vapor from the soil vadose zone below the structure or a background source in indoor or in ambient air. If the Tier II data are not conclusive, a chemical fingerprinting technique called compound-specific isotopic analysis (CSIA) may be utilized to attempt to distinguish which source is impacting indoor air: vapor intrusion from subsurface or a background source. This use of CSIA was previously proposed in the 2012 vapor intrusion assessment report (LAI 2012b), and was further detailed in a response to comments letter to Ecology (LAI 2012d). The use of CSIA was approved by Ecology for the supplemental sampling activities at the Fana West building discussed in Section 1.1. The use of CSIA will be evaluated on a case-by-case basis. Recommendations for conducting CSIA sampling will be presented in a combined Tier II assessment report/work plan submitted to Ecology for approval.

2.3.3 Assessment of Tier II Data

As mentioned previously, typical Tier II samples for a given building of potential concern include indoor air (may include crawlspace or basement air), ambient air, and sub-slab soil gas. However, depending on the depth to water and building construction, a Tier II data set may include only indoor air and ambient air samples. Depending on the combination of indoor air, ambient air, and sub-slab data results, no further action, additional sampling, or mitigation may be required. Area-specific procedures for data analysis and Tier II decision-making will be outlined in future work plans; however, a general Tier II data decision matrix that will be used as the basis for decision matrices in future work plans is presented in Table 7. The decision matrix in Table 7 incorporates some concepts from Ecology's guidelines for evaluating Tier II data (Ecology 2009; Tables E-1 and E-2). However, it also incorporates evaluation of both carcinogenic and non-carcinogenic indoor air SLs and IAALs, discusses when to consider mitigation, and considers the importance of investigating potential background sources.

3.0 VAPOR INTRUSION ASSESSMENT OF CURRENT SITE CONDITIONS

This section presents a vapor intrusion assessment of current Site conditions (as of July 2014) using groundwater VOC data from shallow zone sample points. The shallow groundwater conditions are presented in Section 3.1. The shallow groundwater data is evaluated using the Tier I assessment process in Section 3.2. Recommendations for additional data collection are presented Section 3.3.

3.1 Current Shallow Groundwater Site Conditions

The following sections describe new shallow RI well locations (Section 3.1.1), groundwater flow and depth to water information (Section 3.1.2), and discuss the shallow groundwater data used in this evaluation (Section 3.1.3).

3.1.1 Recent Shallow Well and Borehole Sample Locations

Following submittal of the initial draft of this document (LAI 2014a) new shallow RI groundwater wells were installed at 5 locations between May and September 2013, and 12 locations in July 2014. There were 14 direct-push borings advanced in July 2014 (ASB0230 through ASB0243) for collection of groundwater samples.

In May and September 2013, conventional shallow wells (i.e., single-screen wells with 10-ft screens) were installed at four of the locations and borehole samples were collected at the water table during drilling; these wells include AGW231, AGW232, AGW236, and AGW239. A multi-level well (AGW235) was also installed at one location off Boeing property. AGW235 was installed with three shallow zone screens, each 6 inches in length, with the tops of the screens at 8.5 ft bgs, 18.5 ft bgs, and 28.5 ft bgs. Since each multi-level well screen is effectively an individual well, the three wells (from top to bottom) are named AGW235-1, AGW235-2, and AGW235-3, respectively.

In July 2014, three water table wells (i.e., AGW244, AGW245, and AGW246), and an additional nine multi-level wells (i.e., AGW240 through AGW243 and AGW247 through AGW251) were installed off Boeing property. The uppermost screen (channel 1) of the July 2014 multi-level wells was 2.5 ft in length and installed intersecting the seasonal groundwater table; therefore, groundwater elevation data from channel 1 in these wells will be interpreted as that of a water table well. The remaining screens in these multi-level wells are 6 inches in length.

Additional direct-push borings were also advanced in July 2014. Shallow borehole water samples were collected at the water table from each well; deeper samples were also collected for Site characterization purposes unrelated to vapor intrusion. For the purpose of Tier I screening, only the water table data are considered.

Technical reports summarizing the well installation and borehole sample collection have been prepared (LAI 2014c, 2015). The current shallow RI monitoring well network is shown on Figure 4.

3.1.2 Groundwater Flow and Depth to Water

The most recent groundwater level collection event was in July 2014. Shallow groundwater flow is generally northwesterly toward wetlands and surface water bodies along the west side of the valley. The July 2014 shallow groundwater contours are shown on Figure 8.

The depth to water[25] is an important variable when evaluating the vapor intrusion pathway. The depth to water tends to be greater on Boeing property and decreases off Boeing property toward the north and west. The depth to water is greater than 5 ft bgs in most areas, but locations in the Algona residential area and near surface water bodies tend to be less than 5 ft bgs. Figure 9 presents depth to water measurements based on most recent data (July 2014).

3.1.3 Shallow Groundwater Volatile Organic Compound Data

Prior to conducting a Tier I assessment of TCE and VC shallow groundwater results, it is important to note that several circumstances have occurred where shallow zone VOC data have been collected at multiple depths; in these cases, the shallowest sample result is used for Tier I assessment. In particular, these circumstances included:

- At multi-level wells (AGW200 through AGW203, AGW207 through AGW212, AGW235, AGW240 through AGW243, and AGW247 through AGW251); results from the shallowest screen are used for Tier I assessment.
- Three water table wells (AGW224, AGW225, and AGW226) were installed with 15 ft screens. As a result, Ecology requested that the April 2013 direct-push probe investigation include collection of borehole water samples adjacent to these wells. Therefore, at these locations, borehole data from the top of the water table is considered more representative of VOC concentrations at the water table, thus, the borehole data are used in the Tier I assessment. Newer July 2014 water table wells (AGW244 through AGW246) were installed with 5 ft screens.
- At several locations, borehole samples were collected at the top of the water table during drilling and installation of a conventional well[26]. At these locations, borehole data from the top of the water table is considered more representative of VOC concentrations at the water table and are used in the Tier I assessment.

[25] The depth to water is measured from the top of well casing, which is typically about 3 inches bgs.

[26] Borehole samples may be collected during drilling from a shallow well or from an adjacent deep or intermediate well if they are part of a well cluster. If a water table sample was collected from the borehole of a well adjacent to a shallow well, the data from the shallow well and the borehole sample are considered to represent the same location.

Data from locations where multiple shallow zone samples have been collected were analyzed for trends; a few observations were made:

- TCE concentrations at the shallowest screen compared to the deepest of the shallow screens are:
  - Lower 55 percent of the time
  - Equivalent 45 percent of the time
  - Higher 0 percent of the time.
- VC concentrations at the shallowest screen compared to the deepest of the shallow screens are:
  - Lower 38 percent of the time
  - Equivalent 28 percent of the time
  - Higher 34 percent of the time.

Comparison of data where multiple shallow samples have been collected at the same location is provided in Table 8. The table presents data from the shallow depths and identifies which data were used in the Tier I assessment. The assessment figures (Figures 10 through 18) in the following sections reflect use of these data points identified in Table 8. A complete list of shallow groundwater data that were used in the Tier I assessment are presented in Table 9.

3.2 Tier I Assessment

The Tier I assessment is a comparison of groundwater data (Section 3.1) with SLs based on land use scenario (Section 2.1.1). This assessment is presented by land use type: residential (Section 3.2.1), commercial (Section 3.2.2), and industrial (Section 3.2.3).

3.2.1 Residential Area Tier I Groundwater Assessment

A Tier I groundwater assessment and the Tier II 2013/2014 residential vapor intrusion assessment were previously conducted for the Algona residential area in 2013 and 2014 (LAI 2013a, 2014b). The 2013/2014 residential vapor intrusion assessment indicated that vapor intrusion cannot be identified as the source of the limited detections of TCE at homes in the Algona residential area and no mitigation was necessary to reduce exposure in the residences included in the study (LAI 2014b). At this time, further testing is not proposed for residences in Algona. However, Tier I assessment of new data from residential Algona data is conducted as additional monitoring wells are installed and sampled. Additionally, because of resident turnover (e.g., new residents moving in whose home had been invited for testing, but the previous owners declined), residences within the area defined by the updated PCL for TCE [1.6 parts per billion at the water table (which uses the EPA recommended Vapor Attenuation Factor of 1000)] shall be allowed to request home air testing if they initiate a request to either Ecology or Boeing. Besides Algona, no other residential areas are located within the current extent of the shallow zone groundwater plume. This section provides an updated Tier I groundwater assessment using the most recent data as of July 2014.

Residential TCE and VC shallow groundwater SLs protective of indoor air are 1.6 µg/L and 0.35 µg/L, respectively (see Section 2.1.1 for a complete discussion of SLs). The most recent groundwater data as of July 2014 was used to complete an update to the Tier I vapor intrusion assessment in residential Algona. TCE concentrations exceeded the shallow groundwater SL at two locations: 1) AGW226 with a concentration of 4.7 µg/L, which is comparable to previous results from 2012 through 2014 that ranged from 3.8 µg/L to 4.6 µg/L; and 2) AGW225 with a concentration of 2.2 µg/L, which is comparable to previous results from 2012 through 2014 that ranged from 1.4 to 2.3 µg/L. Homes in the vicinity of AGW226 and AGW225 were evaluated during the 2013/2014 residential vapor intrusion assessment and since concentrations of TCE and VC in groundwater have not increased significantly, additional assessment is not proposed at this time. Recent shallow TCE and VC groundwater data and the Tier II 2013/2014 residential vapor intrusion assessment area are shown on Figures 10 and 11, respectively.

3.2.2 Commercial Area Tier I Data Assessment

Commercial TCE and VC shallow groundwater SLs protective of indoor air are 7.9 µg/L and 1.0 µg/L, respectively. Recent shallow TCE and VC groundwater data exceeded these SLs in a limited area in commercial Algona and in commercial Auburn, as shown on Figures 12 and 13[27]. TCE exceedances occurred at one well (AGW207-1) and one borehole sample (AGW177-29). VC exceedances occurred at three wells (AGW207-1, AGW209-1, and AGW251-1) and three borehole samples (AGW177-29, AGW231-9, and AGW234-21). These data indicate the need for additional Tier I screening or Tier II assessment at nearby buildings. VC also exceeded commercial shallow groundwater vapor intrusion SLs at ASB0182-9; however, a permanent water table well (AGW249-1) was subsequently installed adjacent to the borehole sample location and results from the permanent well show that VC groundwater concentrations are below the commercial shallow groundwater vapor intrusion SLs.

Tier II vapor intrusion assessments were already conducted for buildings adjacent to AGW177-29 (Fana West building) and AGW125 (AMB/Prologis). The Tier II assessment at the AMB/Prologis building was implemented because of a previous VC exceedance in well AGW125; the most recent (i.e., July 2014) concentration is below the VC SL. Constituents of concern in the Tier II assessment of both buildings were not detected in indoor air and it was concluded that vapor intrusion does not present an unacceptable risk at those buildings (LAI 2012b).

Additional assessments have yet to be conducted in the following areas:

1. Commercial Algona: Area along Milwaukee Avenue near AGW251-1
2. Commercial Auburn: Commercial area near AGW207-1, AGW209-1, AGW231-9, and AGW234-21 including The Outlet Collection™ | Seattle (The Outlet Collection); formerly SuperMall.

For clarity, the terms Commercial Algona and Commercial Auburn used in Section 3.0 of this document refer to the areas specifically described above, not the entire commercial areas.

[27] Figures 12 and 13 include results for the shallowest screened interval only.

Commercial Algona is a small, isolated area along Milwaukee Avenue approximately 700 ft south of 10th Avenue North. Commercial Auburn is located north of 15th Street Southwest. These two areas are discussed further in the following subsections.

3.2.2.1 Commercial Algona

The Commercial Algona area is identified where a single VC concentration exceeded the SL[28] (at AGW251-1) near Milwaukee Avenue approximately 700 ft south of 10th Avenue North. Additional Tier I soil gas sampling is recommended along Milwaukee Avenue to verify subsurface conditions and determine if Tier II investigation is necessary. Additional Tier I soil gas investigation will be presented in a separate work plan in fall 2014. The Milwaukee Avenue area along with TCE and VC groundwater concentrations is shown on Figures 14 and 15, respectively. An additional Tier I soil gas investigation in commercial Algona was completed in 2015 (LAI 2016a).

3.2.2.2 Commercial Auburn

The largest commercial area where TCE and VC vapor intrusion groundwater SLs are exceeded is Commercial Auburn, located north of 15th Street Southwest and predominately on The Outlet Collection property. Since the initial draft of this document (LAI 2014a), additional shallow groundwater samples have been collected in this area (see Section 3.1.1). The estimated areas where groundwater TCE and VC concentrations may exceed commercial vapor intrusion SLs in Commercial Auburn are shown on Figure 16.

Approximately seven buildings are located within the area where groundwater concentrations exceed SLs in the commercial area and the associated 100 ft boundary (Figure 16). However, the well locations are widely spaced, so additional Tier I data are needed in the southern portion of this area to more accurately delineate the area where vapor intrusion could potentially be a problem. Due to the size of The Outlet Collection building, a Tier II investigation may be completed instead of collecting additional Tier I soil gas data.

The average depth to water in the area of shallow zone wells AGW207, AGW208, AGW209, and AGW231 was approximately 6.5 ft bgs in January 2014 and approximately 6.3 ft bgs in July 2014. Therefore, additional Tier I data Commercial Auburn would include shallow soil gas data. Borehole water table data may also be collected to determine if there is a correlation between the shallow groundwater concentrations and soil gas concentrations. Boeing completed additional Tier I and Tier II investigations in commercial Auburn in 2015 (LAI 2016a,b).

[28] The VC concentration in boring ASB0190-10 also exceeded the SL; ASB0190-10 was located in residential Algona on the border of the residential and commercial areas, with a large commercial warehouse located immediately to the east (approximately 50 ft away). The Chicago Avenue ditch, which intersects the water table, is located between ASB0190-10 and the building, meaning groundwater concentrations west of the ditch are not necessarily representative of groundwater concentrations or soil gas conditions east of the ditch.

3.2.3 Industrial Area Tier I Assessment

The industrial area where shallow groundwater VOC data are screened encompasses the Boeing Auburn property. Industrial TCE and VC shallow groundwater SLs protective of indoor air are 8.4 µg/L and 3.5 µg/L, respectively. Shallow groundwater TCE data do not exceed SLs in the industrial area. VC SL exceedances occur at one well (AGW202-1) and one borehole sample (AGW164-29). AGW164-29 was collected beneath Building 17-07, downgradient of the former TCE vapor degreaser[29], and has the highest recent VC concentration (6.1 µg/L). The well (AGW202-1) is north of Building 17-07 and has a VC concentration of 4.0 µg/L. The most recent shallow RI well and borehole groundwater data have been screened using the industrial SLs and are presented on Figures 17 and 18 for TCE and VC, respectively. The estimated areas where groundwater VC concentrations may exceed industrial vapor intrusion SLs are shown on Figure 19. The VC SL contour encompasses an area from just downgradient of the former TCE vapor degreaser in Building 17-07 to Building 17-70.

A vapor intrusion assessment and Tier II indoor air sampling have been conducted at Building 17-07. The indoor air results were below reporting limits for all constituents; therefore, no further assessment is proposed at Building 17-07. Between Building 17-07 and Building 17-70 are two open-air storage structures, which do not require further investigation. To the northwest of these structures is a power station with structures that are not occupied by employees and therefore, does not require further assessment. Therefore, within the estimated VC SL exceedance area, the only remaining building of potential concern is Building 17-70. Boeing completed a Tier II assessment at Building 17-70 in 2015 (LAI 2016b).

3.3 Tier II Assessment

Boeing completed collection of indoor air samples and co-located sub-slab soil vapor samples at two locations: 1) The Outlet Collection in commercial Auburn; and 2) Building 17-70 on Boeing property. Boeing obtained utility drawings, conducted building surveys, and submitted a work plan to Ecology for approval. The work was completed during winter 2014/2015. Additional Tier II work will also be completed at a private property near The Outlet Collection. This work is anticipated to be conducted in April 2016.

3.4 Summary

A Tier II assessment was conducted in residential Algona in 2013 and 2014. The results from this assessment indicated that vapor intrusion cannot be identified as the source of the limited detections of TCE at homes in the residential study area. Based on this Tier II assessment, no mitigation was necessary to reduce exposure in any of the residences (LAI 2014b). At this time, further testing is not proposed for residences in Algona. Boeing will continue to monitor VOC concentrations in shallow

[29] The former vapor degreaser pit area is identified in the 2009 RI document (LAI 2009) as SWMU-13.

groundwater over time and annually screen shallow groundwater data via the Tier I screening process for the duration of the RI.

Boeing installed additional monitoring wells in Commercial Algona during June and July 2014. As noted previously, results from those wells indicate that additional Tier I investigation is needed in Commercial Algona. Additional work is also needed in Commercial Auburn. Boeing completed additional Tier I investigation in the southern portion of Commercial Auburn and Tier II investigation at The Outlet Collection in the northern portion of Commercial Auburn. The Tier I investigation was completed in 2015 and results were presented to Ecology in the 2015 Tier I Commercial Vapor Intrusion Assessment Report (LAI 2016a).

Boeing completed Tier II investigations at The Outlet Collection in the northern portion of Commercial Auburn and at Building 17-70 on Boeing property. The Tier II investigation was completed in 2015 and results were presented to Ecology in the 2015 Tier II Commercial Vapor Intrusion Assessment Report (LAI 2016b). An additional Tier II investigation at a private property near The Outlet Collection is planned to be completed in April 2016 and results will be presented to Ecology in a separate technical memorandum.

4.0 USE OF THIS REPORT

This report has been prepared for the exclusive use of The Boeing Company for specific application to the Auburn Fabrication Division Facility remedial investigation. 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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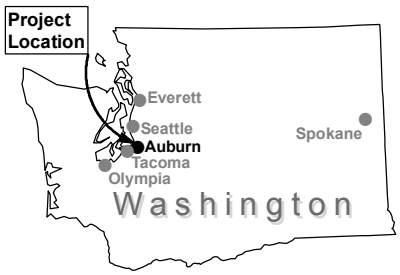
Wynkoop, J. 2013. "Re: HE Leak Method." Jennifer Wynkoop, Landau Associates, Inc. December 11.

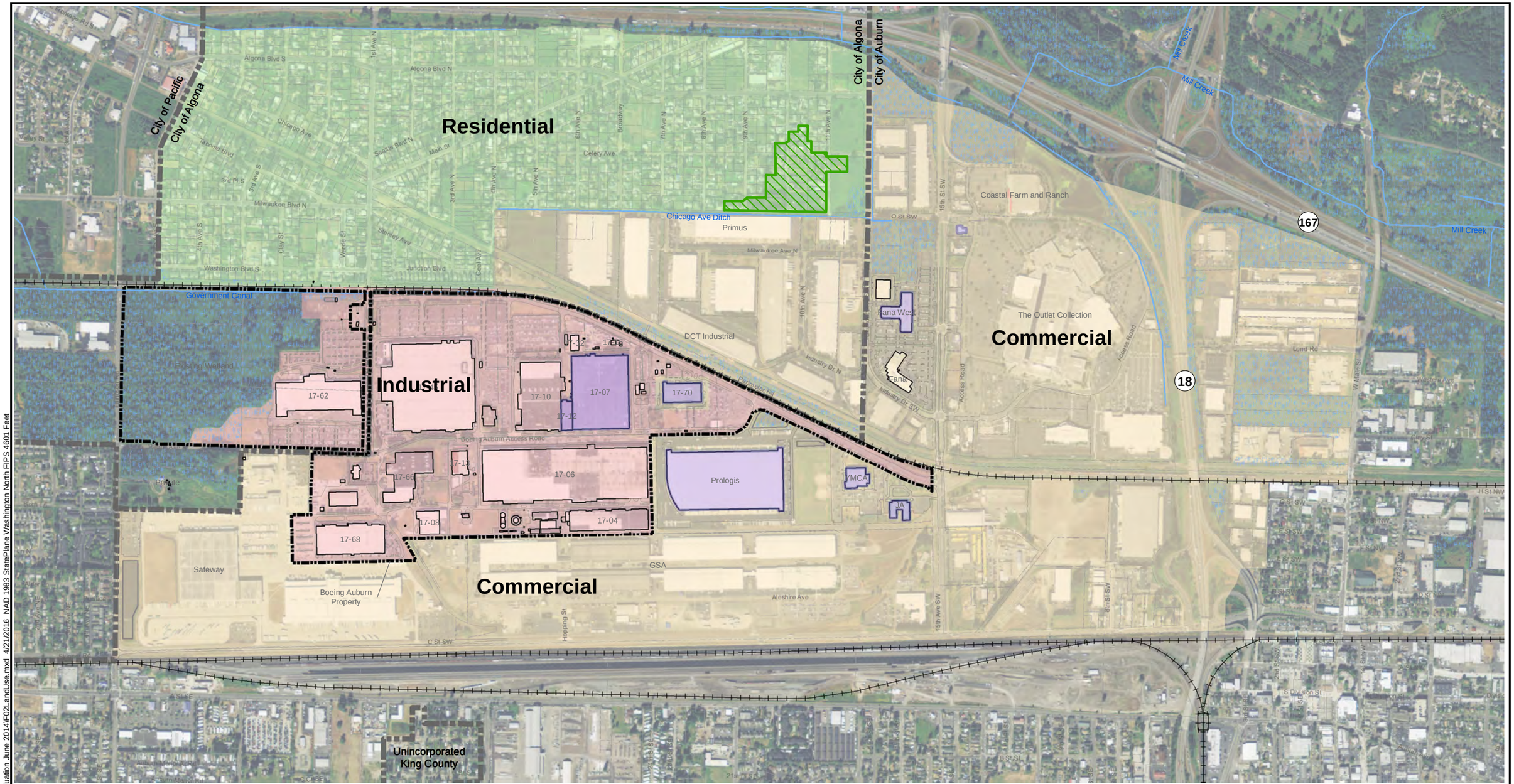


Data Source: Esri 2012

G:\Projects\025\164\110\114\Algona Drilling Work Plan\F01VicinityMap.mxd 4/21/2016 NAD 1983 StatePlane Washington North FIPS 4601 Feet

LANDAU ASSOCIATES

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



G:\Projects\025\164\110\105\IVI Evaluation June 2014\F02LandUse.mxd 4/21/2016 NAD 1983 StatePlane Washington North FIPS 4601 Feet

Note

1. The land use areas delineated here represent those land use areas near to or at which shallow groundwater is impacted by trichloroethene and vinyl chloride.
2. The industrial land use area consists of the Boeing Auburn property, which includes some commercial office buildings.
3. Commercial and industrial vapor intrusion assessments were conducted in 2012 and 2013. Residential vapor intrusion assessments were conducted in 2013 and 2014.
4. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

- Commercial Land Use Area
- Industrial Land Use Area
- Residential Land Use Area
- Building(s) Where Vapor Intrusion Assessments were Conducted (2012)
- 2013/2014 Residential Vapor Intrusion Assessment Area

N

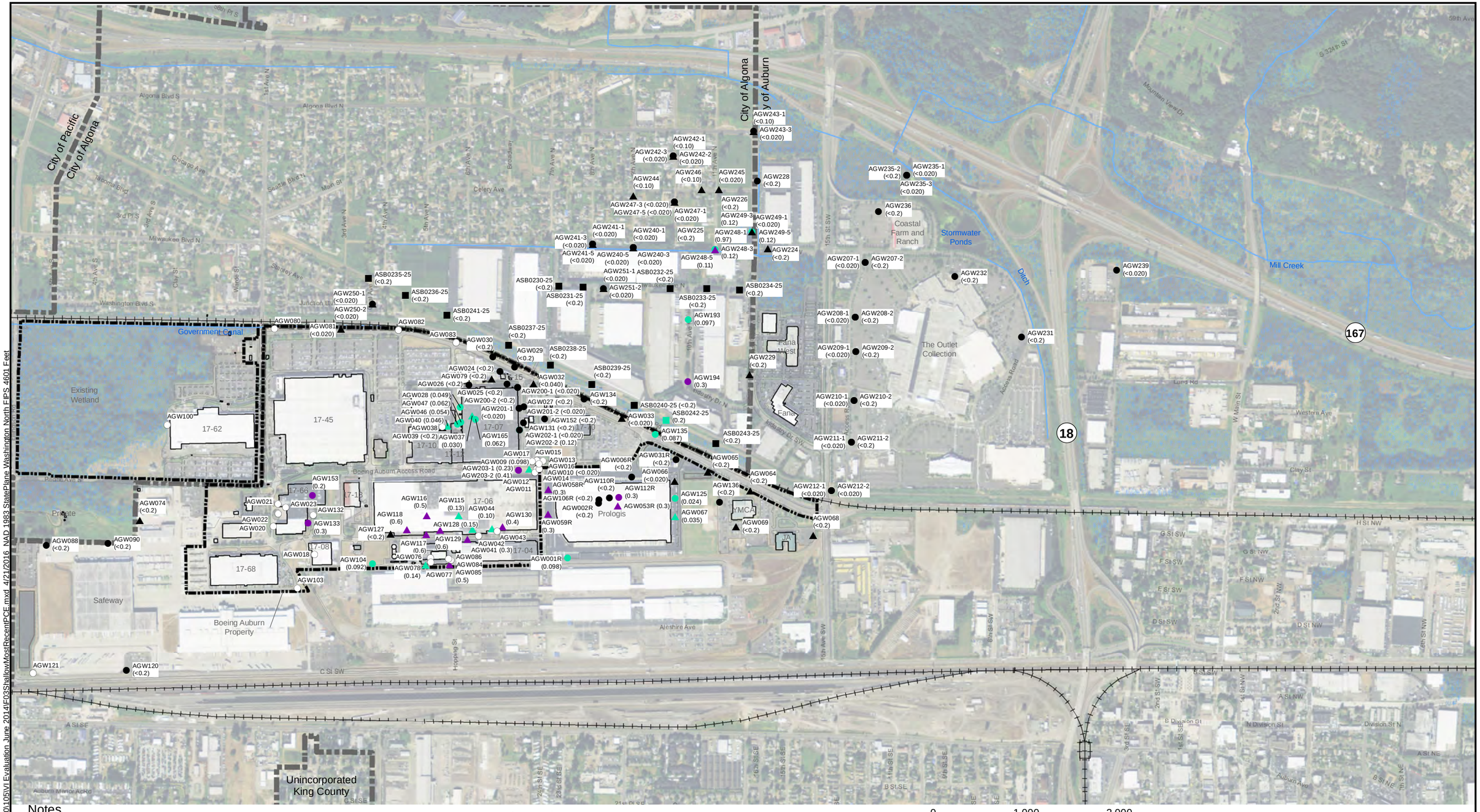
0 1,000 2,000

Scale in Feet

Base map source: Geometrix 2003; Aerial Photo Source: Esri World Imagery; Parcel Data Source: King County GIS 2013.

LANDAU ASSOCIATES

Boeing Auburn Auburn, Washington	**Land Use Areas and Vapor Intrusion Assessments Conducted**	Figure 2



Notes

1. Water table wells are shallow wells screened along the top of the water table.
2. All concentrations shown in µg/L.
3. Multi-level wells have multiple channels, channel designations are included in the well ID (ex: AGW208-5).
4. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

- ▲ Water Table Well
- ● Shallow Well
- ■ Borehole Grab Sample
- ▲■● PCE 0.2 - <2 µg/L
- ▲■● PCE 0.02 - <0.2 µg/L
- ▲■● PCE <0.02 µg/L
- ○ Not Sampled for PCE in the Last 4 Years
- Wetland Areas
- Waterways

0 1,000 2,000

Scale in Feet

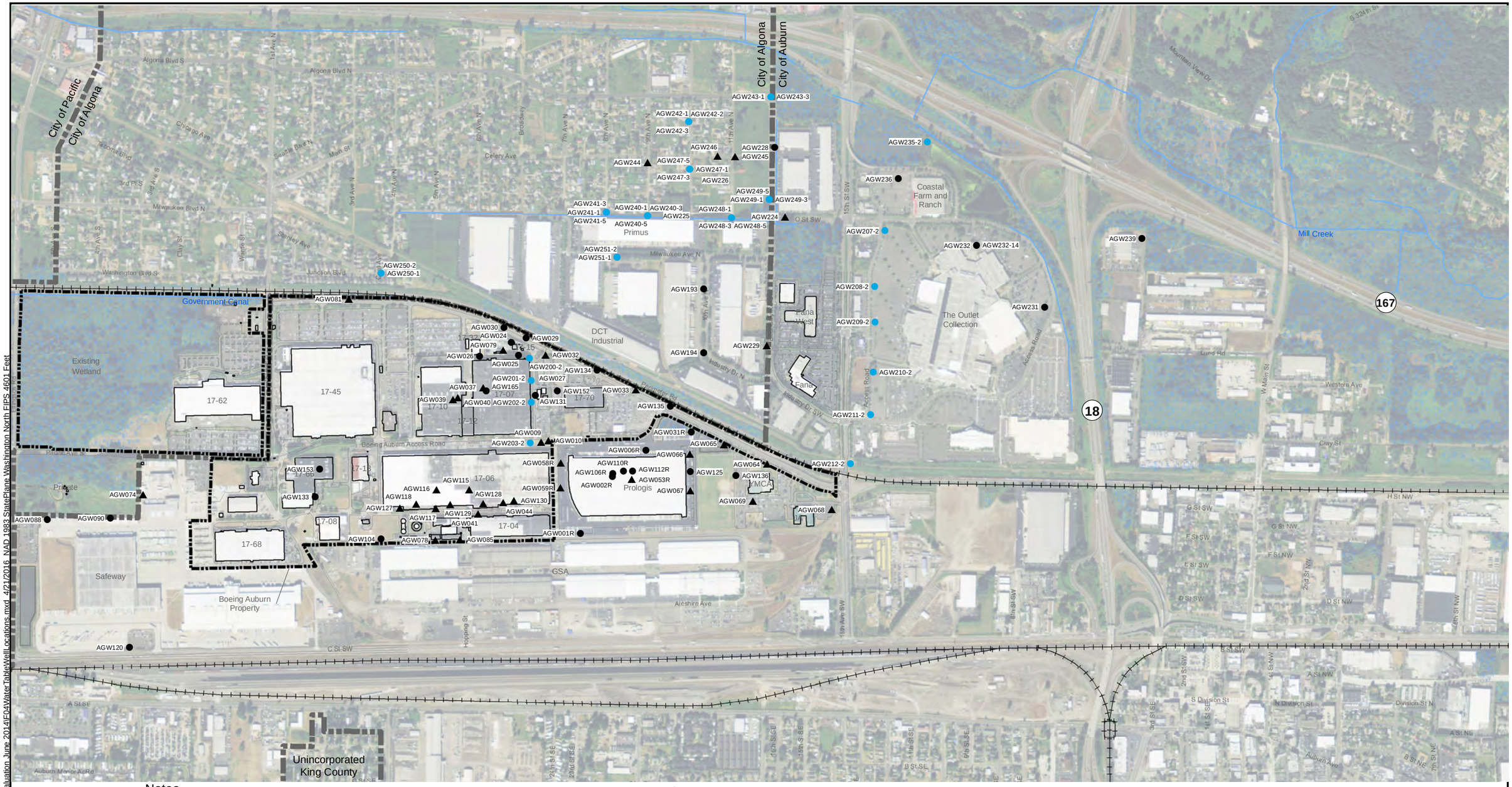
N

Base map source: Geometrix 2003; Aerial Photo Source: ESRI World Imagery; Parcel Data Source: King County GIS 2013

LANDAU ASSOCIATES

Boeing Auburn Auburn, Washington	**Shallow Zone (0-30 ft) PCE Concentrations Most Recent - July 2014**	Figure 3

G:\Projects\025\164\110\105\VI Evaluation June 2014\F03ShallowMostRecentPCE.mxd 4/21/2016 NAD 1983 StatePlane Washington North FIPS 4601 Feet



G:\Projects\025\164\110\105\WI Evaluation June 2014\F04\WaterTableWell_ocations.mxd 4/21/2016 NAD 1983 StatePlane Washington North FIPS 4601 Feet

Notes

1. Water table wells are shallow wells screened along the top of the water table.
2. Multi-level wells have multiple channels, channel designations are included in the well ID (ex: AGW208-5).
3. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

- Water Table Well
- Shallow Well
- Multi-Level Well
- Wetland Areas
- Waterways

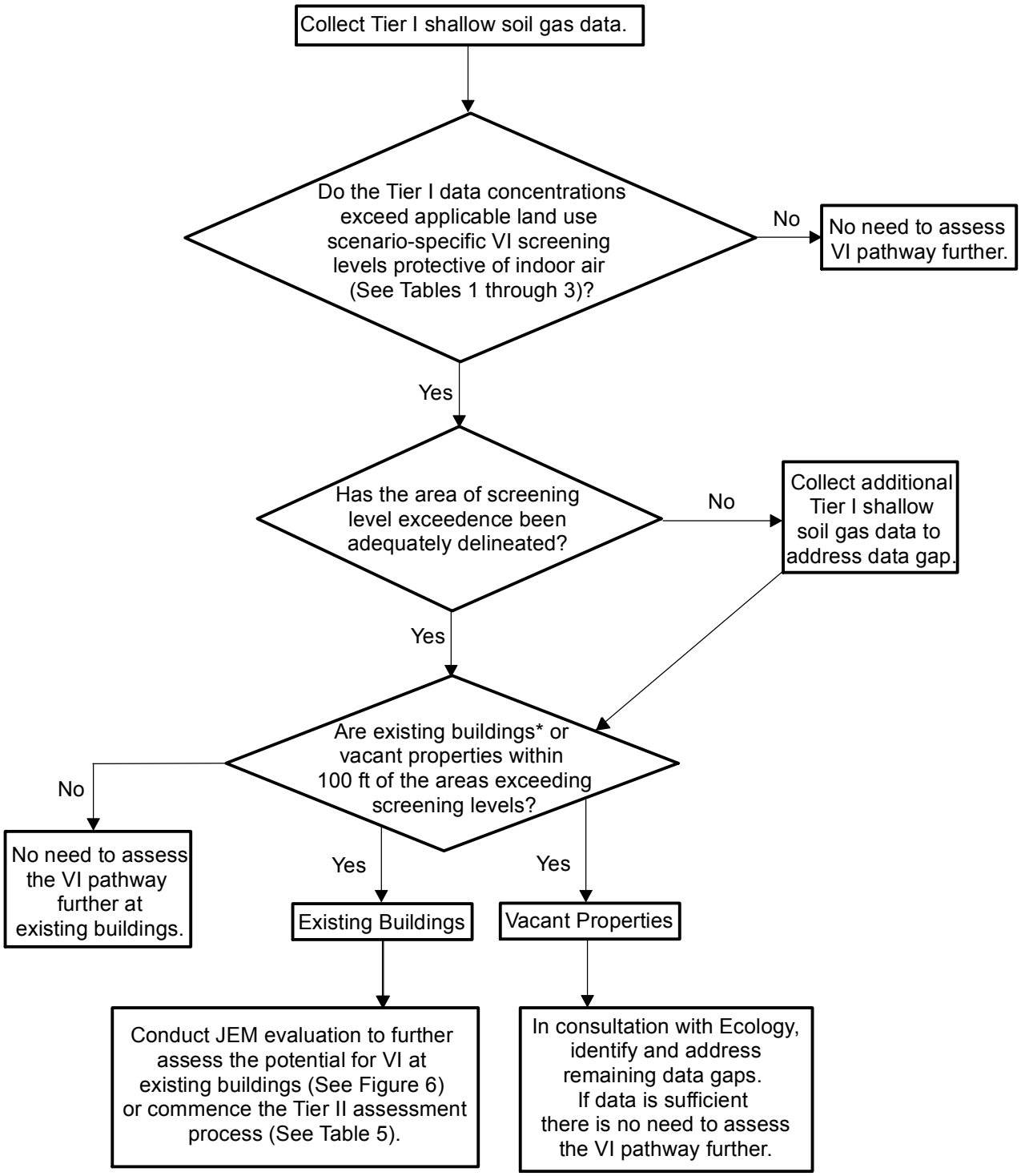
0 1,000 2,000

Scale in Feet

Base map source: Geometrix 2003; Aerial Photo Source: Esri World Imagery; Parcel Data Source: King County GIS 2013

LANDAU ASSOCIATES

Boeing Auburn Auburn, Washington	**Current Shallow Monitoring Well Network**	Figure 4



Note
1.*Depending on building features and foundations, some buildings beyond 100 ft from the area exceeding screening levels may need to be further evaluated for vapor intrusion.

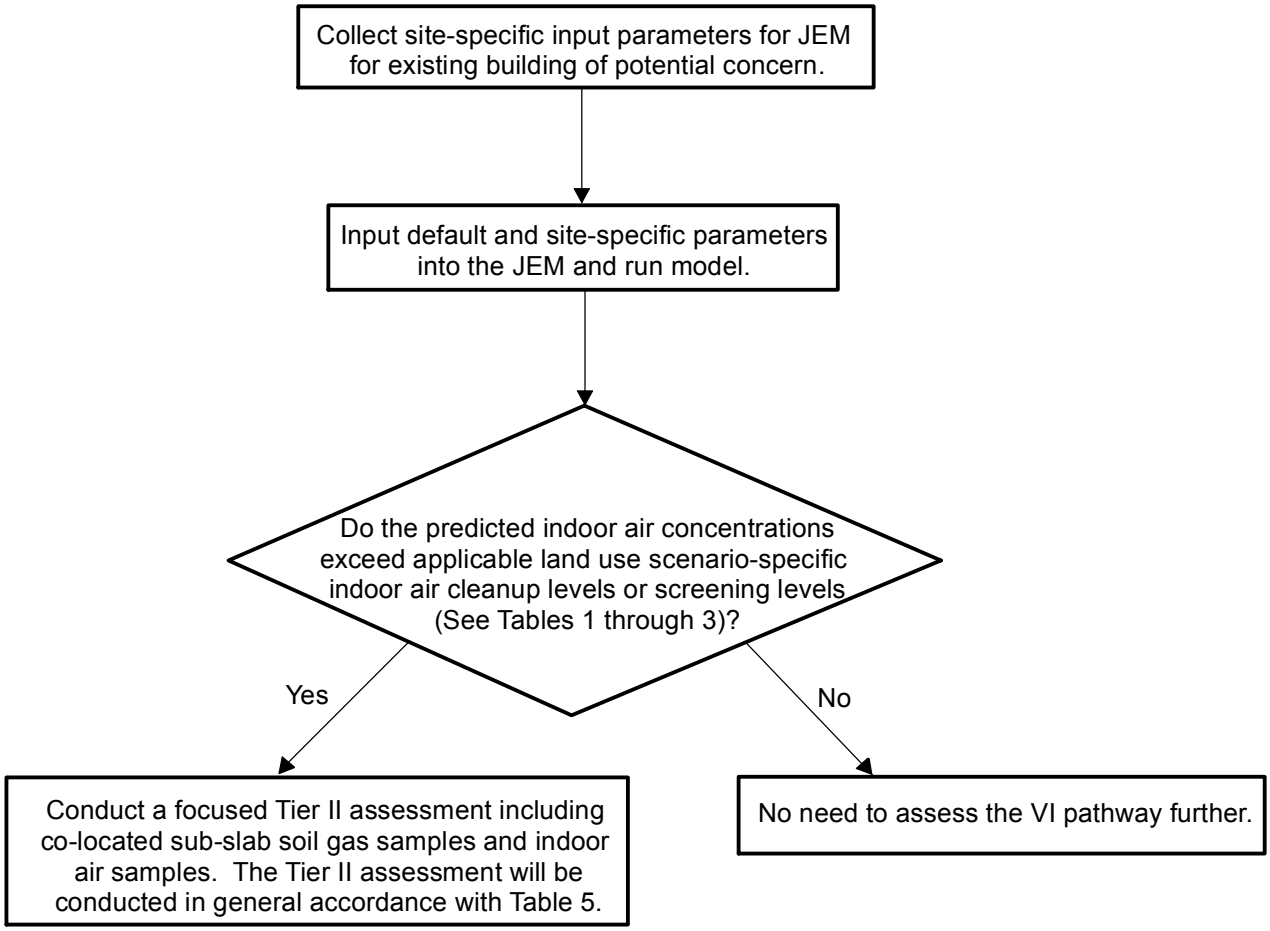
G:\Projects\025\164\110\105\VI Evaluation & Approach Report\F05_Assessment.mxd 7/7/2014

LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

Tier I Vapor Intrusion Assessment Process Using Shallow Soil Gas Data

Figure 5



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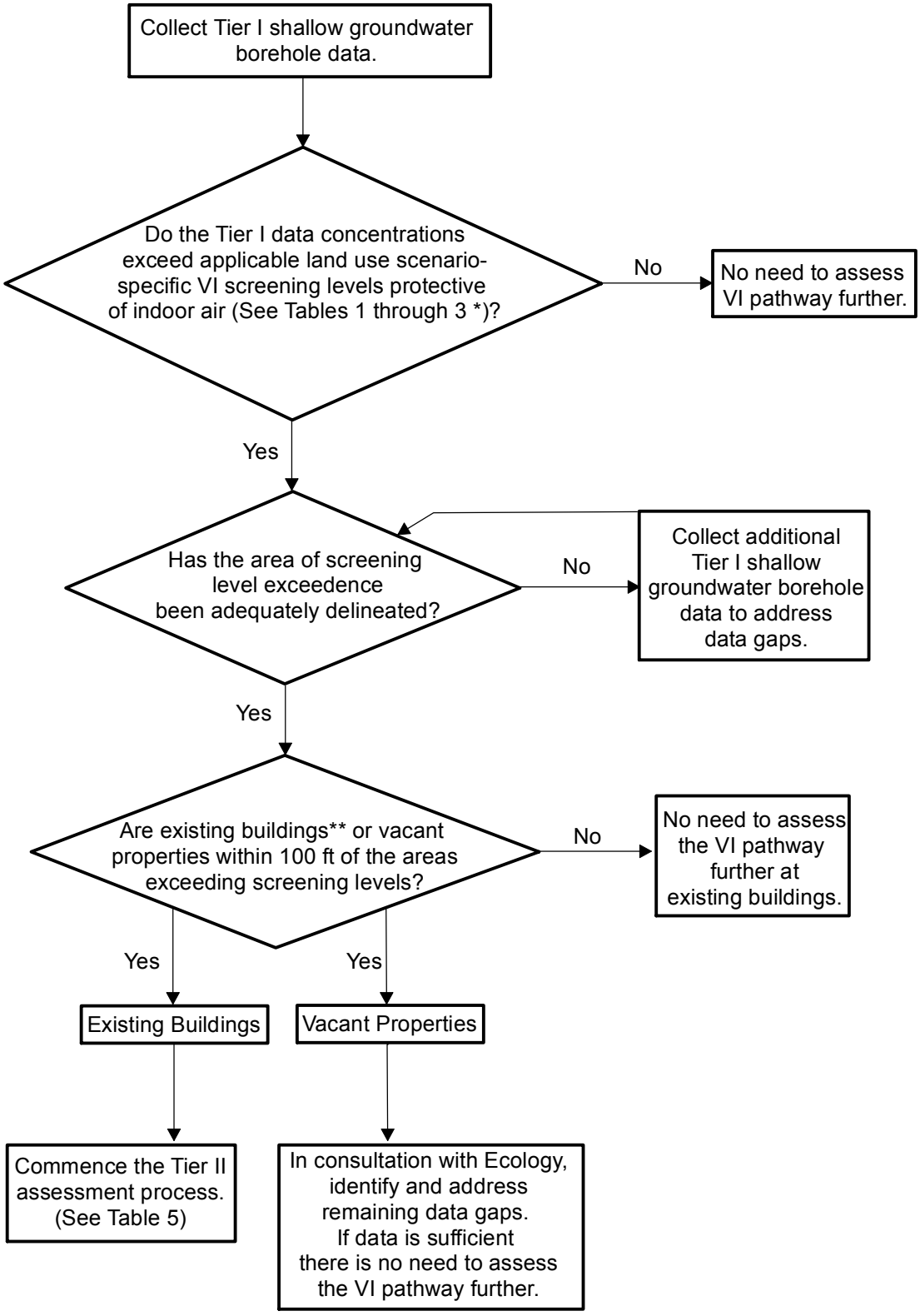
LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

Tier I Vapor Intrusion Assessment
Johnson & Ettinger Model (JEM)

Figure
6



Notes

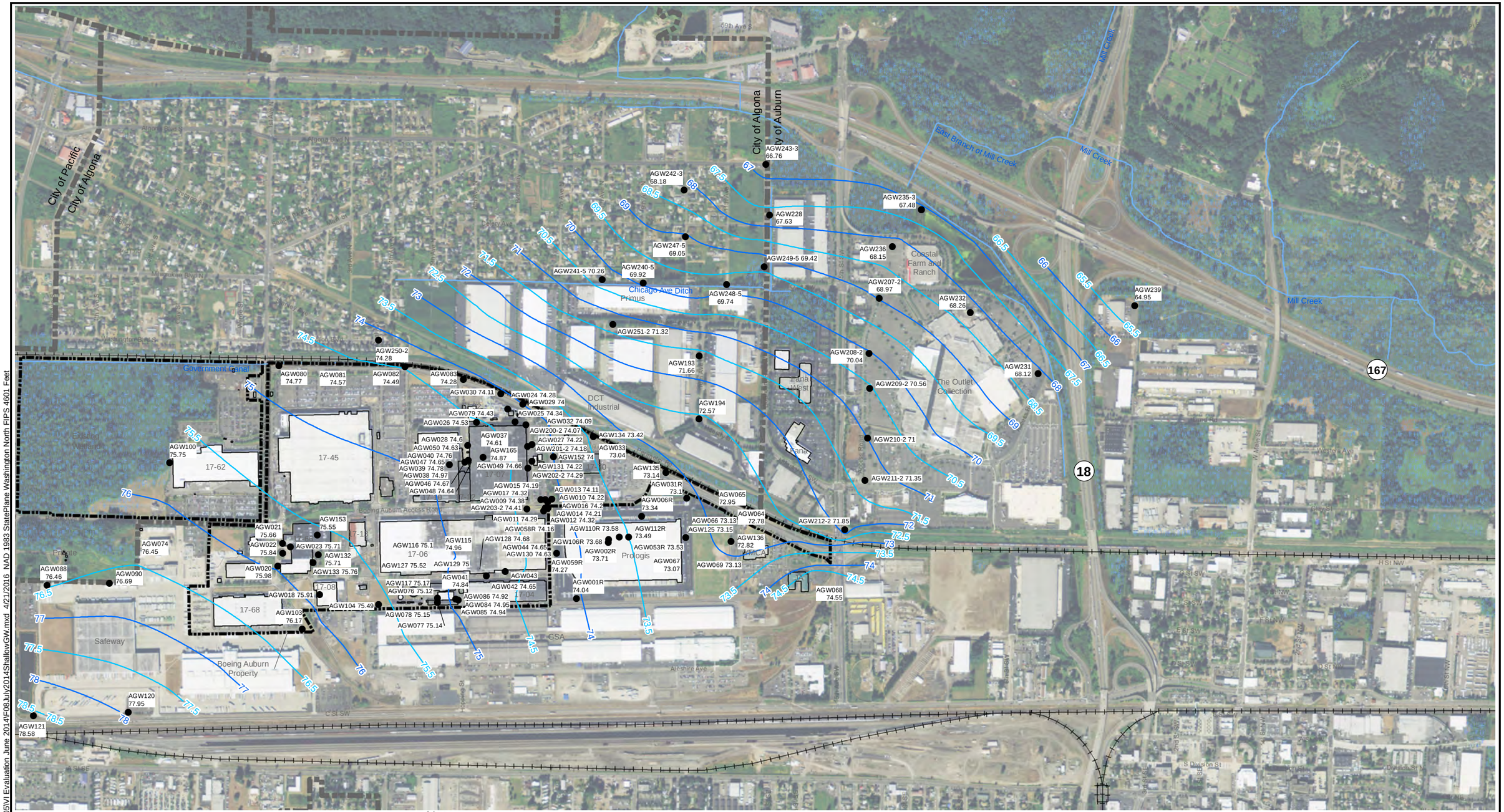
1.*Depending on the depth to groundwater, the SLs (Table 1 through 3) may not be adequately conservative, in which case site-specific SLs may need to be developed and used; such values would be developed in VI work plans.

2.**Depending on building features and foundations, some buildings beyond 100 ft from the area exceeding screening levels may need to be further evaluated for vapor intrusion.

G:\Projects\025\164\110\105\VI Evaluation & Approach Report\F07_Assessment.mxd 7/9/2014

LANDAU ASSOCIATES

Boeing Auburn Auburn, Washington	**Tier I Vapor Intrusion Assessment Process Using Shallow Groundwater Borehole Data**	Figure 7



Legend

- AGW021 75.83 — Monitoring Well Designation, Groundwater Elevation (ft, MSL)
- 72 / 72.5 — Groundwater Elevation Contours
- Boeing Property
- Waterway
- Wetland Area
- City Limits

Notes

1. All water level data in ft, MSL. Data collected in July 2014.
2. Wells without a water level were inaccessible.
3. 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.
4. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

N

0 1,000 2,000

Scale in Feet

Base map source: Geometrix 2003; Aerial Photo Source: Esri World Imagery; Parcel Data Source: King County GIS 2013

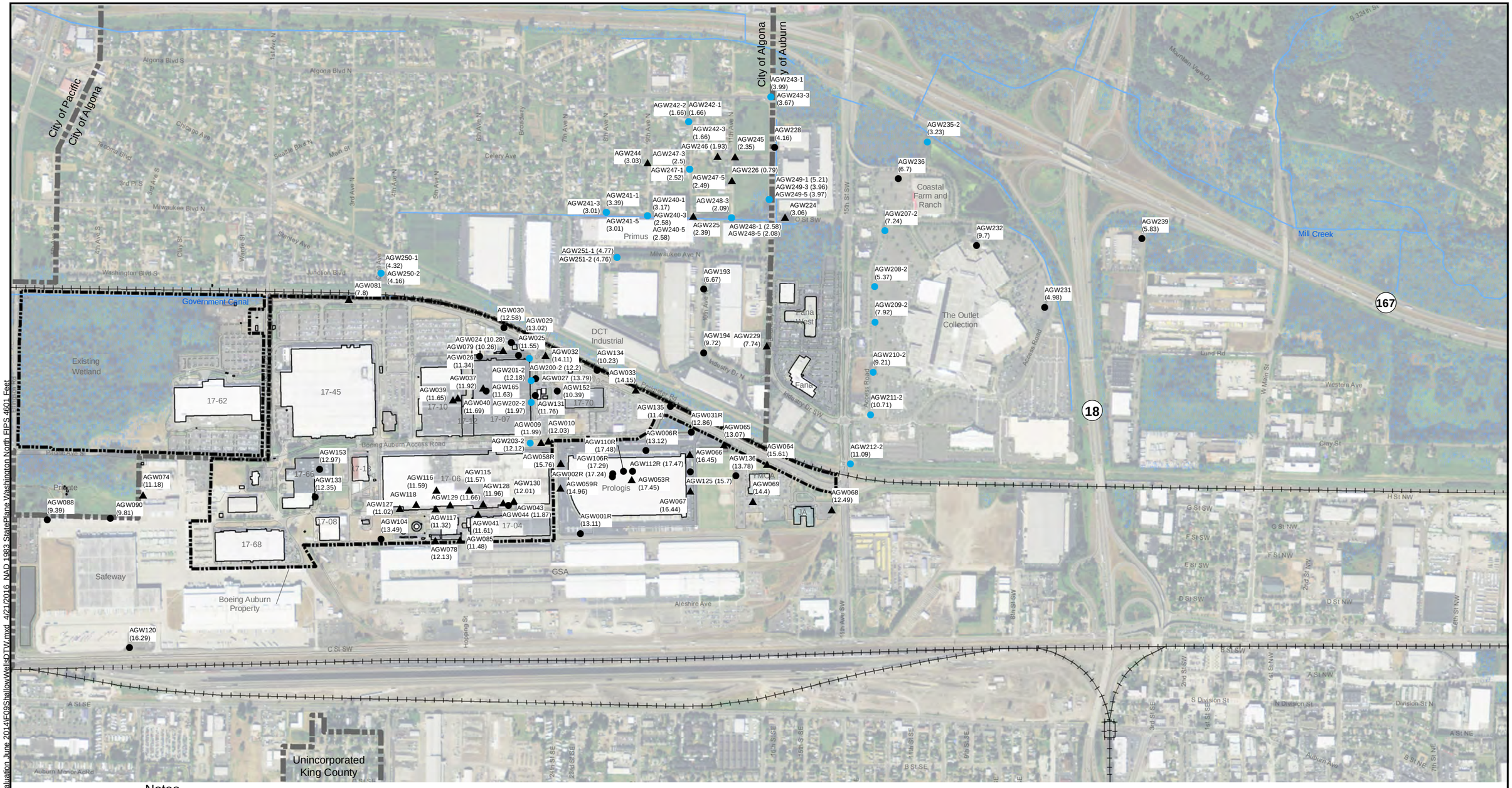
LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

Shallow Zone (20-30 ft)
Groundwater Elevation Contours
July 2014

Figure 8

G:\Projects\025\1641\110\105\VI Evaluation June 2014\F08July2014ShallowGW.mxd 4/21/2016 NAD 1983 StatePlane Washington North FIPS 4601 Feet



Notes

1. Water levels were collected in July 2014.
2. Depth to water is measured from the top of the well casing.
3. Water table wells are shallow wells screened along the top of the water table.
4. Multi-level wells have multiple channels, channel designations are included in the well ID (ex: AGW208-5).
5. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

(12.22) Measured Depth to Groundwater (ft, BGS)

- Water Table Well
- Shallow Well
- Multi-Level Well
- Wetland Areas
- Waterways

N

0 1,000 2,000

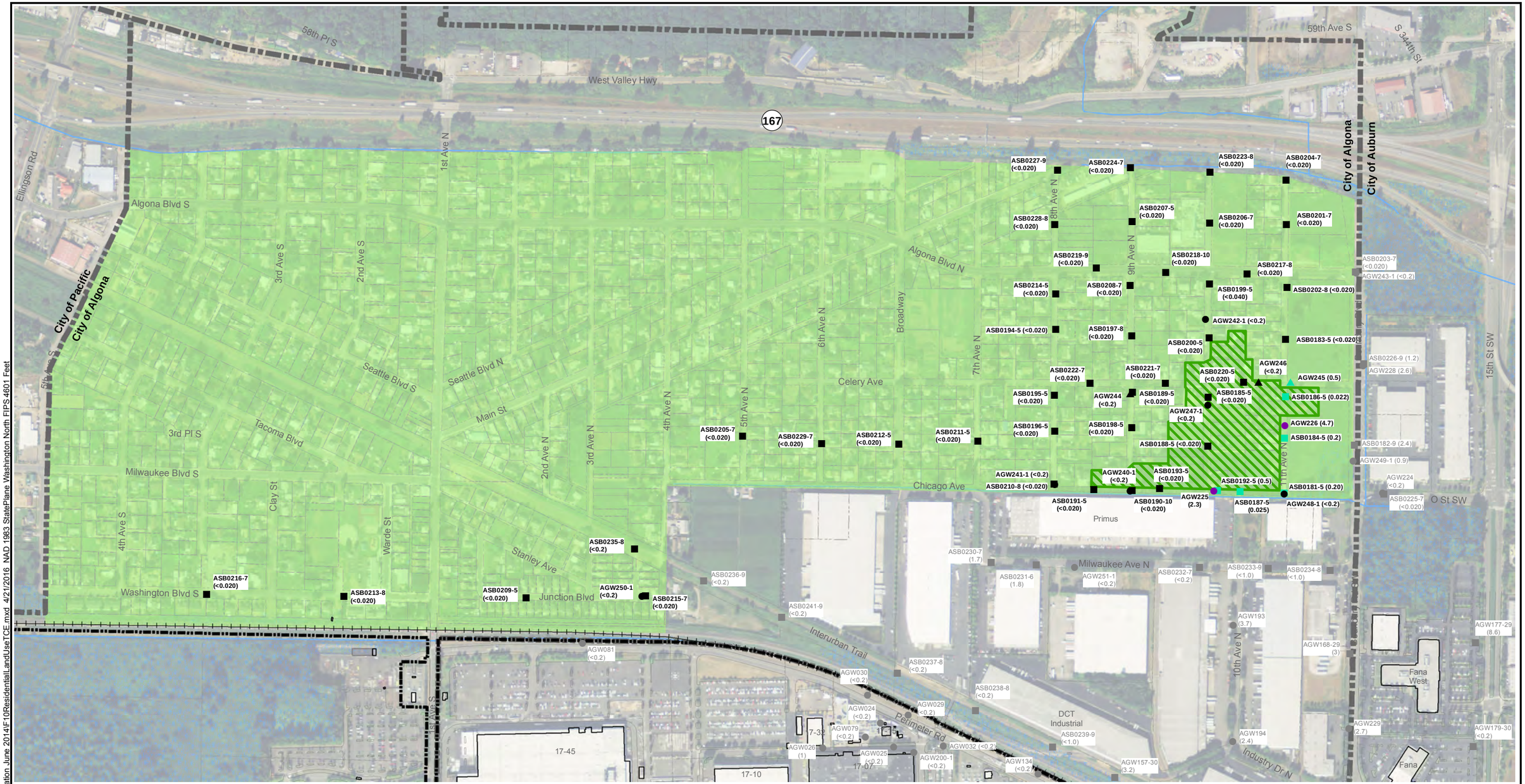
Scale in Feet

Base map source: Geometrix 2003; Aerial Photo Source: Esri World Imagery; Parcel Data Source: King County GIS 2013

LANDAU ASSOCIATES

Boeing Auburn Auburn, Washington	**Shallow RI Groundwater Wells Depth to Water - July 2014**	Figure 9

G:\Projects\025\164\110\105\V1 Evaluation June 2014\F09ShallowWellsDTW.mxd 4/21/2016 NAD 1983 StatePlane Washington North FIPS 4601 Feet



Notes

1. Concentrations shown in µg/L.
2. <0.2 = Compound not detected at indicated reporting limit.
3. Monitoring well results are the most recent (July 2014). Direct-push borehole sample results are from April 2013 and summer 2014. Borehole grab samples from monitoring wells were collected at time of drilling.
4. SL = Residential Groundwater Screening Level.
5. Multi-level wells have multiple channels. Channel designations are included in the well ID (ex: AGW208-1). Channel 1 is the shallowest screen.
6. Direct-push data collected at multiple depths. Data from the shallowest depth is shown.
7. Groundwater monitoring wells are identified by the AGW prefix. Soil borings from the direct-push investigations are identified by the ASB prefix.
8. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

- Water Table Well
- Shallow Well
- Borehole Grab Sample
- Last TCE Detection = < 1.6 µg/L
- Last TCE Detection = ≥ 1.6 µg/L
- Non-Detect
- Non-Residential
- 2013/2014 Residential Vapor Intrusion Assessment Area
- Residential Land Use Area
- Waterways
- Wetland Areas
- Boeing Property
- City Limits

N

0 550 1,100

Scale in Feet

Base map source: Geometrix 2003; Aerial Photo Source: Esri World Imagery; Parcel Data Source: King County GIS 2013

LANDAU ASSOCIATES

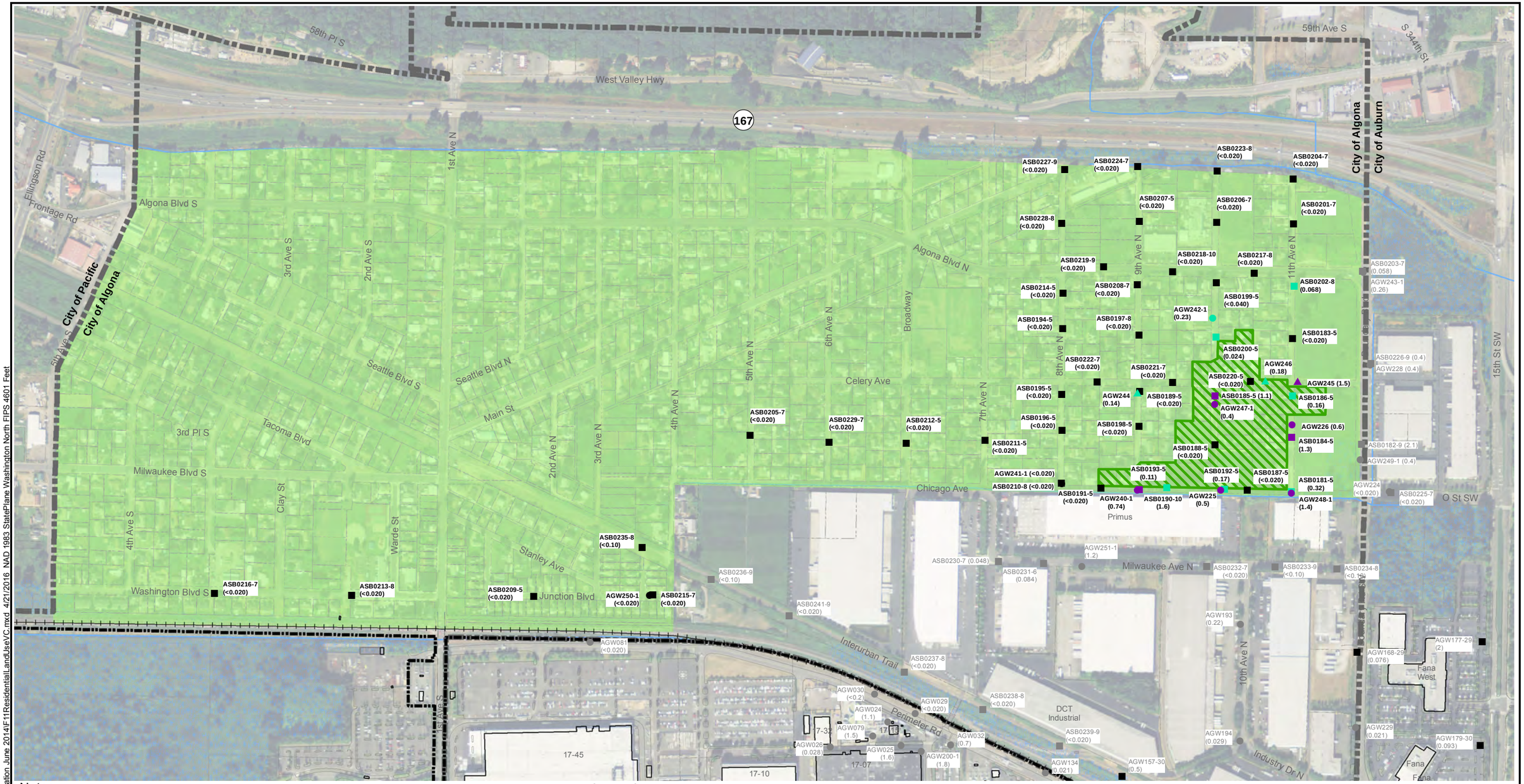
Boeing Auburn
Auburn, Washington

Residential Land Use Area Shallow Groundwater Concentrations Exceeding TCE SL

Figure 10

G:\Projects\025\164110\105\VI Evaluation June 2014\F10ResidentialLandUseTCE.mxd 4/21/2016 NAD 1983 StatePlane Washington North FIPS 4601 Feet

G:\Projects\025\164\110\105\VI Evaluation June 2014\F11ResidentialLandUseVC.mxd 4/21/2016 NAD 1983 StatePlane Washington North FIPS 4601 Feet



Notes

1. Concentrations shown in µg/L.
2. <0.2 = Compound not detected at indicated reporting limit.
3. Monitoring well results are the most recent (July 2014). Direct-push borehole sample results are from April 2013 and Summer 2014. Borehole grab samples from monitoring wells were collected at time of drilling.
4. SL = Residential Groundwater Screening Level.
5. Multi-level wells have multiple channels. Channel designations are included in the well ID (ex: AGW208-1). Channel 1 is the shallowest screen.
6. Direct-push data collected at multiple depths. Data from the shallowest depth is shown.
7. Groundwater monitoring wells are identified by the AGW prefix. Soil borings from the direct-push investigations are identified by the ASB prefix.
8. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

- Water Table Well
- Shallow Well
- Borehole Grab Sample
- Last VC Detection = < 0.35 µg/L
- Last VC Detection = ≥ 0.35 µg/L
- Non-Detect
- Non-Residential
- 2013/2014 Residential Vapor Intrusion Assessment Area
- Residential Land Use Area
- Waterways
- Wetland Areas
- Boeing Property
- City Limits

N

0 550 1,100

Scale in Feet

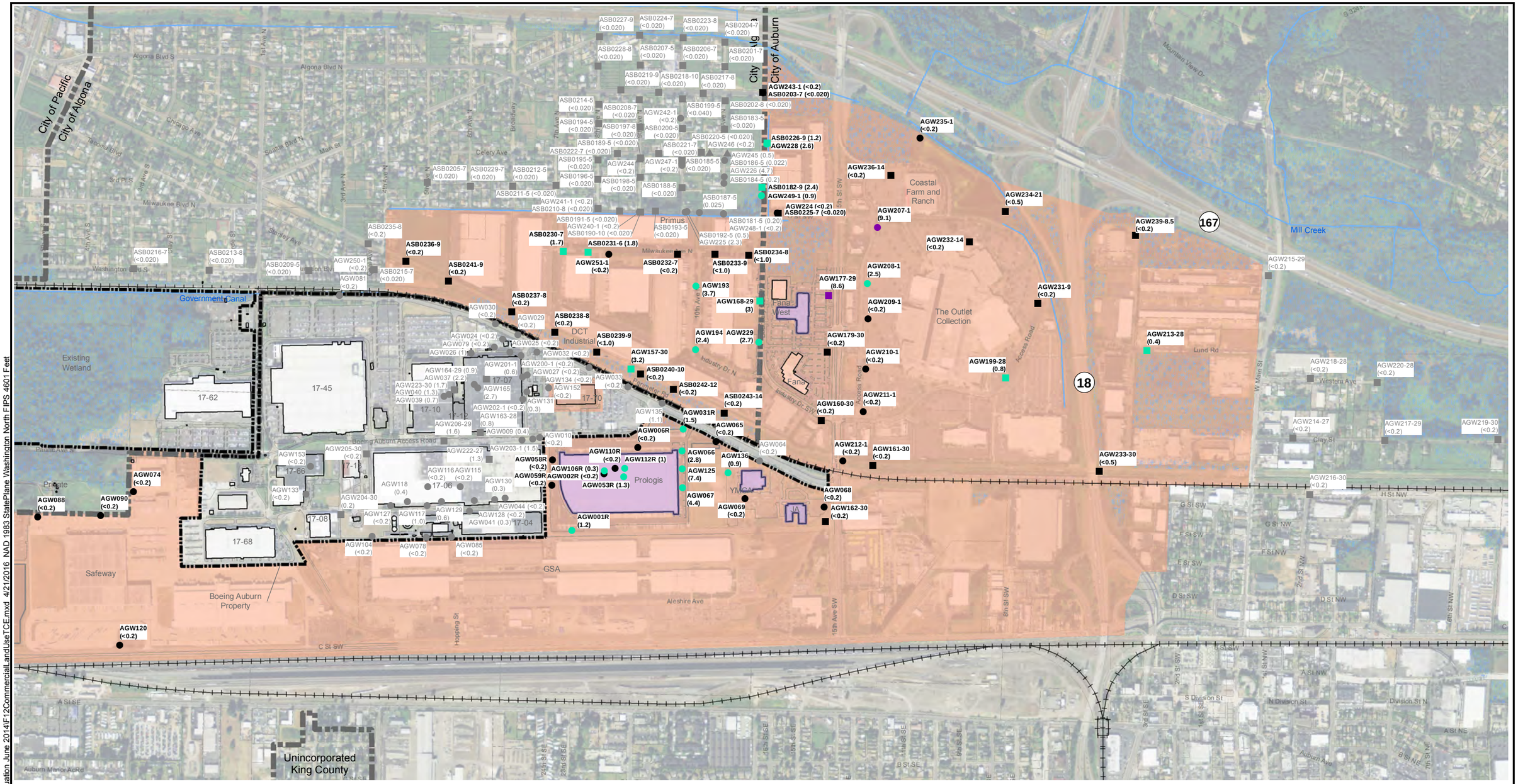
Base map source: Geometrix 2003; Aerial Photo Source: Esri World Imagery; Parcel Data Source: King County GIS 2013

LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

Residential Land Use Area
Shallow Groundwater Concentrations Exceeding VC SL

Figure
11



Notes

1. Concentrations shown in µg/L.
2. <0.2 = Compound not detected at indicated reporting limit.
3. Monitoring well results are the most recent (June 2014). Direct-push borehole sample results are from April 2013 and Summer 2014. Borehole grab samples from monitoring wells were collected at time of drilling.
4. Multi-level wells have multiple channels. Channel designations are included in the well ID (ex: AGW208-1). Channel 1 is the shallowest screen.
5. Direct-push data collected at multiple depths. Data from the shallowest depth is shown.
6. Groundwater monitoring wells are identified by the AGW prefix. Soil borings from the direct-push investigations are identified by the ASB prefix.
7. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

- Water Table Well
- Shallow Well
- Borehole Grab Sample
- Last TCE Detection = < 7.9 µg/L
- Last TCE Detection = ≥ 7.9 µg/L
- Non-Detect
- Non-Commercial
- Commercial Buildings Where Vapor Intrusion Assessments Have Been Conducted
- Waterways
- Wetland Areas
- Boeing Property
- City Limits

N

0 1,000 2,000

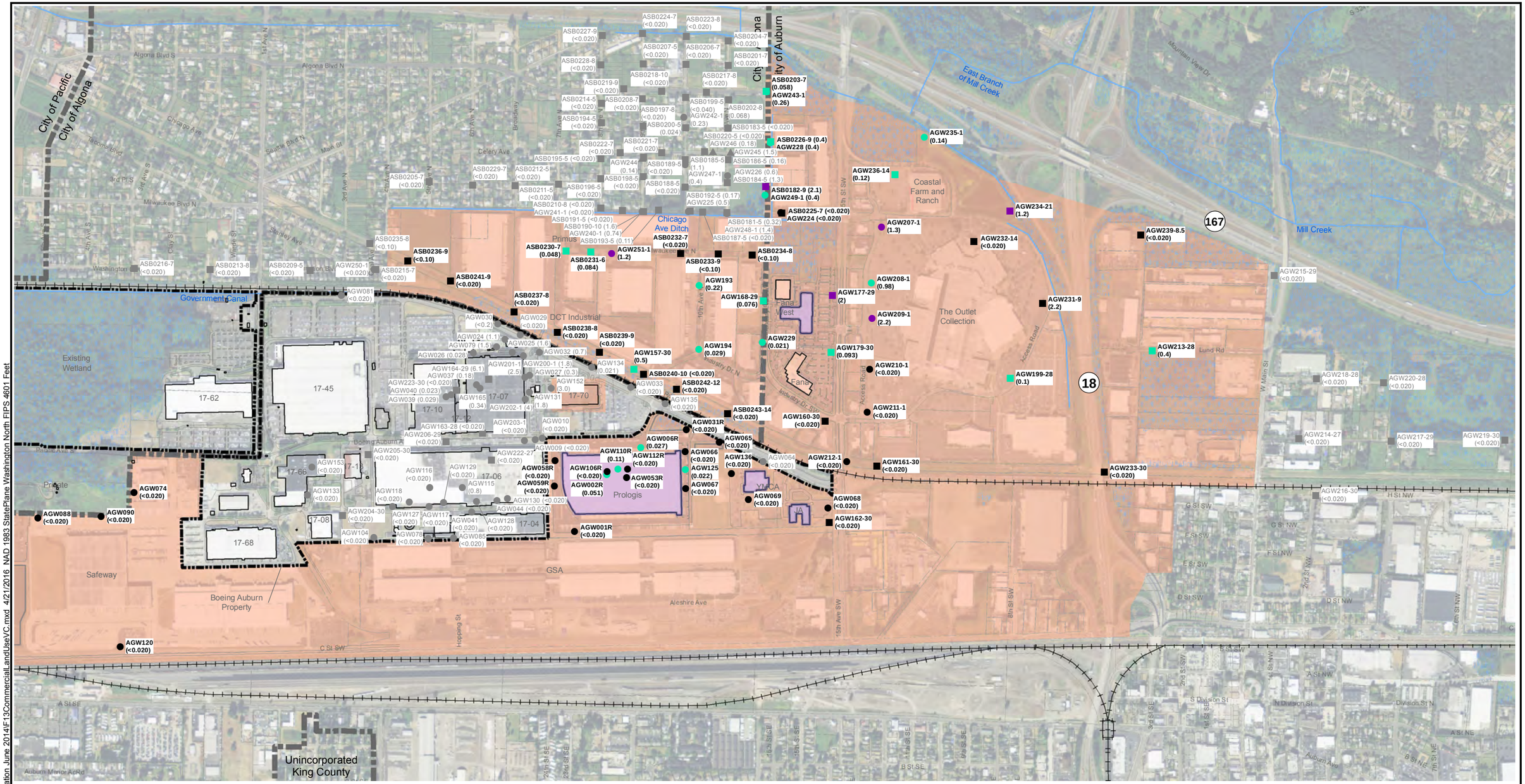
Scale in Feet

Base map source: Geometrix 2003; Aerial Photo Source: Esri World Imagery; Parcel Data Source: King County GIS 2013

LANDAU ASSOCIATES

Boeing Auburn Auburn, Washington	**Commercial Land Use Area Shallow Groundwater Concentrations Exceeding Commercial TCE Vapor Intrusion Screening Level**	Figure 12

G:\Projects\025\164\110\105\VI Evaluation June 2014\F12CommercialLandUseTCE.mxd 4/21/2016 NAD 1983 StatePlane Washington North FIPS 4601 Feet



G:\Projects\025\164\110\105\VI Evaluation June 2014\F13CommercialLandUseVC.mxd 4/21/2016 NAD 1983 StatePlane Washington North FIPS 4601 Feet

Notes

1. Concentrations shown in µg/L.
2. <0.2 = Compound not detected at indicated reporting limit.
3. Monitoring well results are the most recent (June 2014). Direct-push borehole sample results are from Summer 2014. Borehole grab samples from monitoring wells were collected at time of drilling.
4. Multi-level wells have multiple channels. Channel designations are included in the well ID (ex: AGW208-1). Channel 1 is the shallowest screen.
5. Direct-push data collected at multiple depths. Data from the shallowest depth is shown.
6. Groundwater monitoring wells are identified by the AGW prefix. Soil borings from the direct-push investigations are identified by the ASB prefix.
7. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

- ▲ Water Table Well
- ● Shallow Well
- ■ Borehole Grab Sample
- ▲■● Last VC Detection = < 1.0 µg/L
- ▲■● Last VC Detection = ≥ 1.0 µg/L
- ▲■● Non-Detect
- ▲■● Non-Commercial
- Commercial Buildings Where Vapor Intrusion Assessments Have Been Conducted
- Commercial Land Use Area
- Waterways
- Wetland Areas
- Boeing Property
- City Limits

N

0 1,000 2,000

Scale in Feet

Base map source: Geometrix 2003; Aerial Photo Source: Esri World Imagery; Parcel Data Source: King County GIS 2013

LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

Commercial Land Use Area Shallow Groundwater Concentrations Exceeding Commercial VC Vapor Intrusion Screening Level

Figure 13

G:\Projects\025\164\110\105\VI Evaluation June 2014\F14CommercialTier1TCE.mxd 4/21/2016 NAD 1983 StatePlane Washington North FIPS 4601 Feet

Legend

- Monitoring Well
- Borehole Grab Sample
- Water Table Well
- Last TCE Detection - < 7.9 µg/L
- Last TCE Detection - ≥ 7.9 µg/L
- Non-Detect
- Non-Commercial
- Waterways
- Wetland Areas
- Boeing Property
- City Limits
- Commercial Land Use Area
- Residential Land Use Area

Notes

1. Borings denoted by "ASB" were conducted in April 2013 and Summer 2014.
2. 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; Parcel Data Source: King County GIS 2013

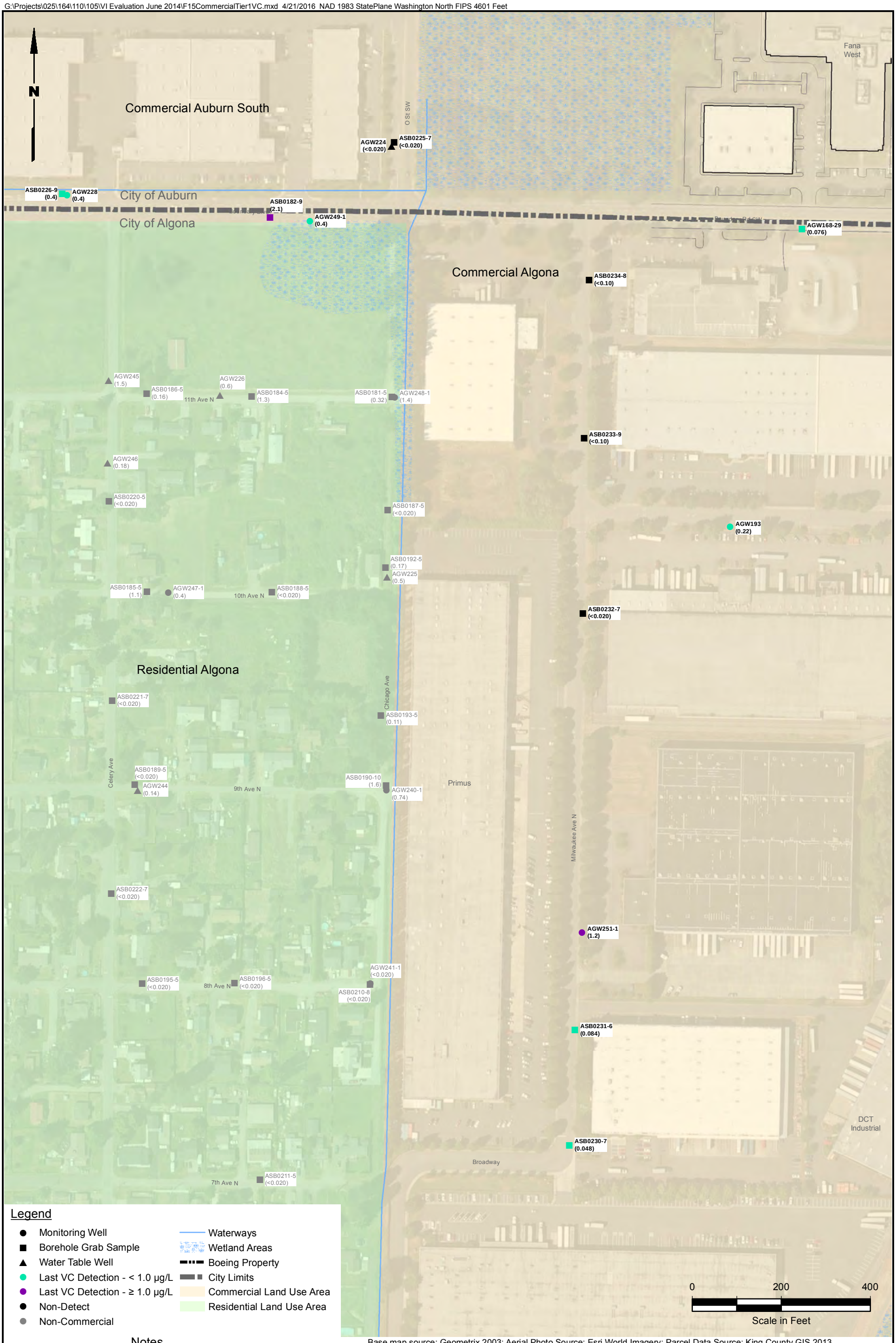
LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

Commercial Algona
Shallow Groundwater Concentrations
Exceeding Commercial TCE
Vapor Intrusion Screening Level

Figure
14

G:\Projects\025\164\110\105\VI Evaluation June 2014\F15CommercialTier1VC.mxd 4/21/2016 NAD 1983 StatePlane Washington North FIPS 4601 Feet



Notes

1. Borings denoted by "ASB" were conducted in April 2013 and Summer 2014.
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

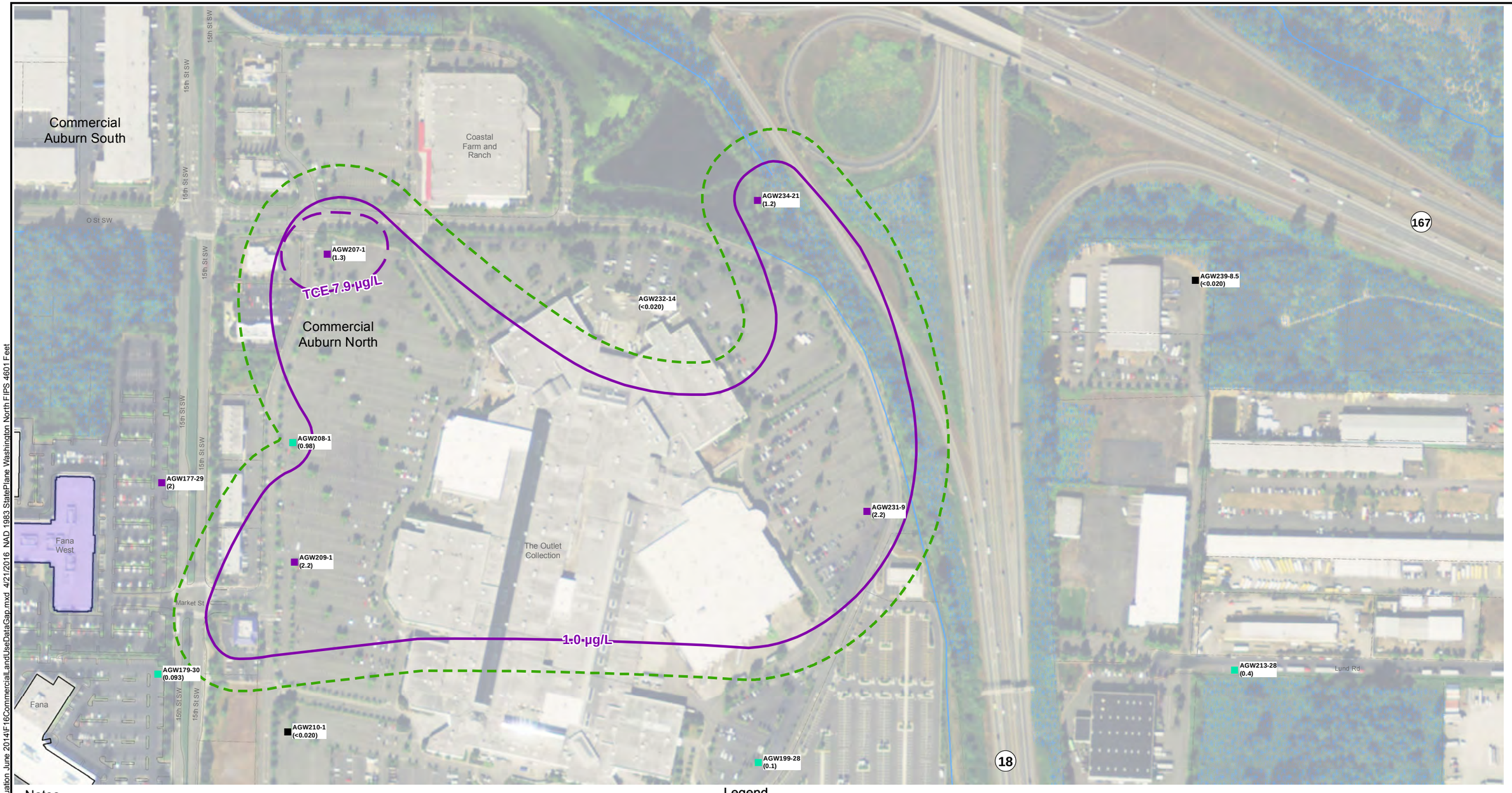
Base map source: Geometrix 2003; Aerial Photo Source: Esri World Imagery; Parcel Data Source: King County GIS 2013

LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

Commercial Algona
Shallow Groundwater Concentrations
Exceeding Commercial VC
Vapor Intrusion Screening Level

Figure
15



Notes

1. Vinyl chloride (VC) data from Figure 16 is shown in micrograms per liter (µg/L). TCE data is not shown, but a TCE commercial screening level contour based on TCE data on Figure 14 is shown; the TCE contour falls within the VC contour.
2. The applicable VC commercial screening level for shallow groundwater protective of indoor air is 1.0 µg/L.
3. The VC concentration data from channel 1 of the multi-level wells were used to develop the 1.0 µg/L contour since it is the shallowest screen.
4. Multi-level wells have multiple channels. Channel designations are included in the well ID (ex: AGW208-1). Channel 1 is the shallowest channel.
5. Borehole sample naming designations include the location name (e.g., AGW213) followed by the depth below ground surface in feet at which the sample was collected at time of drilling (e.g., 29).
6. Area around AGW177-29 previously investigated; no further investigation required.
7. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

- Water Table Well
- Shallow Well
- Borehole Grab Sample
- Last VC Detection = < 1.0 µg/L
- Last VC Detection = ≥ 1.0 µg/L
- Non-Detect
- 100 ft Boundary
- VC Screening Level Contour = 1.0 µg/L
- Commercial Building Where Vapor Intrusion Assessments Have Been Conducted
- TCE Plume (7.9 µg/L)
- Waterways
- Wetland Areas

N

0 300 600

Scale in Feet

Base map source: Geometrix 2003; Aerial Photo Source: Esri World Imagery; Parcel Data Source: King County GIS 2013

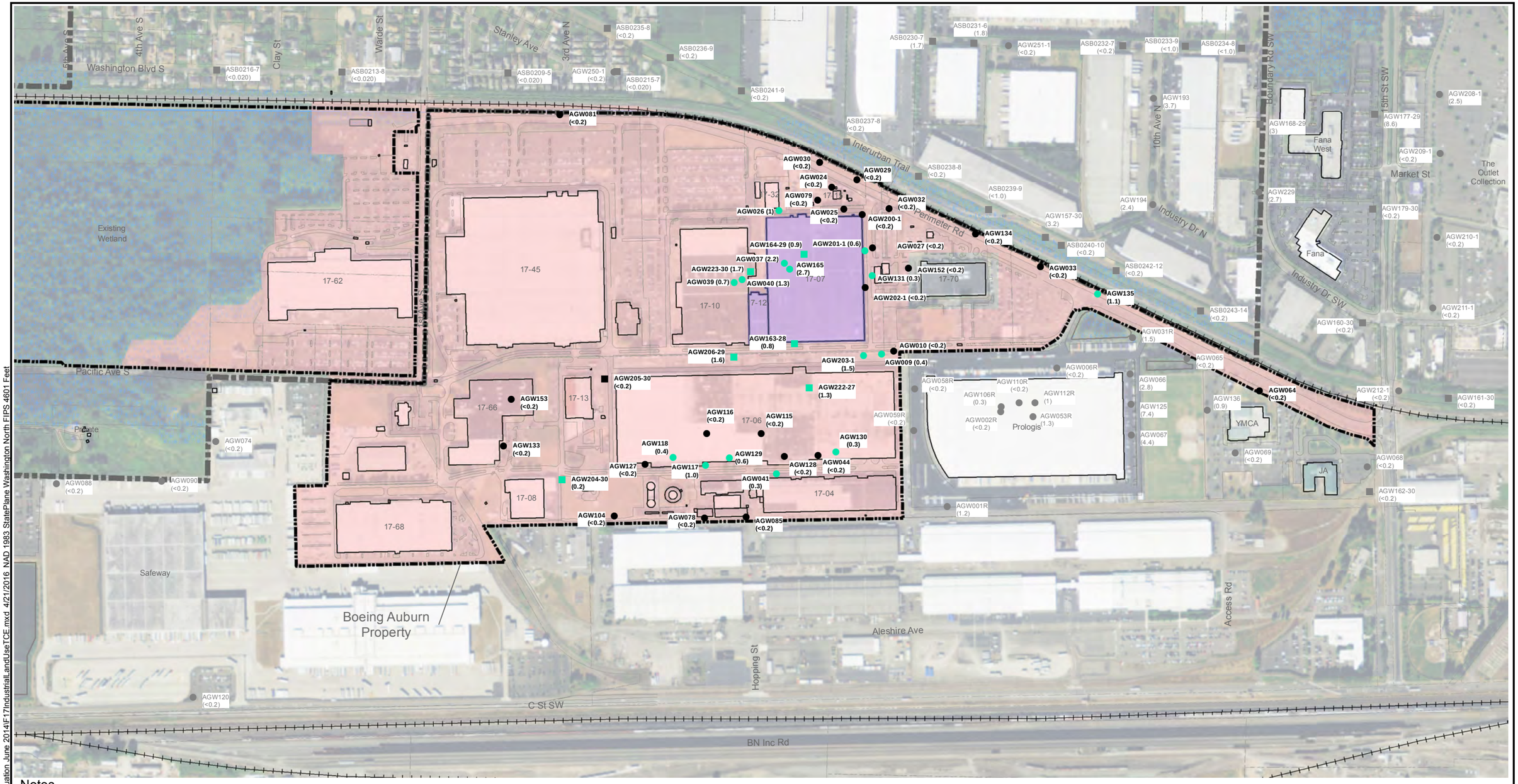
LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

Commercial Auburn Additional Vapor Intrustion Assessment Area

Figure 16

G:\Projects\025\164\110\105\VI Evaluation June 2014\F16CommercialLandUseDataGap.mxd 4/21/2016 NAD 1983 StatePlane Washington North FIPS 4601 Feet



Notes

1. Concentrations shown in µg/L.
2. <0.2 = Compound not detected at indicated reporting limit.
3. Monitoring well results are the most recent as of July 2014. Direct-push borehole sample results are from April 2013 and Summer 2014. Borehole grab samples from monitoring wells were collected at time of drilling.
4. Multi-level wells have multiple channels. Channel designations are included in the well ID (ex: AGW208-1). Channel 1 is the shallowest screen.
5. Direct-push data collected at multiple depths. Data from the shallowest depth is shown.
6. Groundwater monitoring wells are identified by the AGW prefix. Soil borings from the direct-push investigations are identified by the ASB prefix.
7. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

- Water Table Well
- Shallow Well
- Borehole Grab Sample
- Last TCE Detection = < 8.4 µg/L
- Last TCE Detection = ≥ 8.4 µg/L
- Non-Detect
- Non-Industrial
- Industrial Buildings Where Vapor Intrusion Assessments Have Been Conducted
- Industrial Land Use Area
- Waterways
- Wetland Areas
- Boeing Property
- City Limits

N

0 600 1,200

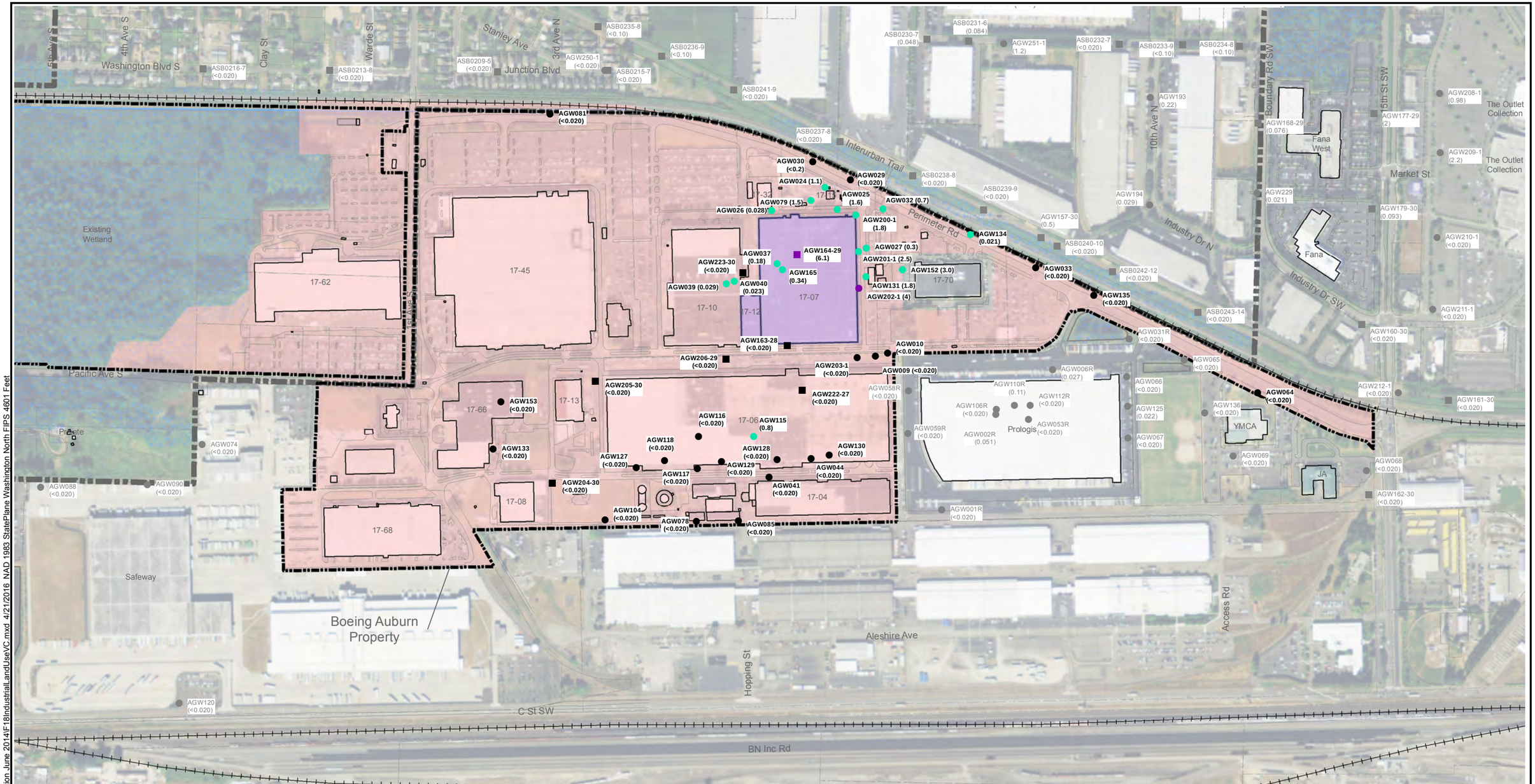
Scale in Feet

Base map source: Geometrix 2003; Aerial Photo Source: Esri World Imagery; Parcel Data Source: King County GIS 2013

LANDAU ASSOCIATES

Boeing Auburn Auburn, Washington	**Industrial Land Use Area Shallow Groundwater Concentrations Exceeding Industrial TCE Vapor Intrusion Screening Level**	Figure 17

G:\Projects\025\164110\105\VI Evaluation June 2014\F17IndustrialLandUseTCE.mxd 4/21/2016 NAD 1983 StatePlane Washington North FIPS 4601 Feet



Notes

1. Concentrations shown in µg/L.
2. <0.2 = Compound not detected at indicated reporting limit.
3. Monitoring well results are the most recent as of July 2014. Direct-push borehole sample results are from April 2013 and Summer 2014. Borehole grab samples from monitoring wells were collected at time of drilling.
4. Multi-level wells have multiple channels. Channel designations are included in the well ID (ex: AGW208-1). Channel 1 is the shallowest screen.
5. Direct-push data collected at multiple depths. Data from the shallowest depth is shown.
6. Groundwater monitoring wells are identified by the AGW prefix. Soil borings from the direct-push investigations are identified by the ASB prefix.
7. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

- Water Table Well
- Shallow Well
- Borehole Grab Sample
- Last VC Detection = < 3.5 µg/L
- Last VC Detection = ≥ 3.5 µg/L
- Non-Detect
- Non-Industrial
- Industrial Buildings Where Vapor Intrusion Assessments Have Been Conducted
- Industrial Land Use Area
- Waterways
- Wetland Areas
- Boeing Property
- City Limits

N

0 600 1,200

Scale in Feet

Base map source: Geometrix 2003; Aerial Photo Source: Esri World Imagery; Parcel Data Source: King County GIS 2013

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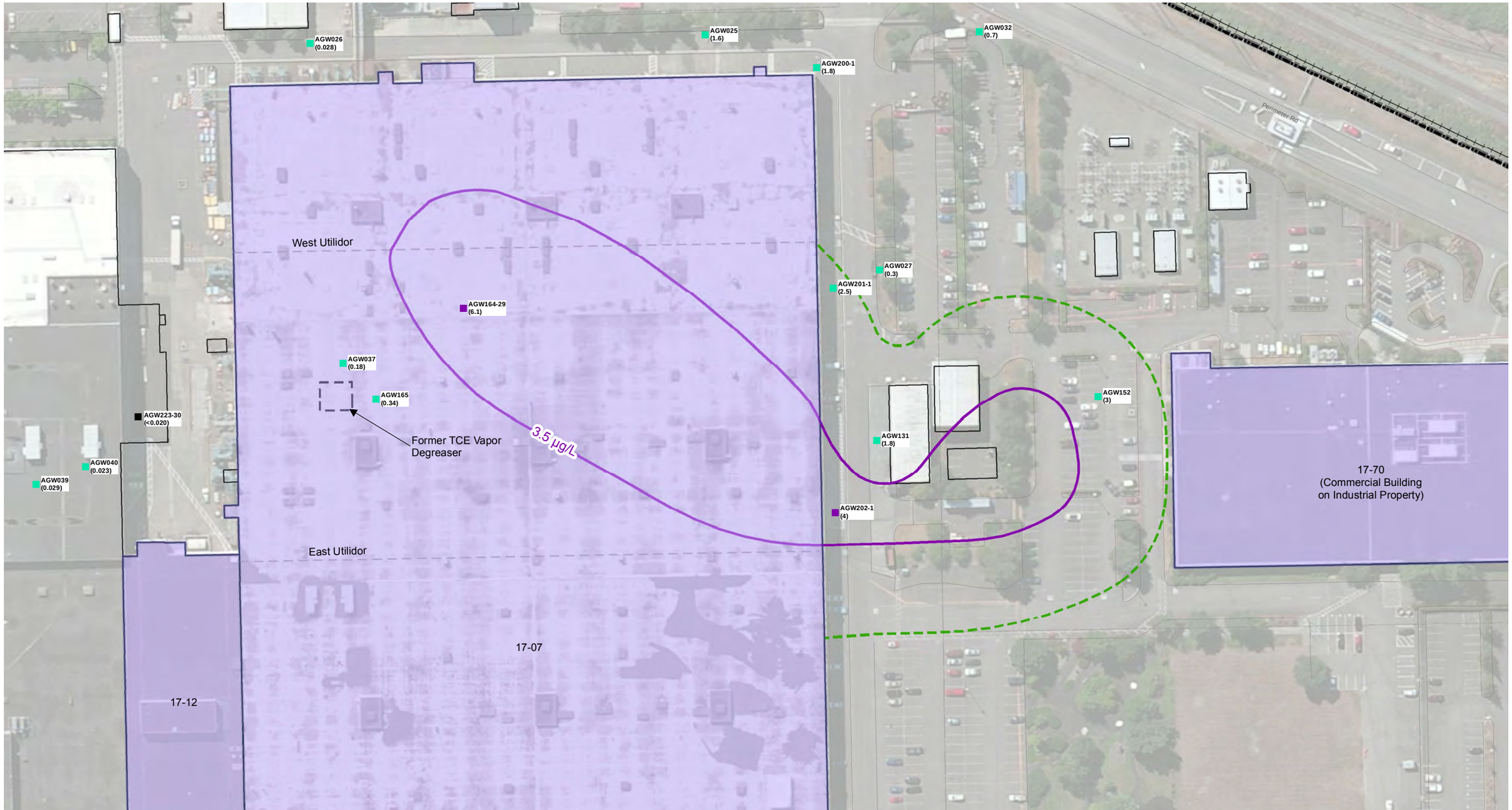
Boeing Auburn Auburn, Washington	**Industrial Land Use Area Shallow Groundwater Concentrations Exceeding Industrial VC Vapor Intrusion Screening Level**	Figure 18

G:\Projects\025\164\110\105\VI Evaluation June 2014\F18IndustrialLandUseVC.mxd 4/21/2016 NAD 1983 StatePlane Washington North FIPS 4601 Feet



G:\Projects\025\164\110\105\VI Evaluation June 2014\F19IndustrialAdditionalVIArea.mxd 4/21/2016 NAD 1983 StatePlane Washington North FIPS 4601 Feet

Notes

1. Vinyl chloride (VC) concentrations are shown in µg/L and represent the most recent as of July 2014 shallow zone results.
2. The applicable VC industrial screening level for shallow groundwater protective of indoor air is 3.5 µg/L.
3. The VC concentration data from channel 1 of the multi-level wells AGW200 through AGW203 were used to develop the 3.5 µg/L contour since it is the shallowest screen.
4. Multilevel wells have multiple channels, channel designations are included in the well ID (ex: AGW208-5). Channel 1 is the shallowest channel.
5. Borehole sample naming designations include the well location name (e.g., AGW213) followed by the depth below ground surface in feet at which the sample was collected at time of drilling (e.g., 29).
6. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend

- Water Table Well
- Shallow Well
- Borehole Grab Sample
- Last VC Detection = < 3.5 µg/L
- Last VC Detection = ≥ 3.5 µg/L
- Non-Detect
- Sanitary Sewer Line
- Stormwater Line
- Water Line
- 100 ft Boundary
- VC Screening Level Contour = 3.5 µg/L
- Industrial Building Where Vapor Intrusion Assessments Have Been Conducted

N

0 100 200

Scale in Feet

Base map source: Geometrix 2003; Aerial Photo Source: Esri World Imagery; Parcel Data Source: King County GIS 2013

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Boeing Auburn Auburn, Washington	**Industrial Additional Vapor Intrusion Assessment Area**	Figure 19

Table 1
Residential Vapor Intrusion Screening Criteria
Boeing Auburn Facility
Auburn, Washington

Constituent of Concern	Air (µg/m^3) (a)			SLs Protective of MTCA Method B Air CULs			
	MTCA Method B		EPA Region 10 Value	Soil Gas (µg/m^3)		Groundwater (µg/L)	
	CUL (carc.)	CUL (non-carc.)	IAAL Sub-Chronic (non-carc) (b)	SL (carc.)	SL (non-carc.)	SL (carc.)	SL (non-carc.)
Trichloroethene	0.37	0.91	2.0	12	30	1.6	3.8
Vinyl Chloride	0.28	46	--	9.5	1500	0.35	56

carc. = carcinogenic
CUL = cleanup level
EPA = U.S. Environmental Protection Agency
IAAL = indoor air action level
µg/m^3 = micrograms per cubic meter
µg/L = micrograms per liter
MTCA = Model Toxics Control Act
non-carc = non-carcinogenic
SL = screnning level
Notes:
Shaded = Most Conservative CUL or SL or level that will be used for assessment.

a. Air screening criteria will be applied to indoor air samples, crawl space and basement air samples, and ambient air samples.
b. The subchronic non-carcinogenic IAAL comes from the EPA Region 10 (EPA 2012). Washington State Department of Ecology has requested that Boeing apply this value as an IAAL when air sampling is conducted where a woman of child bearing age resides.

Table 2
Commercial Vapor Intrusion Screening Criteria
Boeing Auburn Facility
Auburn, Washington

Constituent of Concern	Air (µg/m^3) (a)			SLs Protective of Modified MTCA Method B Air SLs			
	Modified MTCA Method B (b)		EPA Region 10 Value	Soil Gas (µg/m^3)		Groundwater (µg/L) (d)	
	SL (carc.)	SL (non-carc.)	IAAL Sub-Chronic (non-carc) (c)	SL (carc.)	SL (non-carc.)	SL (carc.)	SL (non-carc.)
Trichloroethene	1.9	6.0	8.4	63	200	7.9	25
Vinyl Chloride	0.85	300	--	28	10000	1.0	370

carc. = carcinogenic
EPA = U.S. Environmental Protection Agency
IAAL = indoor air action level
µg/m^3 = micrograms per cubic meter
µg/L = micrograms per liter
MTCA = Model Toxics Control Act
non-carc = non-carcinogenic
SL = screening level
Note:
Shaded = Most Conservative SL.

a. Air screening criteria will be applied to indoor air samples, crawl space, and basement air samples, and ambient air samples.
b. Method for calculating modified MTCA Method B air SLs for commercial land use was defined by Washington State Department of Ecology (Ecology) in their comments to the draft vapor intrusion data report.
c. The sub-chronic non-carcinogenic indoor air action level comes from the EPA Region 10 (EPA 2012). Ecology has requested that Boeing apply this value as an IAAL when air sampling is conducted where a woman of childbearing age resides. Once the EPA Office of Solid Waste and Emergency Resonse determines an official value, the EPA Region 10 subchronic value will be replaced.
d. The Henry's Law constant used to calculate the shallow groundwater screening level assumes a temperature of 13 degrees Celsius per the U.S. temperature map provided by the EPA Online Tools for Site Assessment Calculation for Henry's Law Constants.

Table 3
Industrial Vapor Intrusion Screening Criteria
Boeing Auburn Facility
Auburn, Washington

Constituent of Concern	Air (µg/m^3) (a)			SLs Protective of MTCA Method C Air CULs			
	MTCA Method C		EPA Region 10 Value (b)	Soil Gas (µg/m^3)		Groundwater (µg/L) (c)	
	CUL (carc.)	CUL (non-carc.)	IAAL Sub-Chronic (non-carc)	SL (carc.)	SL (non-carc.)	SL (carc.)	SL (non-carc.)
TCE	6.3	2.0	8.4	210	67	26	8.4
VC	2.8	100		95	3300	3.5	120

carc. = carcinogenic
CUL - cleanup level
EPA = U.S. Environmental Protection Agency
IAAL = indoor air action level
µg/m^3 = micrograms per cubic meter
µg/L = micrograms per liter
MTCA = Model Toxics Control Act
non-carc = non-carcinogenic
SL = screening level
Note:
Shaded = Most Conservative CUL or SL.

a. Air screening criteria will be applied to indoor air samples, crawl space and basement air samples, and ambient air samples.
b. The sub-chronic non-carcinogenic indoor air action level comes from the EPA Region 10 (EPA 2012). Washington State Department of Ecology has requested that Boeing apply this value as an IAAL when air sampling is conducted where a woman of childbearing age resides. Once the EPA Office of Solid Waste and Emergency Response determines an official value, the EPA Region 10 subchronic value will be replaced.
c. The Henry's Law constant used to calculate the shallow groundwater SL assumes a temperature of 13 degrees Celsius per the U.S. temperature map provided by the EPA Online Tools for Site Assessment Calculation for Henry's Law Constants.

Table 4
Shallow Groundwater and Soil Gas Screening Criteria
Boeing Auburn Facility
Auburn, Washington

	Trichloroethene			Vinyl Chloride		
	Indoor Air	Soil Gas	Groundwater	Indoor Air	Soil Gas	Groundwater
MTCA Exposure Scenario and Method	CUL/SL (µg/m^3)	SL (µg/m^3)	SL (µg/L) (a)	CUL/SL (µg/m^3)	SL (µg/m^3)	SL (µg/L) (a)
Residential – Method B	0.37	12	1.6	0.28	9.5	0.35
Commercial – Modified Method B	1.9	63	7.9	0.85	28	1.0
Industrial – Method C	2	67	8.4	2.8	95	3.5

CUL = cleanup level
µg/L = micrograms per liter
µg/m^3 = micrograms per cubic meter
MTCA = Model Toxics Control Act
NA = not applicable
SL = screening level

a. Using standard vapor attenuation factor.

Table 5
Indoor Air Cleanup and Screening Levels
Boeing Auburn Facility
Auburn, Washington

	Trichloroethene - CUL_{IA} ($\mu g/m^3$)		Vinyl Chloride - CUL_{IA} ($\mu g/m^3$)	
MTCA Exposure Scenario and Method	carc.	non-carc.	carc.	non-carc.
Residential – Method B	0.37	0.91	0.28	46
Commercial – Modified Method B (SL)	1.9	6	0.85	300
Industrial – Method C	6.3	2.0	2.8	100

carc. = carcinogenic
CUL = cleanup level
IA = indoor air
$\mu g/m^3$ = micrograms per cubic meter
MTCA = Model Toxics Control Act
non-carc. = non-carcinogenic
SL = screening level
Note:
Shaded = Approved screening criteria.

Table 6
Current Shallow Zone Monitoring Well Network
Boeing Auburn Facility
Auburn, Washington

Well (a)	DTW ATD (ft)	Depth to Top of Screen (ft)	Depth to Bottom of Screen (ft)	Screen Length (ft)	June 2013 DTW (ft)	January 2014 DTW (ft)	July 2014 DTW (ft)	Water Table Wells
AGW001R	11	15	25	10	12.82	13.89	13.11	
AGW002R	22	24.5	34.5	10	17.02	18.03	17.24	
AGW006R	12	16	26	10	12.88	13.86	13.12	
AGW009	--	9	19	10	11.8	12.8	11.99	X
AGW010	--	11.5	21.5	10	11.81	12.88	12.03	X
AGW024	--	13	23	10	10.16	12.77	10.28	
AGW025	18	15	25	10	11.46	12.14	11.55	
AGW026	17	15	25	10	11.26	11.93	11.34	
AGW027	17.5	15	25	10	13.65	14.6	13.79	X
AGW029	17.5	15	25	10	12.86	13.38	13.02	
AGW030	17.2	15	25	10	12.4	12.7	12.58	
AGW031R	11	18	28	10	12.61	13.56	12.86	
AGW032	18	13	28	15	13.93	14.63	14.11	X
AGW033	18	13	28	15	13.96	14.82	14.15	X
AGW037	11.5	8	23	15	11.8	12.6	11.92	X
AGW039	10.5	5	20	15	11.55	12.3	11.65	X
AGW040	10.5	5	20	15	11.56	12.35	11.69	X
AGW041	11.5	4.5	19.5	15	11.38	12.4	11.61	X
AGW044	11.5	4.5	19.5	15	11.65	12.78	11.87	X
AGW053R	22.5	12	27	15	--	18.23	17.45	X
AGW058R	14.5	14.5	24.5	10	15.52	16.57	15.76	X
AGW059R	13.5	15	25	10	14.72	15.76	14.96	X
AGW064	17	12	27	15	15.48	16.54	15.61	X
AGW065	17	12	27	15	12.85	13.57	13.07	X
AGW066	15.5	14	29	15	16.22	17.19	16.45	X
AGW067	--	14	29	15	16.19	17.23	16.44	X
AGW068	17.2	12	27	15	12.44	13.86	12.49	X
AGW069	15.5	12	27	15	14.32	15.53	14.4	X
AGW074	6.9	5	25	20	11.09	11.43	11.18	X
AGW078	9.1	4	19	15	11.88	12.9	12.13	X
AGW079	8.5	4.5	19.5	15	10.15	10.82	10.26	X
AGW081	7.5	5	20	15	7.46	7.84	7.8	X
AGW085	12	5	20	15	11.26	12.3	11.48	X
AGW088	15.5	15	25	10	9.36	9.42	9.39	
AGW090	14.4	15	25	10	9.6	10.02	9.81	
AGW104	13.75	20	30	10	13.27	14.24	13.49	
AGW106R	22.5	24.5	34.5	10	17.07	18.06	17.29	
AGW110R	22.75	24.5	34.5	10	17.24	18.24	17.48	
AGW112R	22.5	25	35	10	17.23	18.22	17.47	
AGW115	16.5	9	24	15	11.38	12.45	11.57	X
AGW116	16.25	9	24	15	11.38	12.43	11.59	X
AGW117	16	9	24	15	11.13	12.11	11.32	X
AGW118	16	9	24	15	11.27	12.26	--	X
AGW120	18	20	30	10	16.07	16.72	16.29	
AGW125	14.5	20	30	10	15.46	16.5	15.7	
AGW127	14	9	24	15	10.87	11.73	11.02	X
AGW128	15.75	9	24	15	11.66	12.99	11.96	X

Table 6
Current Shallow Zone Monitoring Well Network
Boeing Auburn Facility
Auburn, Washington

Well (a)	DTW ATD (ft)	Depth to Top of Screen (ft)	Depth to Bottom of Screen (ft)	Screen Length (ft)	June 2013 DTW (ft)	January 2014 DTW (ft)	July 2014 DTW (ft)	Water Table Wells
AGW129	15	9	24	15	11.44	12.48	11.66	X
AGW130	15.5	8.5	23.5	15	11.78	12.92	12.01	X
AGW131	15.25	14.5	24.5	10	11.61	12.63	11.76	
AGW133	17.25	17	27	10	12.16	12.98	12.35	
AGW134	13.5	17.5	27.5	10	10.04	10.77	10.23	
AGW135	14.75	17	27	10	11.18	12.04	11.4	
AGW136	17.25	18	28	10	13.54	14.56	13.78	
AGW152	13	19.5	29.5	10	10.22	11.18	10.39	
AGW153	21	19.5	29.5	10	12.81	13.52	12.97	
AGW165	15.25	18	28	10	11.8	12.64	11.63	
AGW193	15	20	30	10	6.43	6.97	6.67	
AGW194	14.5	19.5	29.5	10	9.5	10.26	9.72	
AGW200-2	15.5	29.25	29.75	0.5	12.04	12.66	12.2	
AGW201-2	15.5	29.25	29.75	0.5	12	12.86	12.18	
AGW202-2	15	30.25	30.75	0.5	11.94	12.77	11.97	
AGW203-2	15	29.25	29.75	0.5	11.94	12.93	12.12	
AGW207-2	8.5	29.5	30	0.5	7.1	7.21	7.24	
AGW208-2	7	29.05	29.55	0.5	5.12	5.58	5.37	
AGW209-2	10.75	29.25	29.75	0.5	7.72	8.21	7.92	
AGW210-2	11.5	29.75	30.25	0.5	8.99	9.65	9.21	
AGW211-2	7.75	29.5	30	0.5	10.57	11.32	10.71	
AGW212-2	14.25	29.5	30	0.5	10.94	11.3	11.09	
AGW224	1.75	1.75	16.75	15	2.88	2.77	3.06	X
AGW225	2.5	3	18	15	2.16	2.25	2.39	X
AGW226 (b)	0.5	2	17	15	0.47	0.36	0.79	X
AGW228	3.75	18	28	10	3.9	3.73	4.16	
AGW229	8	2.5	17.5	15	7.56	8.27	7.74	X
AGW231	10	19.5	29.5	10	4.87	5.06	4.98	
AGW232	13	20.5	31	10.5	9.57	9.76	9.7	
AGW235-1	3	8.5	9	0.5	2.95	2.75	3.08	
AGW235-2	3	18.5	19	0.5	2.94	2.77	3.23	
AGW235-3	3	28.5	29	0.5	2.2	2.07	2.46	
AGW236	9	19.5	29.5	10	6.52	6.55	6.7	
AGW239	6	20	30	10	--	5.51	5.83	
AGW240-1	3.09	5	7.5	2.5	--	--	3.17	X
AGW240-3	3.09	17.5	18	0.5	--	--	2.58	
AGW240-5	3.09	28	28.5	0.5	--	--	2.58	
AGW241-1	5	4	6.5	2.5	--	--	3.39	X
AGW241-3	5	16.5	17	0.5	--	--	3.01	
AGW241-5	5	27	27.5	0.5	--	--	3.01	
AGW242-1	5.2	3.5	6	2.5	--	--	1.66	X
AGW242-2	5.2	16	16.5	0.5	--	--	1.66	
AGW242-3	5.2	26.5	27	0.5	--	--	1.66	
AGW243-1	5.09	4	6.5	2.5	--	--	3.99	X
AGW243-3	5.09	25	25.5	0.5	--	--	3.67	
AGW244 (b)	4	2.5	7.5	5	--	--	3.03	X
AGW245 (b)	4.8	2.5	7.5	5	--	--	2.35	X

Table 6
Current Shallow Zone Monitoring Well Network
Boeing Auburn Facility
Auburn, Washington

Well (a)	DTW ATD (ft)	Depth to Top of Screen (ft)	Depth to Bottom of Screen (ft)	Screen Length (ft)	June 2013 DTW (ft)	January 2014 DTW (ft)	July 2014 DTW (ft)	Water Table Wells
AGW246 (b)	3.3	2.5	7.5	5	--	--	1.93	X
AGW247-1	5	3.5	6	2.5	--	--	2.52	X
AGW247-3	5	16	16.5	0.5	--	--	2.5	
AGW247-5	5	26.5	27	0.5	--	--	2.49	
AGW248-1	3.5	3	5.5	2.5	--	--	2.58	X
AGW248-3	3.5	15.5	16	0.5	--	--	2.09	
AGW248-5	3.5	26	26.5	0.5	--	--	2.08	
AGW249-1	7.5	6	8.5	2.5	--	--	5.21	X
AGW249-3	7.5	18.5	19	0.5	--	--	3.96	
AGW249-5	7.5	29	29.5	0.5	--	--	3.97	
AGW250-1	6.5	6.5	9	2.5	--	--	4.32	X
AGW250-2	6.5	26	26.5	0.5	--	--	4.16	
AGW251-1	5.8	6	8.5	2.5	--	--	4.77	X
AGW251-2	5.8	25	25.5	0.5	--	--	4.76	

-- = not measured
ATD = at time of drilling
DTW = depth to water
ft = feet

a. Water table wells are wells screened along the top of the water table. This table includes the 108 shallow wells currently a part of the remedial investigation monitoring program.
b. AGW226, AGW244, AGW245, and AGW246 were screened as shallow as well construction regulations allow.

Table 7
Tier II Assessment Decision Matrix
Boeing Auburn Facility
Auburn, Washington

Indoor air measurements (a) / sub-slab soil gas measurement.	Indoor air concentration < indoor air SL	Indoor air concentration > indoor air SL, but is < IAALs	Indoor air concentration ≥ long term IAALs	Indoor air concentration ≥ short term IAAL
Sub-slab soil gas concentration < applicable SL.	No need for mitigation and no need to further evaluate the vapor intrusion pathway.	Repeat sampling and investigate potential background sources.	Immediately repeat sampling; investigate potential indoor sources.	Immediately repeat sampling; investigate potential indoor sources; notify property owner and occupants; assess sensitive populations.
Sub-slab soil gas concentration > applicable SL, but < 10 times the SL.	No need for mitigation and no need to further evaluate the vapor intrusion pathway.	Repeat sampling and investigate potential background sources; consider mitigation if multiple consecutive indoor air samples exceed the SL and if unable to locate/isolate background sources.	Immediately repeat sampling and investigation of potential indoor sources; mitigate if unable to locate/isolate indoor sources.	Immediately repeat sampling and investigate potential indoor sources; notify property owner and occupants; assess sensitive populations and potential need for alternative accomodations; mitigate if unable to locate/isolate indoor sources.
Sub-slab soil gas concentration > 10 times the applicable SL.	Repeat sampling and consider mitigation.	Repeat sampling and investigate potential background sources; mitigation recommended if multiple consecutive indoor air samples exceed the SL.		
No Sub-slab soil gas data.	No need for mitigation and no need to further evaluate the vapor intrusion pathway.	Repeat sampling and investigate potential background sources; collect sub-slab data if possible; if there are no background sources, consider mitigation.	Immediately repeat sampling and investigation of potential indoor sources;mitigate if unable to locate/isolate indoor sources and concentrations in indoor air samples are again elevated.	Immediately repeat sampling and investigation of potential indoor sources; notify property owner and occupants; assess sensitive populations and potential need for alternative accomodations; mitigate if unable to locate/isolate indoor sources and concentrations in indoor air samples are again elevated.

IAAL = Indoor Air Action Level
SL = Screening Level
Notes:
Indoor source = Background chemical source that contains chemicals being investigated for vapor intrusion (e.g., TCE).
This decision matrix incorporates aspects from Ecology's comments (Ecology 2013) and tables E-1 and E-2 of Ecology's draft vapor intrusion guidance (Ecology 2009).
This decision matrix is kept general and therefore, covers carcinogenic and non-carcinogenic indoor air SLs and IAALs. The practioner is responsible for applying the appropriate screening criteria when using this decision matrix; please refer to Tables 1-3, SL and IAAL values for proper use of these values.

a. This refers to the indoor air concentration measurements that may be attributed to vapor intrusion. Commonly this will be estimated to be the max measured indoor concentration or representative measured, same-day, ambient air concentration.

Table 8
Comparison of Shallow Groundwater Results from Multi-Depth Sampling Locations
Boeing Auburn Facility
Auburn, Washington

Locations	Type of Sample	Well	Date	Depth (ft)	Most Recent (a,b) TCE Results (µg/L)	Shallowest Sample Concentration Comparison to Deepest	Most Recent (a,b) VC Results (µg/L)	Shallowest Sample Concentration Comparison to Deepest
AGW200	Multi-level well screens	AGW200-1	4/26/2012	19.75	<0.2	Lower	**1.8**	Higher
		AGW200-2	4/26/2012	29.75	**0.3**		**1.7**	
AGW201	Multi-level well screens	AGW201-1	4/27/2012	19.75	**0.6**	Lower	**2.5**	Same
		AGW201-2	4/27/2012	29.75	**0.7**		**2.5**	
AGW202	Multi-level well screens	AGW202-1	4/27/2012	20.75	<0.2	Lower	**4**	Higher
		AGW202-2	4/27/2012	30.75	**2.3**		**0.22**	
AGW203	Multi-level well screens	AGW203-1	4/30/2012	19.75	**1.5**	Same	<0.02	Same
		AGW203-2	4/30/2012	29.75	**1.5**		<0.02	
AGW207	Multi-level well screens	AGW207-1	4/23/2012	20	**9.1**	Lower	**1.3**	Higher
		AGW207-2	4/23/2012	30	**10**		**0.16**	
AGW208	Multi-level well screens	AGW208-1	4/23/2012	21.55	**2.5**	Lower	**0.98**	Same
		AGW208-2	4/23/2012	29.55	**4.4**		**0.98**	
AGW209	Multi-level well screens	AGW209-1	4/24/2012	19.75	<0.2	Same	**2.2**	Lower
		AGW209-2	4/24/2012	29.75	<0.2		**2.7**	
AGW210	Multi-level well screens	AGW210-1	4/24/2012	21.75	<0.2	Same	<0.2	Same
		AGW210-2	4/25/2012	30.25	<0.2		<0.2	
AGW211	Multi-level well screens	AGW211-1	4/25/2012	20	<0.2	Same	<0.2	Same
		AGW211-2	4/25/2012	30	<0.2		<0.2	
AGW212	Multi-level well screens	AGW212-1	4/26/2012	21	<0.2	Same	<0.2	Same
		AGW212-2	4/26/2012	30	<0.2		<0.2	
AGW224 Area	Borehole	ASB0225	4/29/2013	7	<0.020	Lower	<0.020	Lower
	Water Table Well	AGW224	5/30/2014	5	<0.2		<0.020	
	Borehole	AGW182-29	4/29/2011	29	**6.7**		**0.3**	
AGW225 Area	Borehole	ASB0192	4/11/2013	5	**0.5**	Lower	**0.17**	Same
	Water Table Well	AGW225	5/29/2014	4	**2.3**		**0.5**	
	Borehole	ASB0192	4/11/2013	25	**2.4**		**0.5**	
AGW226 Area	Borehole	ASB0184	4/5/2013	5	**0.2**	Lower	**1.3**	Higher
	Water Table Well	AGW226	5/29/2014	2	**4.7**		**0.6**	
	Borehole	ASB0184	4/5/2013	25	**6.6**		**0.3**	
AGW228 Area	Borehole	ASB0226	4/29/2013	9	**1.2**	Lower	**0.4**	Same
	Conventional Well	AGW228	5/29/2014	25	**2.6**		**0.4**	

Table 8
Comparison of Shallow Groundwater Results from Multi-Depth Sampling Locations
Boeing Auburn Facility
Auburn, Washington

Locations	Type of Sample	Well	Date	Depth (ft)	Most Recent (a,b) TCE Results (µg/L)	Shallowest Sample Concentration Comparison to Deepest	Most Recent (a,b) VC Results (µg/L)	Shallowest Sample Concentration Comparison to Deepest
AGW231	Borehole	AGW231-9	5/19/2013	9	<0.2	Lower	**2.2**	Lower
	Conventional Well	AGW231	5/29/2014	25	**1.4**		**2.9**	
AGW232	Borehole	AGW232-14	5/20/2013	14	<0.2	Same	<0.020	Lower
	Conventional Well	AGW232	5/29/2014	25	<0.2		**1.3**	
AGW235	Multi-level well screens	AGW235-1	9/6/2013	9	<0.2	Lower	**0.14**	Lower
		AGW235-2	9/6/2013	19	<0.2		**0.5**	
		AGW235-3	9/6/2013	29	**2.5**		**0.3**	
AGW236	Borehole	AGW236-14	5/28/2013	14	<0.2	Lower	**0.12**	Higher
	Conventional Well	AGW236	5/30/2014	25	**7.6**		**0.059**	
AGW239	Borehole	AGW239-8.5	9/25/2013	8.5	<0.2	Same	<0.020	Lower
	Conventional Well	AGW239	5/28/2014	25	<0.2		**0.8**	
AGW240	Multi-level well screens	AGW240-1	7/11/2014	7.5	<0.2	Same	**0.74**	Lower
		AGW240-3	7/11/2014	18	<0.2		**3.7**	
		AGW240-5	7/11/2014	28.5	<0.2		**4.1**	
AGW241	Multi-level well screens	AGW241-1	7/11/2014	6.5	<0.2	Same	<0.020	Lower
		AGW241-3	7/11/2014	17	<0.2		**0.022**	
		AGW241-5	7/11/2014	27.5	<0.2		**0.032**	
AGW242	Multi-level well screens	AGW242-1	7/15/2014	6	<0.2	Same	**0.23**	Higher
		AGW242-2	7/15/2014	16.5	<0.2		<0.020	
		AGW242-3	7/15/2014	27	<0.2		<0.020	
AGW243	Multi-level well screens	AGW243-1	7/14/2014	6.5	<0.2	Same	**0.26**	Higher
		AGW243-3	7/14/2014	25.5	<0.2		<0.020	
AGW245 Area	Borehole	ASB0186	4/8/2013	5	**0.022**	Lower	**0.16**	Lower
	Borehole	ASB0186	4/8/2013	25	**0.039**		**0.93**	
	Conventional Well	AGW245	7/14/2014	7.5	**0.5**		**1.5**	
AGW247	Multi-level well screens	AGW247-1	7/14/2014	6	<0.2	Same	**0.4**	Lower
		AGW247-3	7/14/2014	16.5	<0.2		**1.1**	
		AGW247-5	7/14/2014	27	<0.2		**0.8**	
AGW248	Multi-level well screens	AGW248-1	7/14/2014	5.5	<0.2	Lower	**1.4**	Higher
		AGW248-3	7/14/2014	16	**5**		**0.2**	
		AGW248-5	7/14/2014	26.5	**4.4**		**0.2**	

Table 8
Comparison of Shallow Groundwater Results from Multi-Depth Sampling Locations
Boeing Auburn Facility
Auburn, Washington

Locations	Type of Sample	Well	Date	Depth (ft)	Most Recent (a,b) TCE Results (µg/L)	Shallowest Sample Concentration Comparison to Deepest	Most Recent (a,b) VC Results (µg/L)	Shallowest Sample Concentration Comparison to Deepest
AGW249	Multi-level well screens	AGW249-1	7/11/2014	8.5	**0.9**	Lower	**0.4**	Higher
		AGW249-3	7/11/2014	19	**6.4**		**0.13**	
		AGW249-5	7/11/2014	29.5	**6.7**		**0.13**	
AGW250	Multi-level well screens	AGW250-1	7/14/2014	9	<0.2	Lower	<0.020	Lower
		AGW250-2	7/14/2014	26.5	**0.2**		**0.034**	
AGW251	Multi-level well screens	AGW251-1	7/11/2014	8.5	<0.2	Same	**1.2**	Higher
		AGW251-2	7/11/2014	25.5	<0.2		**0.6**	
					Lower	55%	Lower	38%
					Higher	0%	Higher	34%
					Same	45%	Same	28%
						100%		100%

µg/L = Micrograms per Liter
TCE = Trichloroethene
VC = Vinyl Chloride
Notes:
Bold = Detected concentration.
Shaded = Value at or closest to the top of the water table, and thus used for Tier I screening.
a. Multi-level well data represents results from the most recent sampling event where all shallow screens at a given well were sampled; at present, only one shallow well screen is sampled at each location.
b. Conventional and water table well results are most recent as of July 2014.

Table 9
Data Used for Tier I Assessment
Boeing Auburn Facility
Auburn, Washington

Sample Location	Sample Date	TCE (µg/L)	VC (µg/L)
AGW001R	5/30/2014	1.2	<0.020
AGW002R	6/2/2014	<0.2	0.051
AGW006R	5/30/2014	<0.2	0.027
AGW009	6/18/2014	0.4	<0.020
AGW010	6/23/2014	<0.2	<0.020
AGW024	6/16/2014	<0.2	1.1
AGW025	6/16/2014	<0.2	1.6
AGW026	6/16/2014	1	0.028
AGW027	6/9/2014	<0.2	0.3
AGW029	6/16/2014	<0.2	<0.020
AGW030	6/16/2014	<0.2	<0.020
AGW031R	5/30/2014	1.5	<0.020
AGW032	6/10/2014	<0.2	0.7
AGW033	6/17/2014	<0.2	<0.020
AGW037	6/19/2014	2.2	0.18
AGW039	6/24/2014	0.7	0.029
AGW040	6/24/2014	1.3	0.023
AGW041	6/18/2014	0.3	<0.020
AGW044	6/23/2014	<0.2	<0.020
AGW053R	6/2/2014	1.3	<0.020
AGW058R	5/30/2014	<0.2	<0.020
AGW059R	5/30/2014	<0.2	<0.020
AGW064	5/29/2014	<0.2	<0.020
AGW065	5/29/2014	<0.2	<0.020
AGW066	6/2/2014	2.8	<0.020
AGW067	6/2/2014	4.4	<0.020
AGW068	5/30/2014	<0.2	<0.020
AGW069	5/30/2014	<0.2	<0.020
AGW074	6/18/2014	<0.2	<0.020
AGW078	6/10/2014	<0.2	<0.020
AGW079	6/16/2014	<0.2	1.5
AGW081	6/16/2014	<0.2	<0.020
AGW085	6/10/2014	<0.2	<0.020
AGW088	6/18/2014	<0.2	<0.020
AGW090	6/18/2014	<0.2	<0.020
AGW104	6/10/2014	<0.2	<0.020
AGW106R	6/2/2014	0.3	<0.020
AGW110R	6/2/2014	<0.2	0.11
AGW112R	6/2/2014	1	<0.020
AGW115	6/18/2014	<0.2	0.8
AGW116	6/18/2014	<0.2	<0.020

Table 9
Data Used for Tier I Assessment
Boeing Auburn Facility
Auburn, Washington

Sample Location	Sample Date	TCE (µg/L)	VC (µg/L)
AGW117	6/10/2014	1	<0.020
AGW118	6/18/2014	0.4	<0.020
AGW120	6/18/2014	<0.2	<0.020
AGW125	6/2/2014	7.4	0.022
AGW127	6/10/2014	<0.2	<0.020
AGW128	6/23/2014	<0.2	<0.020
AGW129	6/18/2014	0.6	<0.020
AGW130	6/23/2014	0.3	<0.020
AGW131	6/9/2014	0.3	1.8
AGW133	6/10/2014	<0.2	<0.020
AGW134	6/16/2014	<0.2	0.021
AGW135	6/16/2014	1.1	<0.020
AGW136	5/30/2014	0.9	<0.020
AGW152	6/10/2014	<0.2	3
AGW153	6/23/2014	<0.2	<0.020
AGW157-30	3/1/2010	3.2	0.5
AGW160-30	2/25/2010	<0.2	<0.020
AGW161-30	3/2/2010	<0.2	<0.020
AGW162-30	2/24/2014	<0.2	<0.020
AGW163-28	8/26/2010	0.8	<0.020
AGW164-29	8/24/2010	0.9	6.1
AGW165	6/19/2014	2.7	0.34
AGW168-29	10/28/2014	3	0.076
AGW177-29	9/21/2010	8.6	2
AGW179-30	9/22/2014	<0.2	0.093
AGW193	5/29/2014	3.7	0.22
AGW194	5/29/2014	2.4	0.029
AGW199-28	10/6/2011	0.8	0.1
AGW200-1	4/26/2012	<0.2	1.8
AGW201-1	4/27/2012	0.6	2.5
AGW202-1	4/27/2012	<0.2	4
AGW203-1	4/30/2012	1.5	<0.020
AGW204-30	10/27/2011	0.2	<0.020
AGW205-30	10/27/2011	<0.2	<0.020
AGW206-29	10/28/2011	1.6	<0.020
AGW207-1	4/23/2012	9.1	1.3
AGW208-1	4/23/2012	2.5	0.98
AGW209-1	4/24/2012	<0.2	2.2
AGW210-1	4/24/2012	<0.2	<0.020
AGW211-1	4/25/2014	<0.2	<0.020
AGW212-1	4/26/2012	<0.2	<0.020

Table 9
Data Used for Tier I Assessment
Boeing Auburn Facility
Auburn, Washington

Sample Location	Sample Date	TCE (µg/L)	VC (µg/L)
AGW213-28	11/14/2011	0.4	0.4
AGW214-27	11/15/2011	<0.2	<0.020
AGW215-29	11/16/2011	<0.2	<0.020
AGW216-30	11/17/2011	<0.2	<0.020
AGW217-29	11/18/2011	<0.2	<0.020
AGW218-28	11/21/2011	<0.2	<0.020
AGW219-30	11/22/2011	<0.2	<0.020
AGW220-28	11/28/2011	<0.2	<0.020
AGW222-27	12/2/2012	1.3	<0.020
AGW223-30	12/3/2012	1.7	<0.020
AGW224	5/30/2014	<0.2	<0.020
AGW225	9/10/2014	2.3	0.5
AGW226	5/29/2014	4.7	0.6
AGW228	5/29/2014	2.6	0.4
AGW229	5/29/2014	2.7	0.021
AGW231-9	5/19/2013	<0.2	2.2
AGW232-14	5/20/2013	<0.2	<0.020
AGW233-30	5/21/2013	<0.5	<0.020
AGW234-21	5/22/2013	<0.5	1.2
AGW235-1	9/6/2013	<0.2	0.14
AGW236-14	5/28/2013	<0.2	0.12
AGW239-8.5	9/25/2013	<0.2	<0.020
AGW240-1	7/11/2014	<0.2	0.74
AGW241-1	7/11/2-14	<0.2	<0.020
AGW242-1	7/15/2014	<0.2	0.23
AGW243-1	7/14/2014	<0.2	0.26
AGW244	7/11/2014	<0.2	0.14
AGW245	7/14/2014	0.5	1.5
AGW246	7/14/2014	<0.2	0.18
AGW247-1	7/14/2014	<0.2	0.4
AGW248-1	7/14/2014	<0.2	1.4
AGW249-1	7/11/2014	0.9	0.4
AGW250-1	7/14/2014	<0.2	<0.020
AGW251-1	7/11/2014	<0.2	1.2
ASB0181-5	4/3/2013	0.13	0.22
ASB0182-9	4/4/2013	2.4	2.1
ASB0183-5	4/4/2013	<0.020	<0.020
ASB0184-5	4/5/2013	0.2	1.3
ASB0185-5	4/5/2013	<0.020	1.1
ASB0186-5	4/8/2013	0.022	0.16
ASB0187-5	4/8/2013	0.025	<0.020

Table 9
Data Used for Tier I Assessment
Boeing Auburn Facility
Auburn, Washington

Sample Location	Sample Date	TCE (µg/L)	VC (µg/L)
ASB0188-5	4/9/2013	<0.020	<0.020
ASB0189-5	4/9/2013	<0.020	<0.020
ASB0190-10	4/10/2013	<0.020	0.4
ASB0191-5	4/10/2013	<0.020	<0.020
ASB0192-5	4/11/2013	0.5	0.16
ASB0193-5	4/11/2013	<0.020	0.11
ASB0194-5	4/12/2013	<0.020	<0.020
ASB0195-5	4/12/2013	<0.020	<0.020
ASB0196-5	4/12/2013	<0.020	<0.020
ASB0197-8	4/15/2013	<0.020	<0.020
ASB0198-5	4/15/2013	<0.020	<0.020
ASB0199-5	4/16/2013	<0.040	<0.040
ASB0200-5	4/16/2013	<0.020	0.024
ASB0201-7	4/17/2013	<0.020	<0.020
ASB0202-8	4/17/2013	<0.020	0.070
ASB0203-7	4/18/2013	<0.020	0.058
ASB0204-7	4/18/2013	<0.020	<0.020
ASB0205-7	4/18/2013	<0.020	<0.020
ASB0206-7	4/19/2013	<0.020	<0.020
ASB0207-5	4/19/2013	<0.020	<0.020
ASB0208-7	4/22/2013	<0.020	<0.020
ASB0209-5	4/22/2013	<0.020	<0.020
ASB0210-8	4/22/2013	<0.020	<0.020
ASB0211-5	4/23/2013	<0.020	<0.020
ASB0212-5	4/23/2013	<0.020	<0.020
ASB0213-8	4/23/2013	<0.020	<0.020
ASB0214-5	4/24/2013	<0.020	<0.020
ASB0215-7	4/24/2013	<0.020	<0.020
ASB0216-7	4/24/2013	<0.020	<0.020
ASB0217-8	4/25/2013	<0.020	<0.020
ASB0218-10	4/25/2013	<0.020	<0.020
ASB0219-9	4/25/2013	<0.020	<0.020
ASB0220-5	4/26/2013	<0.020	<0.020
ASB0221-7	4/26/2013	<0.020	<0.020
ASB0222-7	4/26/2013	<0.020	<0.020
ASB0223-8	4/29/2013	<0.020	<0.020
ASB0224-7	4/29/2013	<0.020	<0.020
ASB0225-7	4/29/2013	<0.020	<0.020
ASB0226-9	4/29/2013	1.2	0.4
ASB0227-9	4/30/2013	<0.020	<0.020
ASB0228-8	4/30/2014	<0.020	<0.020

Table 9
Data Used for Tier I Assessment
Boeing Auburn Facility
Auburn, Washington

Sample Location	Sample Date	TCE (µg/L)	VC (µg/L)
ASB0229-7	4/30/2013	<0.020	<0.020
ASB0230-7	6/23/2014	1.7	0.048
ASB0231-6	6/24/2014	1.8	0.084
ASB0232-7	6/24/2014	<0.2	<0.020
ASB0233-9	6/25/2014	<1.0	<0.10
ASB0234-8	6/26/2014	<1.0	<0.10
ASB0235-8	7/7/2014	<0.2	<0.10
ASB0236-9	7/8/2014	<0.2	<0.10
ASB0237-8	7/9/2014	<0.2	<0.020
ASB0238-8	7/9/2014	<0.2	<0.020
ASB0239-9	7/10/2014	<1.0	<0.020
ASB0240-10	7/10/2014	<0.2	<0.020
ASB0241-9	7/11/2014	<0.2	<0.020
ASB0242-12	7/14/2014	<0.2	<0.020
ASB0243-14	7/15/2014	<0.2	<0.020

µg/L = micrograms per liter
TCE = trichloroethene
VC = vinyl chloride

APPENDIX A

Response to Ecology Comments on the Draft Vapor Intrusion Evaluation and Assessment Approach

LANDAU ASSOCIATES

July 16, 2014

Washington State Department of Ecology
Northwest Regional Office
3190 160th Avenue Southeast
Bellevue, Washington 98008-5452

Attn: Ms. Robin Harrover

RE: RESPONSE TO THE APRIL 12, 2013 WASHINGTON STATE DEPARTMENT OF ECOLOGY COMMENTS AND REQUEST FOR REVISION OF THE DRAFT VAPOR INTRUSION EVALUATION AND ASSESSMENT APPROACH DATED FEBRUARY 20, 2013
WAD 041337130, STATE FS ID: 2018

Dear Ms. Harrover:

On behalf of The Boeing Company (Boeing), Landau Associates submitted a draft *Vapor Intrusion Evaluation and Assessment Approach* (Landau Associates 2013a) on February 20, 2013 to the Washington State Department of Ecology (Ecology). Ecology provided comments on the draft report in a letter dated April 12, 2013. Ecology had many good comments and we are modifying the draft report accordingly. Boeing's responses to Ecology's comments are provided below. Each Ecology comment is listed in italicized font followed by Boeing's response in normal font. After you review our responses, please let us know if you have any final questions and concerns. After we hear back from Ecology, we will prepare the final report for your records.

Ecology Comment 1a

Pages 2-1 and 2-2, section 2.1.1. Boeing identifies VI-based cleanup levels (CULs) and screening levels (SLs) for three compounds: tetrachloroethene (PCE), trichloroethene (TCE), and vinyl chloride. The SLs are media (groundwater and soil gas) and land use (unrestricted, commercial, and industrial) specific, as are the CULs. 8 Please revise the VI approach based on the following comments:

> *As we have discussed previously with Boeing, the protective concentrations associated with commercial indoor air should be identified as SLs, not CULs.*
>
> *SLs for DCEs are not provided. Both trans-1,2-DCE and 1,1-DCE have air CULs. Although these constituents are not consistently detected in the Boeing Auburn Site groundwater, there have been some instances of reported detection in the site database. Please track these data by noting when trans-1,2-DCE and 1,1- DCE are detected, and continuing to include the results in the data reports that are submitted to Ecology.*

[8] Only (indoor) air CULs are identified.

As new water table VOC data are collected, Boeing should be prepared to: a) identify SLs for any additional site-related VOCs detected, and b) evaluate whether those compounds may be potential VI COCs.

Boeing Response to Ecology Comment 1a: Text and Table 2 have been updated to show that commercial vapor intrusion indoor air screening criteria are SLs, not CULs. Boeing acknowledges that there are Model Toxics Control Act (MTCA) Method B indoor air cleanup levels for TCE breakdown products trans-1,2-dichloroethene [trans-1,2-DCE; 27 micrograms per cubic meter (µg/m^3)] and 1,1-dichloroethene (1,1-DCE; 91 µg/m^3). Per the current project draft Quality Assurance Project Plan (QAPP; Landau Associates 2013b), Boeing reports trans-1,2-DCE and 1,1-DCE for all groundwater samples and will continue to do so. The maximum groundwater concentrations of trans-1,2-DCE and 1,1-DCE were 2.4 micrograms per liter (µg/L; ASB0134; February 18, 2004) and 15.6 µg/L (AGW002; June 27, 1994; was located where the Prologis building is now located), respectively. Based on the MTCA Method B indoor air CULs and a standard vapor attenuation factor from groundwater to indoor air of 0.001 (unitless), the MTCA Method B shallow groundwater screening levels protective of indoor air for trans-1,2-DCE and 1,1-DCE would be approximately 69 µg/L and 232 µg/L, respectively; maximum concentrations are well below these groundwater SLs. Therefore, Boeing does not consider trans-1,2-DCE and 1,1-DCE to be vapor intrusion constituents of concern (COCs) at this time and has not incorporated them into the *Revised Draft Vapor Intrusion Evaluation and Assessment Approach* (Landau Associates 2014a).

With regards to potential future vapor intrusion COCs, Boeing will continue to monitor groundwater data for volatile organic compounds (VOCs) and will screen for potential vapor intrusion constituents of concern.

Ecology Comment 1b

It appears that Boeing has chosen to identify the lowest SL or CUL concentration per VOC, instead of providing SLs and CULs based on both carcinogenicity and non-carcinogenicity. Later, in Tables 1, 2, and 3, SLs for both carcinogenicity, non-carcinogenicity, and- for TCE- sub-chronic non-carcinogenicity, should be provided.

Boeing Response to Ecology Comment 1b: Tables 1 through 3 have been updated per Ecology's request to include MTCA-based carcinogenic and non-carcinogenic MTCA values as well as the subchronic TCE air SL from U.S. Environmental Protection Agency (EPA) Region 10 (EPA 2012).

Ecology Comment 1c

Where there is an accessible crawlspace for sampling and the homeowner permits crawlspace and indoor air sampling, Ecology requests that Boeing collect residential crawlspace air samples and indoor air

samples at all homes in the Algona residential area that are selected for VI sampling. This eliminates any additional waiting period for the homeowner for either indoor air or crawlspace sampling, and results in the least amount of opportunity for misinterpretation of the data. Ecology also requests that in the rare instance where VOCs are detected in indoor air, but not in the crawlspace, that Boeing (or Boeing with the assistance of the City of Algona) continues to educate the homeowner and assist them in finding a possible indoor air source. When there are VOCs detected in indoor air but not in the crawlspace, Ecology will require Boeing to be diligent in locating and ruling out all potential sources of vapor intrusion into the home from VOCs in soil gas, groundwater, or surface water (if VOCs are detected above the PCLs in surface water). Ecology may require Boeing to re-sample the crawlspace and/or indoor air in these cases. The document should therefore include crawlspace air SLs (set to the same concentrations as indoor air SLs).

Boeing Response to Ecology Comment 1c: Crawl space air sampling and basement air sampling were incorporated into the *Algona Residential Vapor Intrusion Work Plan* (Landau Associates 2013c). Collection of crawl space and basement air samples as part of Tier II assessments is now discussed more explicitly in Section 2.3.1 of the *Revised Draft Vapor Intrusion Evaluation and Assessment Approach* (Landau Associates 2014a). Additionally, the screening criteria and tables now clearly indicate that indoor air CULs and SLs will be used to evaluate crawl space and basement air samples. In regard to background sources, use of compound-specific isotope analysis (CSIA) has been included as an option for differentiating background indoor air sources from vapor intrusion sources (Section 2.3.2). In the rare instances when detections are found in indoor air but not in the sub-floor air space (whether crawlspace or basement) and CSIA cannot be conducted, Boeing and Landau Associates will work with Ecology to provide additional education to the property owner and attempt to locate a background source.

Ecology Comment 1d

Method C air CULs may certainly be listed in the table, and corresponding groundwater and soil gas concentrations (SLs) can be derived based on those air CULs. But the document should then make clear how these levels will be used and what the consequences are for applying them during screening. For example, Ecology agrees that Method C air CULs may be used to evaluate indoor air data-- and develop soil gas and groundwater SLs -- where the current receptors of concern are industrial workers. But the conclusions of such an evaluation, then, may only apply as long as all receptors of concern for that building or area remain industrial workers.[9]

Similarly, commercial air SLs, and the groundwater and soil gas SLs derived from those air SLs, can be used to assess VI at buildings where the current receptors of concern are "commercial" workers. But the document should then make clear that: a) the conclusions of such an evaluation may only apply as long as all receptors of concern for that building or area remain "commercial" workers, and b) the applicable indoor air CULs for such non-industrial buildings are the Method B, unrestricted-use CULs.

Boeing Response to Ecology Comment 1d: Agreed. The concepts noted in the above comments have been addressed in Section 2.1.1 with detailed footnotes.

[9] Application of Method C as part of the site cleanup action requires imposition of institutional controls.

Ecology Comment 1d continued

(Comment 1d Continued): There are two needs that the RI must fulfill. The first, and most important, is to determine if current receptors may be potentially exposed to unacceptable health risks. Boeing's document properly focuses on this question. But the second objective of the RI is to determine where concentrations of groundwater contaminants exceed the cleanup levels likely to be ultimately applied at the site. If the site cleanup will be designed to attain Method B unrestricted groundwater CULs, those groundwater levels - at least at the water table - must be low enough to protect unrestricted indoor air quality. Knowing where such levels are exceeded, even in "industrial" and "commercial" areas, will be important for completing post-RI phases of the site cleanup.

Boeing Response to Ecology Comment 1d continued: Agreed. The Tier I screening process does look at shallow groundwater site-wide, applying each of the vapor intrusion groundwater screening criteria for the three land uses (residential, commercial, and industrial). Proposed vapor intrusion assessment activities that result from the re-occurring Tier I screening process aim to address the first remedial investigation (RI) objective described above, which is appropriate. The second objective of the RI continues to be evaluated as the RI groundwater monitoring program continues; the re-occurring Tier I screening of site-wide shallow groundwater data will continue to support this second objective of the RI.

Ecology Comment 1e

Later in the document there is more clarity about how each proposed SL and CUL in the table would be used during the assessment, and what would usually follow from either exceeding the SLs/CULs or determining that media concentrations are below their respective SLs/CULs. How these levels will typically be used to trigger a Tier II investigation, for example, seems clear. What is less clear; however, are the criteria that will trigger an action (such as mitigation). Table 5 seems to be the document's primary articulation of how Boeing intends to use Tier II data in its decision-making. The document needs to: a) better establish the criteria that will be used following Tier II to trigger mitigation or other response measures for the building of interest; and, b) discuss these criteria and the basis for their choice in the text.

Boeing Response to Ecology Comment 1e: Agreed. The development and use of SLs, CULs, and indoor air action levels (IAALs) is explained in detail in Section 2.1.1. Section 2.3.3 and Table 7 provide a general outline for Tier II decision making; more specific decision making procedures will be outlined in area-specific work plans.

Ecology Comment 1f

The residential and commercial indoor air CULs/SLs and soil gas and groundwater SLs for TCE are based on the Method B carcinogenic air CUL (0.37 µg/m3). [10] Hopefully, Boeing will not detect indoor air levels of TCE higher than 0.37 µg/m3 in a home, or 1.9 µg/m3 in the workplace. But the potential for such elevated concentrations exists, and as the bullet above notes, the document is not clear about what will trigger mitigation. Boeing's document should consider the possibility that indoor air TCE levels, due

[10] The industrial air CUL is based on the non-carcinogenic Method C air CUL of 2 µg/m3.

to vapor intrusion, will approach or exceed 2 µg/m3 in a home. At this concentration the potential exists for fetal heart malformation if a pregnant woman is exposed for a short period (three weeks; please see the December 13, 2012, EPA Region 10 memorandum discussing "OEA Recommendations Regarding Trichloroethene Toxicity in Human Health Risk Assessments"). [11] *Building occupants and the Department of Health would therefore need to be immediately notified, regardless of other follow-up actions (plans for mitigation, for example, or re-sampling with passive diffusive samplers, CSIA, etc.) Boeing undertook.*

Boeing Response to Ecology Comment 1f: Agreed. Concentration levels that would trigger an interim action such as mitigation were developed for the *Algona Residential Vapor Intrusion Work Plan* (Landau Associates 2013c). A communication plan for the notification process to use if levels were reached or exceeded the concentration levels was negotiated with Boeing, Ecology, and Washington State Department of Health (WDOH) in August 2013 during a conference call and email correspondence. As mentioned in the above comment response, IAALs are discussed in section 2.3.3. Essentially, the values to be used for a particular vapor intrusion assessment would be developed on a work plan to work plan basis, as would the mitigation plan and stakeholder communication strategy.

Ecology Comment 1g

Ecology agrees that the soil gas and groundwater SLs presented in the section 2.2.1 table are based on EPA's most recent attenuation-assumption recommendations (in EPA's Vapor Intrusion Database: Evaluation and Characterization of Attenuation Factors for Chlorinated Volatile Organic Compounds and Residential Buildings; EPA 530-R-10-002; March 16, 2012). However, the document should have additionally provided a listing of those conditions - some of which are likely to be found in the site area - that challenge the conservativeness of these levels. For example,

> *a) the SLs may not be conservative if there are significant preferential pathways linking the indoor air space to the immediate below-building surface or subsurface. Such pathways could include first floor or basement sumps; elevators; or very large cracks or other significant "openings" in the foundation slab, basement, or the first floor of a building constructed with a crawlspace; and*
>
> *b) the proposed groundwater SLs may not be conservative if there is very little (or no) vadose zone, or if there is little-to-no unsaturated zone beneath a basement. These conditions are likely to be present in at least some locations in north Algona.* [12]

Boeing's screening approach will need to account for such conditions. Please see Ecology's recommendations for the Algona site area in our cover letter.

Boeing Response to Ecology Comment 1g: Agreed. Section 2.1.1.1 has been updated to address this comment.

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[11] The corresponding workplace concentration (for both "commercial" and "industrial" scenarios) is 8.4 µg/m3.

[12] EPA's March 2012 database report concludes that "groundwater attenuation factors for residences tend to be smaller (indicating greater attenuation in vapor concentrations during subsurface migration) for deeper groundwater tables than for shallow groundwater tables, which is also consistent with the conceptual model for vapor intrusion."
Although the report generally recommends an assumption of 1 000 times attenuation between groundwater and indoor air concentrations, it also states that the 95th percentile attenuation observed at buildings where the water table was less than 1.5 m was approximately 150.

Ecology Comment 1h

At the end of section 2.1.1 Boeing proposes to use the groundwater SLs "to screen all shallow groundwater (less than 35ft BGS) data..." The document should explain, however, how Boeing has- and will- conservatively estimate site-wide water table VOC concentrations at locations where:

a) there is no nearby monitoring well with a relatively short screen (≤10' if groundwater table elevations fluctuate less than 2 feet seasonally) that intercepts the water table, or

b) a direct push sample has not been collected from a depth interval which intercepts the water table.

Applying the groundwater VI SL to data collected from depths below the water table is only conservative if there is a high degree of confidence that the measured VOC concentrations at depth are representative of (at least as high as) those present at the water table.

Boeing Response to Ecology Comment 1h: Shallow groundwater data collected at the water table and at greater depths in the shallow zone have been compared. Results show that the VOC concentrations are typically greater with depth (Landau Associates 2014b). Therefore, using the shallow groundwater data that is deeper than the water table is a conservative approach to Tier I screening. However, water table data will continue to be used where available. Boeing will continue to conduct Tier I screening as described in the body of this report and will continue to incorporate collection of additional shallow groundwater samples as appropriate. Additionally, water table well designs may include use of screens that are 5 feet (ft) or shorter if water table fluctuation is limited; the *Revised Draft Vapor Intrusion Evaluation and Assessment Approach* (Landau Associates 2014a) does not cover well design. Section 2.2.1 was revised in response to this comment and a second, updated site-wide Tier I shallow groundwater screening evaluation using data through December 2013 is included in Section 3.0.

Ecology Comment 2

Pages 2-2 and 2-3, section 2.1.2. The detection of PCE in soil gas at Building 17-07 suggests a subsurface source and this source may be present above the saturated zone. It is therefore prudent to include PCE as an analyte when conducting the Tier 2 assessment at the 17-70 Building.

Furthermore, as discussed in comments from the City of Algona's environmental consultant (ICF), dated and received by Ecology on February 26, 2013, PCE should remain - at this time - a potential COC for VI assessment. If, as a result of efforts to characterize water table VOC concentrations in Algona, it appears that PCE is not currently present in shallow groundwater, future Algona VI work plans need not include the compound as an analyte.

Likewise, although there is presently no State air cleanup level for cis-1,2-DCE, if detected in shallow groundwater (or soil gas) it should be included as an analyte in future VI work plans.

Boeing Response to Ecology Comment 2: Although PCE was detected in soil gas below Building 17-07 at 19 out of 39 locations sampled the maximum detection of PCE was 220 $\mu g/m^3$, which is significantly less than the approved industrial soil gas SL of 1,300 $\mu g/m^3$. The maximum PCE detection in the most

recent onsite shallow groundwater sampling was 0.81 µg/L, which is significantly less than both the industrial vapor intrusion groundwater SL (100 µg/L) and the most conservative approved vapor intrusion groundwater SL (the residential exposure scenario) of 24 µg/L. In addition to recent PCE data, historical PCE data from 1990 to present were evaluated. The maximum shallow groundwater PCE concentration detected was 2.2 µg/L (onsite well AGW078 on May 21, 2001), which is less than the residential PCE vapor intrusion SL of 24 µg/L. More recent data from this well (2011 through 2013) has ranged from non-detect to 0.7 µg/L. PCE has only been detected once in onsite soil, in a sample collected from beneath Building 17-06 (AGW128 September 12, 2008). The PCE concentration in soil was 2.7 micrograms per kilogram (µg/kg). The data presented here indicates that PCE is unlikely to pose a vapor intrusion risk at the site. Additionally, PCE is a commonly used chemical and, as a result, there is a significant potential for background sources to be present in indoor air. For these reasons, PCE has not been included as a contaminant of concern for vapor intrusion assessments either on or off Boeing property.

The study area for the Algona residential vapor intrusion assessment was delineated using the Tier I groundwater data. No PCE was detected in the Tier I groundwater samples; therefore, as agreed to by Ecology, PCE was not included as an analyte. The Algona residential vapor intrusion assessment is complete. If, based on future groundwater data, additional vapor intrusion assessment is needed in Algona, PCE will not be included as an analyte unless groundwater data available at that time indicates PCE is present in concentrations exceeding groundwater screening levels.

Cis-1,2-dichloroethene (cis-1,2-DCE) will continue to be included in vapor intrusion assessment work and will continue to be reported if detected in groundwater.

Ecology Comment 3

Page 2-4, section 2.2.1. Please see our discussion of shallow groundwater representativeness in the last bullet of Comment #1.

Boeing Response to Ecology Comment 3: Comment reviewed and a response is provided with the last bullet of Comment #1 above.

Ecology Comment 4

Page 2-4, section 2.2.1. Boeing's proposed screening procedure is generally reasonable, but in applying the procedure the company should:

> *also consider the presence of preferential subsurface pathways such as utility corridors. The proposed procedure is based on an assumption that soil gas above the water table is contaminated by the contamination present directly (or nearly directly) below it in groundwater. This may not be a conservative assumption if preferential pathways provide a means for: a) elevated levels of soil gas VOCs to be present in areas above relatively clean shallow*

groundwater, or b) elevated levels of shallow groundwater VOCs to be present in unexpected areas (based on groundwater flow directions);

as noted in ICF's comments, use the 100-foot "rule" with caution and only where reasonably applicable. This means that where utility lines are present, or conditions exist that promote the migration of VOCs in the vapor phase, the area under consideration for vapor intrusion sampling should be expanded, based on that information; and

apply the 4th step flexibly. While it is true that sampling soil gas at depths less than 5' bgs is generally not advised (unless the sample is collected sub-slab), it is also true that applying Boeing's groundwater SLs at locations where the water table approaches ground surface (or a foundation) may be insufficiently conservative. Please see our discussion of attenuation assumptions in the second-to-last bullet of Comment #1.

Boeing Response to Ecology Comment 4: Agreed. Comment noted.

Ecology Comment 5

*Page 2-5, section 2.2.2.2. A minor point perhaps, but the second sentence of this section would be better stated as: "If the data... then there **may be** no need to assess the VI pathway...triggered." Please revise this sentence. Ecology agrees that the soil gas SLs (or PCLs for the residential area of Algona) can be used to focus the building surveys when also taking into consideration all the information gathered in Steps 1-3 of the VI approach. Therefore, while we agree with Boeing that exceeding the SL may result in the need for additional assessment, we also believe that detecting levels below the SLs is likely to, but **may not** necessarily lead to a screen-out decision. For further clarification, please see comments 1, and 4 above.*

Boeing Response to Ecology Comment 5: Understood and sentence revised as requested.

Ecology Comment 6

Pages 2-5 and 2-6, sections 2.2.2.2 and 2.2.2.3. The document proposes to identify buildings in areas where measured soil gas VOC levels exceed SLs. For these buildings Boeing will then either use the JEM to predict indoor air concentrations (from the soil gas data) or initiate Tier II.[13]

Ecology understands the company's reasoning here: the soil gas SLs are sub-slab SLs. However, contaminated soil gas concentrations that Boeing has measured just above the water table may attenuate to a greater degree than the sub-slab concentrations. One way to approximate this amount of extra attenuation is to use the JEM, which can simulate and account for it.

Ecology would prefer, however, that Boeing proceed as follows (when measured soil gas VOC levels exceed sub-slab SLs):

Initiate Tier II (which at slab-on-grade or basement buildings could entail sub-slab sampling prior to indoor air sampling) unless –

[13] As stated in Comment#I above, and as acknowledged in Boeing's document, the water table in the residential area of Algona is generally too high for reliable soil gas sampling. However, attempts to collect soil gas samples can be made if it is viable to do so and is needed to clarify the situation at a particular building. In any case, Ecology does not expect Boeing to utilize the JEM for predicting indoor air concentrations from soil gas or groundwater measurements in Algona. Instead, the information gathered from the building surveys, the utility corridors, and the groundwater characterization data will be used to identify buildings where indoor air sampling is needed.

the vadose zone at that location has features such as a layer of fine-grained soils at a depth above the soil gas sampling location, or other features that suggest the default sub-slab soil gas attenuation factor (0.03) is clearly overly-conservative. In these cases, the JEM can be used to estimate the amount of attenuation expected between the sampling depth and sub-slab. And then,

only use the JEM-generated vadose zone attenuation estimate, not the JEM estimate of indoor air levels. That is, the JEM-generated vadose zone attenuation estimate should be added to the attenuation assumed in developing the sub-slab soil gas SL (0.03). If the additional amount of attenuation is enough to suggest that soil gas concentrations are too low to produce indoor air concentrations at their CULs/SLs, Boeing may propose that the respective building be screened out after considering the results of the information gathered in Steps 1 - 3.

We recommend the steps above, instead of simply using the JEM to predict indoor air levels, for three reasons: (1) in order to use the JEM for the screen-out purposes discussed in this section we will need to access the building to ensure that there are no building or foundation characteristics that would disqualify use of the model. It may be more practical, then, to simply use this visit to collect sub-slab samples; (2) EPA has, over time, relied less on JEM indoor air estimates for screen-out decisions; and, (3) we generally have more confidence in the conservativeness of the 0.03 sub-slab-to-indoor air attenuation assumption than the attenuation value calculated by the JEM.

Boeing Response to Ecology Comment 6: Section 2.2.2.2 and Section 2.2.2.3 have been updated to incorporate Ecology's concerns and requests, and Appendix B has been added to further illustrate a hypothetical use of the Johnson & Ettinger Model (JEM).

Ecology Comment 7

Page 2-6, section 2.2.2.3. In the last paragraph of this section Boeing discusses a scenario where measured soil gas concentrations exceed SLs and the JEM predicts an exceedance of the indoor air CUL/SL. A Tier II evaluation is thereby triggered and indoor air samples are collected "at the highest-risk vapor intrusion exposure sampling location..."

Ecology is unsure what Boeing means by this proposal. We agree that if soil gas SLs are exceeded, a Tier II assessment will typically be needed. And we also agree that it is reasonable to assume that this will entail indoor air sampling (although sub-slab sampling alone could potentially be an option). Selecting the one location in a building that corresponds to the "highest-risk vapor intrusion exposure" can be very difficult, though- especially before any indoor air sampling data have become available. Similarly, selecting the one building from among a group that corresponds to the "highest-risk vapor intrusion exposure" is also difficult, since vulnerability to VI can be so building-specific. Please also see Comments #25 and 26 on Figure 7.

Ecology does not agree that we will typically be able to phase the collection of indoor air · samples as Boeing suggests here. However, if Tier I screening results in north Algona indicate the need for a large number of Tier IIs, it is reasonable to begin Tier IIs at locations where we believe VI impacts are likely to be greatest. Based on the results from this first group of Tier II evaluations, we can then decide how to proceed at those homes where we would expect- based on groundwater concentrations, depth to the water table, foundation/building characteristics, etc. -less impact on indoor air quality.

Boeing Response to Ecology Comment 7: Figure 7 (now Figure 6) has been revised, and addresses comments #25, 26, and 27. Language in Section 2.2.2.3 pertaining to "highest-risk vapor intrusion exposure" has been removed.

Ecology Comment 8

Page 2-6, section 2.2.3. Additional water table data will be collected to "refine the area where groundwater exceeds SLs." Ecology agrees. However,

> *It is unclear to us what the document means when it suggests that the data may be obtained by means other than direct push techniques.*
>
> *Obtaining samples from within 2' of the water table is reasonable; short (≤5') screen lengths should be utilized if fluctuations in the water table elevations will be within the length of the screen.*
>
> *While the draft document is properly focused on VI, it would be improved by acknowledging the absence of water table monitoring wells - even in areas where direct push groundwater sampling will be performed. Ecology assumes that in a number of areas, including areas in northern Algona, there will be a need to install additional wells. Future wells installed for VI assessment purposes should be screened across the water table, with screen lengths as short as possible, preferably ≤5' if fluctuations in the water table elevations will be within the length of the screen.*
>
> *While we agree that collecting additional groundwater data from areas where the depth to the water table is less than 5' bgs is a good idea, Boeing should also consider collecting such data in selected areas where the water table is deeper. Part of the overall VI strategy should include an assessment of whether there are data gaps associated with the characterization of site-wide water table VOC concentrations. Where such gaps exist, proposals should be put forward to address them directly, regardless of the depth to the water table. Please see Comment #1 above.*

Boeing Response to Ecology Comment 8: Drilling techniques other than direct-push (like sonic drilling) also allow for collection of borehole samples as is done for this project regularly; this is explained in Section 2.2.3. Since receipt of this comment letter, new water table well screen designs are constructed in general accordance with this comment; for example, wells being installed during summer 2014. This document is to be used as guidance for conducting vapor intrusion assessments and does not serve to present where groundwater wells need to be installed; see separate groundwater investigation work plans for suggested additional well locations.

Ecology Comment 9

Pages 2-6 and 2-7, section 2.2.3. New direct-push groundwater data will be collected to aid in Tier 1 evaluations. The data are proposed to be used as discussed on page 7. Although Ecology is in general agreement with Boeing's proposals here we note that:

> *The shallow groundwater SLs Boeing has proposed may not be conservative in areas where the water table is very shallow. Please see Comment.#1 above.*

Application of groundwater SLs may lead to a preliminary screen-out decision, but such a decision must consider more than a simple comparison of concentrations. As noted in other comments, there are some conditions- both above and below ground - that, if present, reduce confidence in the SLs' conservativeness.

This section would be improved by including proposals for determining how subsurface and foundation (or other building) features will be factored into the Tier I decision to either screen a building out or proceed to Tier II. It is not apparent to Ecology how Boeing intends to gather the information for making these determinations (since, for example, building surveys only seem to be part of the Tier II evaluation).

It may be appropriate to identify "vacant land" above or near elevated groundwater VOC levels, but it is not clear how Boeing intends to use this information.

Exceedances of Boeing proposed groundwater SLs in these shallow water table areas will often trigger a Tier II assessment, even if additional Tier I data are subsequently collected. It is not clear to us why Boeing uses the word "may" in the third-to-last sentence of the section's last paragraph.

Please see Ecology's cover letter recommendations for assessing VI in Algona. There, among other recommendations, we recommend selecting preliminary concern levels (PCLs) for shallow groundwater in Algona. Although these levels would be used similarly, in some respects, to Boeing's proposed SLs, they would not be used by themselves to make building-by-building "screen-out" determinations.

Neither Boeing nor Ecology know at this time whether a groundwater SL based on an assumption of 1000 times attenuation will be conservative in the shallow water table areas of Algona. It may be, but we will not be confident this is the case until we have collected more information, including indoor air data. Ecology therefore suggests that Boeing initially use a groundwater TCE "preliminary concern level" calculated using 667 times attenuation instead of 1000 for the purposes described in our cover letter. This concentration is close to Boeing's proposed groundwater screening level (intended to protect indoor air to the 1E-6 risk level), but is somewhat lower to, at least marginally, account for minimal vadose zone attenuation.

Boeing Response to Ecology Comment 9: All aspects of this comment specific to residential Algona have been addressed. The concept of potentially needing site-specific Tier I screening is presented in Section 2.1.1.1. Boeing primarily intends to conduct building surveys when a Tier II assessment is planned. Therefore, the general presentation of how to conduct building surveys is presented in Section 2.3.1. Vapor intrusion work plans that are to include building surveys may elaborate on how the building surveys will be conducted and how the data will be used. The word “may” is now replaced with “would.” References to vacant land have been removed and will be dealt with on a case by case basis in individual work plans.

Ecology Comment 10

Page 2-7, section 2.3. Ecology agrees that a visit to the building of concern must precede Tier II indoor air and/or crawlspace sampling. For the residential areas where VI will be assessed, however, there is a need for more than just an evaluation/sampling strategy and identification of building-specific points of contact. Boeing needs to consider how and when the company will provide and solicit VI-related information to/from the affected public. This includes informing the public about the planned assessment,

explaining what its corresponding data needs are and how they will be obtained, and asking for the community's cooperation in helping us successfully complete the assessment. The VI Assessment Approach document would be significantly improved, then, by the inclusion of a public outreach section, describing how Boeing plans to carry out these aspects of the upcoming VI evaluation.

Boeing Response to Ecology Comment 10: This comment was addressed in the *Algona Residential Vapor Intrusion Work Plan* (Landau Associates 2013c) and subsequent planning steps closely negotiated with Ecology in 2013.

Ecology Comment 11

Page 2-8, section 2.3.1. A minor point, but the description of tasks related to gathering "receptor details" (3rd bullet) should not imply that this activity is only relevant for non- residential buildings.

Boeing Response to Ecology Comment 11: The third bullet has been revised to be more generic such that it would include residential buildings.

Ecology Comment 12

Page 2-8, section 2.3.1. Ecology agrees that there may be non-residential buildings that will not require indoor air sampling. And we also agree that Boeing may make such a proposal (not just "document" the conditions) in lieu of submitting a Tier II sampling and analysis plan. But at this time Ecology believes it is unlikely that we would approve such a proposal in the absence of reliably conservative sub-slab soil gas data.

Boeing Response to Ecology Comment 12: Understood. The word "documented" has been replaced with "proposed."

Ecology Comment 13

Page 2-8, section 2.3.1. Boeing is correct: it will not be possible to collect sub-slab soil gas data for some buildings. And in these cases it may be reasonable to assume that only indoor and ambient outdoor air samples will be collected. However, Ecology recommends that crawlspace air samples be collected in addition to indoor air samples for buildings with this type of foundation. The document should therefore identify the SLs that would be applied to crawlspace sampling data. Please see the third bullet of Comment #1 above.

Boeing Response to Ecology Comment 13: The text has been clarified to include crawlspace sampling and basement sampling.

Ecology Comment 14

Page 2-9, section 2.3.2. The Tier II analyte list, per building, should be based on which VOCs are possibly in soil gas beneath the building being evaluated. Once Boeing is confident that TCE and vinyl chloride are the only soil gas VOCs present at detectable levels, Ecology agrees that the indoor air (and

any sub-slab) analyte list for that building may be limited to these two substances. Please see Comments #1 and 2 above.

Boeing Response to Ecology Comment 14: Text has been revised to incorporate this comment.

Ecology Comment 15

Page 2-9, section 2.3.2. A minor point, but at the end of the first paragraph of this section the document should have stated that analytical reporting limits will be well below the VI SLs.

Boeing Response to Ecology Comment 15: Agreed. Changes have been made to reflect this.

Ecology Comment 16

Page 2-9, section 2.3.2. In the second paragraph of this section the document states that indoor detections of TCE and vinyl chloride could be due to a "background indoor air source." Ecology agrees. It is also possible that ambient outdoor air may be contaminated with these compounds, however, and the document should note this. Ecology requests that Boeing include in their ambient air sampling proposal an ambient air sample from within the Chicago Avenue Ditch. The results of this sampling will provide data for Ecology and DOH to use in future evaluation of risk to workers and children in the ditch from TCE and vinyl chloride.

When evaluating VI, ambient air samples are collected at the same time as indoor air samples in an attempt to estimate how much of the indoor air measurement may be attributable to an outdoor source. This is an important estimate to obtain where the same VOCs in soil gas are present in outdoor air. Without a measurement of ambient air, if indoor air levels are elevated we will not know if the elevated indoor levels are due to VI or outdoor air contamination entering the building.

In Algona, however, if indoor air levels are elevated because of outdoor air contamination entering the building, the RI will need to determine if the source of the outdoor air contamination is site-related. That is, even if VI is not the cause of unacceptable indoor levels of TCE and/or vinyl chloride, Boeing must investigate the possibility that outdoor air contamination may be due, or partially due, to contaminated shallow groundwater and/or surface water.

Boeing Response to Ecology Comment 16: Comments specific to residential Algona Tier II data collection were addressed in the *Algona Residential Vapor Intrusion Work Plan* (Landau Associates 2013c). The text has been updated to identify that background sources can also be found in ambient air. A draft *Chicago Avenue Ditch Air and Surface Water Sampling Work Plan* (Landau Associates 2013d) was submitted to Ecology for review on October 16, 2013; and is currently being revised based on comments from Ecology.

Ecology Comment 17

Page 2-9, section 2.3.3. Please see Comment #36 below regarding Table 5.

Boeing Response to Ecology Comment 17: Table 5 has been updated. See response to Comment #36 below.

Ecology Comment 18

Page 3-1, section 3.1.1. Since the February 2013 VI document is devoted exclusively to evaluating VI, the paragraph here would be improved by noting:

> *which site monitoring wells are screened across the water table;*
>
> *the screened intervals of those wells which intercept the water table; and,*
>
> *which site monitoring wells not screened across the water table can be used as reliably conservative surrogates for water table wells.*

Boeing Response to Ecology Comment 18: The above aspects are presented in Section 2.2.1, Figure 4 and Table 6 identify water table wells and Table 6 provides well construction information.

Ecology Comment 19

Pages 3-2 through 3-4, section 3.2. This section of the document discusses Tier I screening for three land use scenarios. This is a valuable discussion and Ecology agrees with many of statements on the three pages. However, to determine how much confidence we should place in the screening results, we must acknowledge the uncertainty inherent in applying the screening process <u>now</u>. As noted above, at the present time there appears to be at least four sources of significant uncertainty:

> *a) groundwater VOC concentrations at the water table at locations that have not been sampled, or have not been sampled recently;*
>
> *b) knowledge about the buildings themselves. There is a possibility that certain building-specific features will facilitate gas-phase VOC transport indoors with less attenuation than the SLs assume;*
>
> *c) knowledge about subsurface utility corridors or other potentially preferential pathways for groundwater or soil gas VOC transport. There is a possibility, for example, that buildings located above shallow groundwater which we believe has low levels of TCE and vinyl chloride actually have elevated soil gas concentrations beneath them; and,*
>
> *d) the conservativeness of the SLs being applied. The groundwater SLs may not be conservative if they are applied in areas with very shallow water tables.*

The document's Tier I screening results will therefore need to be revisited. First, reasonable modifications to the assessment approach should be made to account for the obvious sources of uncertainty. Later on, after additional subsurface and building- specific information has been gathered, the screening results should be revisited again. The objective in both cases should be to reduce the degree of uncertainty and better ensure protectiveness.

Boeing Response to Ecology Comment 19: The above concerns related to level of conservativeness have been addressed throughout Section 2.0, the true guidance portion of this document that the project will lean on when developing area-specific vapor intrusion work plans. The subject section of this comment (Section 3.0) provides a high-level Tier I screening based on data we have available right now and directs the project to produce the area-specific work plans. For example, this document identifies the general area where commercial Tier I data is still needed in what's termed "Commercial Auburn North",

and it is expected that acquisition of utility plans and other details related to preferential pathways will be collected when preparing the proposed data collection site plan.

Ecology Comment 20

Pages 3-4 and 3-5, section 3.3. Multiple indoor air sampling stations have been selected and approved by Ecology for the 17-07 Building, and re-sampling is taking place the week of April 8, 2013.

Please also see our comments regarding PCE and Table 5 (Comments #2 and 35).

Boeing Response to Ecology Comment 20: Comment noted. Boeing completed Building 17-07 confirmation indoor air sampling in April 2013 (as noted by Ecology), and results were presented in *Status Report No. 43* (Landau Associates 2013e). The reported analytes included PCE, TCE, cis-1,2-DCE, and vinyl chloride (VC), which are the some analytes that were previously reported during 2012 air sampling. The vapor intrusion assessment for Building 17-07 is considered complete.

Ecology Comment 21

Page 3-5, section 3.3. Ecology agrees that Tier II sampling decisions in north Algona should be informed by the results of the proposed direct-push sampling. However, obtaining information about the buildings in north Algona need not be delayed. Boeing should immediately begin collecting needed building-specific information in this area.

Boeing Response to Ecology Comment 21: This comment is dated. The northern Algona residential vapor intrusion assessment has been completed.

Ecology Comment 22

Figures 4, 13, 14, and 15. Note: the value of such figures is dependent on how well sampling results obtained from below the water table conservatively represent current water table VOC concentrations.

Boeing Response to Ecology Comment 22: Comment noted.

Ecology Comment 23

Figures 6 and 8. Question: how does "no existing building" differ from "vacant property"?

Boeing Response to Ecology Comment 23: Former figures 6 and 8 (now figures 5 and 7) have been updated to more clearly address vapor intrusion assessment off ramps.

Ecology Comment 24

Figures 6, 7, and 8. As noted in comments above, there are certain building/foundation features that, if present, can cause questions to arise about the conservativeness of the proposed subsurface screening levels. The figures do not state how Boeing will determine if the buildings above the plume have any of

these features. A large number of building visits, especially in north Algona, are likely to be needed to obtain this information.

Boeing Response to Ecology Comment 24: A brief note has been added to former Figures 6 and 8 (now Figures 5 and 7). Former Figure 7 (now Figure 6) has been revised, as addressed below under comment #25.

Ecology Comment 25

Figure 7. The flowchart states that if the JEM predicts exceedances of the indoor air CULs/SLs, a Tier II will be initiated "at buildings representative of the highest-risk VI scenario." This seems to suggest that Tier II will not be initiated at each building where the JEM and soil gas results suggest potentially unacceptable indoor air impacts. If so, Ecology disagrees. In these cases Tier II should routinely be the next step. Ecology is not confident that we can identify a single building (among those in this category), which is clearly representative of the "highest-risk VI scenario."

Boeing Response to Ecology Comment 25: Comment noted. Simplified figure and removed reference to "highest-risk vapor intrusion scenario."

Ecology Comment 26

Figure 7. The flowchart states that if indoor air VOC concentrations are below the CULs/SLs, the assessment is complete "for all previously-identified buildings of concern." It is unclear what this means. Ecology is not confident that measuring acceptably low indoor levels at a single building will assure us that levels are also acceptably low at other "previously identified" buildings.

Boeing Response to Ecology Comment 26: Comment noted. Simplified figure and removed reference to "for all previously-identified buildings of concern."

Ecology Comment 27

Figure 7. The flowchart states that if indoor air VOC concentrations are found to be above the CULs/SLs, Boeing will initiate additional Tier II assessment activities, and that that additional buildings may then be evaluated. Ecology agrees that if indoor air VOC concentrations exceed CULs/SLs, more Tier II work may be needed. However,

moving directly to mitigation is also an option,

the follow-up work will need to be conducted quickly, and

as noted above, it is not clear how the indoor sampling results from one building can be used to make decisions about others. But if Boeing simply means that finding unacceptably high concentrations in a building - when this was not expected - may lead to enhanced concerns about the indoor air quality in nearby buildings, we agree that this is a reasonably conservative approach to take.

Boeing Response to Ecology Comment 27: Comment noted. Simplified figure to end earlier and defer to Table 5 more readily. The need for additional vapor intrusion assessments at additional buildings is an implied potential outcome and does not need to be a part of this figure.

Ecology Comment 28

Figure 8. The flowchart states that if shallow groundwater concentrations are below the proposed SLs, there is no need for further VI assessment of buildings in the immediate area. Ecology disagrees that the proposed groundwater SLs can be used by themselves to reach such a conclusion. Please see our comments above and in the cover letter.

Boeing Response to Ecology Comment 28: Comment noted. Revised language in figure to indicate that site-specific shallow groundwater screening levels may be necessary for areas with unique conditions requiring more conservative assumptions, and that development of such SLs would be completed in the associated vapor intrusion work plan(s).

Ecology Comment 29

Figure 12. As the VI assessment proceeds, mapping of the depths (bgs) <u>to the water table</u> in areas such as north Algona could provide beneficial information for both VI evaluations and the assessment of other exposure pathways in parts of the site where the water table is at very shallow depths.

Boeing Response to Ecology Comment 29: Agreed. An Algona-specific depth to water (DTW) figure was included in the direct-push results tech memo (Landau Associates 2013f).

Ecology Comment 30

Figure 14. The figure would be improved by contouring concentrations associated with the residential (0.35 ug/1) and commercial (1 ug/1) groundwater SLs for vinyl chloride.

Boeing Response to Ecology Comment 30: Comment noted. We provide the residential and commercial land use scenario specific VC contour figures later in the document (current figures 13 and 16, respectively).

Ecology Comment 31

Figures 15 through 19. A minor point, but the titles and notes to these figures could be improved by making clear that the data shown are not only from monitoring wells (in the titles), and that highlighted SL exceedances are only shown for locations with a corresponding current land use. For example, exceedances of the residential SL are only shown in areas where the current land use is residential.

Boeing Response to Ecology Comment 31: Figure titles have been clarified.

Ecology Comment 32

Figures 17 and 20. While it is helpful to have such figures, Ecology has not concluded that the depicted data gaps are the only outstanding data gaps. Please see Comment #1 and other comments above concerning our present understanding of VOC concentrations at the water table.

In addition, ICF has noted that Figure 17's "data gap area" only extends as far south as 8th Ave. in Algona. Ecology realizes that the Boeing figure was developed prior to obtaining new direct push groundwater data from Algona and assumptions had to be made about the possible western and southern extent of shallow groundwater contamination. Once the new direct push groundwater data become available, however, the figure should be re-visited and modified as needed.

Boeing Response to Ecology Comment 32: Comments noted and effectively addressed in the *Algona Residential Vapor Intrusion Work Plan* (Landau Associates 2013c). All groundwater screening figures in this document have been updated to include all new shallow groundwater TCE and VC results from wells and borehole samples.

Ecology Comment 33

Figures 21 and 22 (and 23). It is Ecology's understanding that all the buildings located in the Industrial Land Use Area, depicted on Figure 3, are owned by Boeing. However, Ecology does not agree with Boeing that Building 17-70 meets MTCA's 'industrial' use definition:

"Industrial properties" means properties that are or have been characterized by, or are to be committed to, traditional industrial uses such as processing or manufacturing of materials, marine terminal and transportation areas and facilities, fabrication, assembly, treatment, or distribution of manufactured products, or storage of bulk materials, that are either:

> *Zoned for industrial use by a city or county conducting land use planning under chapter 36.70A RCW (Growth Management Act); or*
>
> *For counties not planning under chapter 36.70A RCW (Growth Management Act) and the cities within them, zoned for industrial use and adjacent to properties currently used or designated for industrial purposes.*

Ecology believes that Building 17-70 is a commercial office building. Therefore, please apply the CULs and SLs developed for Commercial Buildings when Boeing and Landau Associates write the work plan for evaluating vapor intrusion at Building 17-70.

Boeing Response to Ecology Comment 33: Comment noted. Former Figure 3 (now Figure 2) updated to show that Building 17-70 is a commercial office building. Section 3.2.3 updated to indicate that data from Building 17-70 will be screened using commercial screening criteria rather than industrial. Note added to figure explaining that some buildings within the industrial area may be for commercial use.

Ecology Comment 34

Tables 1, 2, and 3. As noted in Comment #I, the document would be improved by having both the carcinogenic and non-carcinogenic SLs, per VOC, listed. In addition,

the sub-chronic TCE indoor air screening levels suggested by EPA Region 10 should be added (for both residential and workplace receptors); and,

the document should note how the assessment will determine the total inhalation risk and HI posed by VI. Since Method C is being used for certain SLs and since multiple VOCs may be present in groundwater, soil gas, and indoor air, the document should describe how the proposed approach will ensure that VI decisions are not based solely on contaminant-by-contaminant exceedances of SLs/CULs.

Boeing Response to Ecology Comment 34: Tables 1 through 3 have been revised. Total inhalation risk (i.e., cumulative potential cancer risk) and cumulative non-cancer hazard index are now discussed in Section 2.1.1.3.

Ecology Comment 35

Table 5. This table appears to contain the document's only "discussion" of mitigation triggers. Ecology agrees that when both sub-slab and indoor air data are available for a building, it is wise to consider both when deciding what the next (post-sampling) assessment or response steps should be. And using a matrix such as Table 5 is a way of showing how both sets of information can be used.

However, we have a number of concerns with the summarized "next steps" Boeing has proposed in the table. Our comments follow:

We suggest that there be two table 5s --one for TCE and one for the other VOCs of concern. Our reasons will become apparent in the following bullets.

The last column of the table should be titled "action levels" or something similar that conveys the meaning that these are air concentrations (or risks/hazards) that will typically trigger an action. For the three VOCs Boeing has listed we recommend:

a) two action levels for TCE, one for chronic exposures (based on an HQ of 1) and one for sub-chronic exposures (the 2 and 8.4 ug/m3 EPA Region 10 concentrations discussed in comments above)
b) a 1E-5 combined risk action level for all detected carcinogens
c) an HI combined hazard action level for all detected non-carcinogens

So, for example, if TCE were the only compound detected in indoor air, its primary action level would be 0.9 ug/m3 (the HQ = 1 concentration). However, if the detected level of TCE exceeded this level and also exceeded or approached 2 ug/m3, additional actions would be triggered (immediate notification; re-sampling with passive diffusion samplers PDSs; etc.).

We agree that if sub-slab soil gas VOC concentrations are below their respective SLs, but indoor air concentrations are above action levels, it is possible that indoor air quality is being affected by an indoor source. Rather than immediately mitigate, it may be prudent to first collect additional information about potential indoor VOC emitters. We may also need to collect additional sub-slab soil gas data. These non- (or pre-) mitigation follow-up actions will need to occur quickly, however, especially in cases where the indoor air action levels are significantly exceeded <u>and</u> no obvious or likely indoor source is apparent.

It is reasonable to use an indoor air <u>action</u> level, not the 1E-6 indoor air <u>SL</u>, as the mitigation trigger. However, if indoor air concentrations exceed their 1E-6 indoor air SLs, but not the action level, it is also reasonable to:

a) re-sample indoor air, [14] and
b) consider mitigation if sub-slab VOC concentrations significantly exceed their SLs.

Boeing Response to Ecology Comment 35: Boeing understands Ecology's comments and has addressed them in the most effective manner for the purposes of future use of this document. First, Boeing has incorporated the IAALs concept into Tables 1 through 3 and in the report text. Secondly, Table 5 has been updated to 1) clarify when mitigation should be considered, is recommended, or shall happen; 2) be useful for scenarios where carcinogenic or non-carcinogenic screening criteria apply; and, 3) include the concept of IAALs. Incorporating actual IAAL values and specific chemicals into Table 5 is not practicable, but the table has been updated to cross reference the need for the practitioner to use Tables 1 through 3, the approach document, and any work plan under which they are operating. Decision making steps will also be incorporated into area-specific work plans. Also, Boeing acknowledges footnote #14 associated with this comment, but points out that it appears to pertain specifically to northern residential Algona, and therefore, it has been addressed in the *Algona Residential Vapor Intrusion Work Plan* (Landau Associates 2013c).

Sincerely,
LANDAU ASSOCIATES, INC.

Jennifer W. Wynkoop
Senior Associate

JWW/jrc

cc: James Bet, The Boeing Company

REFERENCES

EPA. 2012. Memorandum: *OEA Recommendations Regarding Trichloroethylene Toxicity in Human Health Risk Assessments.* From Joyce C. Kelly, Office of Environmental Assessment, U.S. Environmental Protection Agency, to Rick Albright, Office of Environmental Cleanup, U.S. Environmental Protection Agency. December 13.

[14] The document does not appear to propose how many indoor air sampling events should typically be conducted during a Tier II assessment. Since the first sampling is unlikely to occur until the late spring of 2013, it is reasonable at this time to assume that two sampling events will be needed for "screen-out" decisions.

Landau Associates. 2014a. *2nd Revised Agency Review Draft Vapor Intrusion Evaluation and Assessment Approach, Boeing Auburn Facility, Auburn, Washington*. Prepared for The Boeing Company (in preparation).

Landau Associates. 2014b. Agency Review Draft Report: *Supplemental Remedial Investigation, Data Summary Report Fall 2012 to Fall 2013, Boeing Auburn Facility, Auburn, Washington.* Prepared for The Boeing Company. June 27.

Landau Associates. 2013a. Agency Review Draft Report: *Vapor Intrusion Evaluation and Assessment Approach, Boeing Auburn Facility, Auburn, Washington*. Prepared for The Boeing Company. February 20.

Landau Associates. 2013b. Draft Report: *Quality Assurance Project Plan, Remedial Investigation, Boeing Auburn Facility, Auburn, Washington*. Prepared for the Boeing Company. May 9.

Landau Associates. 2013c. Report: *Work Plan, Algona Residential Neighborhood Vapor Intrusion Assessment, Boeing Auburn Facility, Auburn, Washington*. Prepared for The Boeing Company. June 13.

Landau Associates. 2013d. Agency Review Draft Report: *Chicago Avenue Ditch Air and Surface Water Sampling Work Plan*. Prepared for The Boeing Company. October 16.

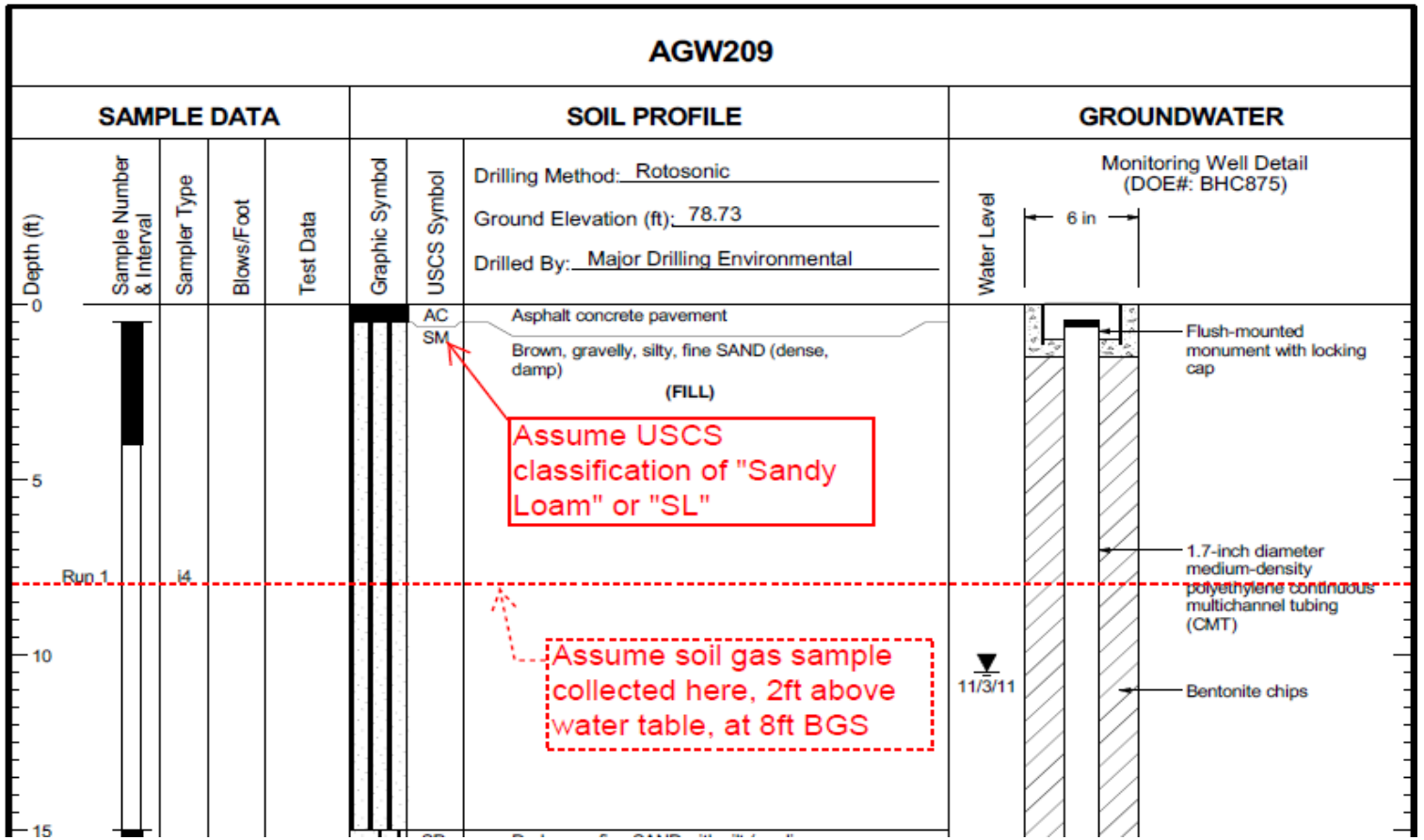
Landau Associates. 2013e. Letter Report: *Status Report No. 43, April Through June 2013 Activity Period, Boeing Auburn Facility, WAD041337130, RCRA Corrective Action Agreed Order, No. 01HWTRNR-3345*. July 15.

Landau Associates. 2013f. Agency Review Draft Report: *Work Plan, Direct-Push Probe Investigation, Winter 2013, Boeing Auburn Facility, Auburn, Washington*. Prepared for The Boeing Company. February 18.

APPENDIX B

Example Commercial Vapor Intrusion Soil Gas Screening Using John & Ettinger Model (JEM) SG-ADV

TABLE B-1
SITE-SPECIFIC DATA FOR USE IN EXAMPLE JOHNSON ETTINGER MODEL SG-ADV RUN
VAPOR INTRUSION ASSESSMENT
BOEING AUBURN



Note: Groundwater monitoring well AGW209 is located in a commercial area of Auburn, Washington where relatively elevated shallow groundwater concentration of chlorinated solvents have been detected.

TABLE B-2
JOHNSON ETTINGER MODEL SG-ADV RUN DATA ENTRY SCREEN
VAPOR INTRUSION ASSESSMENT
BOEING AUBURN

SG-ADV Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g ($\mu g/m^3$)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical
79016	1.00E+01			Trichloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (^oC)	ENTER Totals must add up to value of Ls (cell F24) Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
200	243.84	10	243.84	0	0	SL		

MORE ↓

ENTER Stratum A SCS soil type (Lookup Soil Parameters)	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type (Lookup Soil Parameters)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type (Lookup Soil Parameters)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
SI	1.35	0.489	0.167	LS	1.62	0.39	0.076				

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm\text{-}s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1000	1000	366	0.1	0.25	5

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
70	30	30	350

END

TABLE B-3
JOHNSON ETTINGER MODEL SG-ADV INTERMEDIATE CALCULATIONS SHEET
VAPOR INTRUSION ASSESSMENT
BOEING AUBURN

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. ($\mu g/m^3$)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	43.84	0.322	0.314	ERROR	0.284	5.93E-09	0.837	4.96E-09	4,000	1.00E+01	2.54E+04

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)
1.80E+06	2.22E-04	200	8,557	4.78E-03	2.06E-01	1.75E-04	7.59E-03	0.00E+00	0.00E+00	7.59E-03	43.84

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
200	1.00E+01	0.10	8.33E+01	7.59E-03	4.00E+02	1.66E+119	2.59E-03	2.59E-02	1.1E-04	4.0E-02

END

TABLE B-4
JOHNSON ETTINGER MODEL SG-ADV FORUMLA FOR
INFINITE SOURCE INDOOR AIR ATTENUATION COEFFICIENT (ALPHA)
VAPOR INTRUSION ASSESSMENT
BOEING AUBURN

$$\alpha = \frac{\left[\left(\frac{D_T^{eff} A_B}{Q_{building} L_T}\right) x \exp\left(\frac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right)\right]}{\left[\exp\left(\frac{Q_{soil} L_{crack}}{D_{crack} A_{crack}}\right) + \left(\frac{D_T^{eff} A_B}{Q_{building} L_T}\right) + \left(\frac{D_T^{eff} A_B}{Q_{soil} L_T}\right)\left[\exp\left(\frac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right) - 1\right]\right]} \quad (13)$$

where

α	= Steady-state attenuation coefficient, unitless
D_T^{eff}	= Total overall effective diffusion coefficient, cm^2/s
A_B	= Area of the enclosed space below grade, cm^2
$Q_{building}$	= Building ventilation rate, cm^3/s
L_T	= Source-building separation, cm
Q_{soil}	= Volumetric flow rate of soil gas into the enclosed space, cm^3/s
L_{crack}	= Enclosed space foundation or slab thickness, cm
A_{crack}	= Area of total cracks, cm^2
D_{crack}	= Effective diffusion coefficient through the cracks, cm^2/s (assumed equivalent to D_i^{eff} of soil layer i in contact with the floor).

TABLE B-5
COMMERCIAL INDOOR AIR CONCENTRATION PREDICTION USING JOHNSON ETTINGER MODEL SG-ADV INPUT
VAPOR INTRUSION ASSESSMENT
BOEING AUBURN

Given:

Kidney Cancer	$CPF_{TCE,i}$(kg-day/mg)	=	0.0035	Converted CPF_i from current EPA IUR.
Non-Hodgkin's Lymphoma (NHL)	$CPF_{TCE,i}$(kg-day/mg)	=	0.007	Converted CPF_i from current EPA IUR.
Liver Cancer	$CPF_{TCE,i}$(kg-day/mg)	=	0.0035	Converted CPF_i from current EPA IUR.
	H_{cc} @ 13° Celsius (C)	=	0.238	***Henry's Law Constant (H_{cc}) from EPA On-line Tools for Site Assessment***

Constants from MTCA Equation 750-2, for Carcinogens with reduced RISK per WAC 173-340-750 (4)(b)(ii)(B)

RISK	=	1.E-06	Acceptable cancer risk level
ABW (kg)	=	70	Average body weight over exposure duration
AT (yr)	=	75	Averaging time
UCF (µg/mg)	=	1000	Unit conversion factor
CPF	=	Carcinogenic potency factor per WAC 173-340-708(8) (kg-day/mg)	
BR (m^3/day)	=	20	Breathing/inhalation rate
ABS (unitless)	=	1	Inhalation absorption fraction
ED (yr)	=	30	Exposure duration
EF (unitless)	=	0.33	Exposure frequency

Find: (a) Total CPF_i, (b) Indoor Air Screening Level (SL_{IA}), (c) combined vapor attenuation factor (VAF) from literature and JEM, (d) minimum soil gas concentration that may cause an indoor air (IA) concentration to be equal to the SLIA

Equations:

(1)	Total CPF_i (for 3 cancers) = (kg-day/mg)	Final Kidney Cancer CPF_i + NHL CPF_i + Liver Cancer CPF_i	
(2)	SL_{IA} (µg/m^3)=	$\frac{\text{RISK x ABW x AT x UCF}}{\text{CPF x BR x ABS x ED x EF}}$	***MTCA Equation 750-2***
(3)	Combined VAF for SG & SSV=	SG VAF+SSV VAF	***Eqn. EPA JEM SG-ADV Derived SG VAF (alpha; see Table X-3 and X-4) + Std SSV VAF*** See enclosed JEM model information for how VAF was calculated. The standard sub-slab soil gas screening level is based on a Vapor Attenuation Factor (VAF) of 0.03, per EPA's updated database (EPA's Vapor Intrusion Database: *Evaluation and Characterization of Attenuation Factors for Chlorinated Volatile Organic Compounds and Residential Buildings; EPA 530-R-10-002. March 16, 2012) and communications with Ecology.*
(4)	Iterated value for soil gas to cause IA concentration equal to SL_{IA} (µg/m3)		Calculated by iteratively in Excel
(5)	Calc'd IA concentration equal to SL_{IA} (µg/m3)=	SG concentration x Calc'd VAF	***Reciprocal of Eqn 2. Generic soil gas VI SLs from Ecology's Draft Vapor Intrusion Guidance Document using calc'd VAF (eqn 3 above)***

Solve:

(a)	Total CPF_i (kg-day/mg) =	**0.014**	
(b)	SL_{IA} (µg/m3)=	**1.9**	
(c)	Calc'd Combined VAF	**0.033**	
(d)	Theoretical soil gas concentration (µg/m3)=	**58**	Concentration assumed to occur at 8 ft BGS. Depth represents sample collected 2 ft above the groundwater table using the depth to water at time of drilling from boring log AGW209
(e)	Calc'd IA	**1.9**	In this case, soil gas concentration suggests that the potential IA concentration would exceed the actual SLIA