STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
Northwest Regional Office • 3190 160th Ave SE • Bellevue, WA 98008-5452 • 425-649-7000
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July 12, 2013

Mr. James Bet
The Boeing Company
EHS Remediation Group
PO Box 3707 Mail code 9U4-26
Seattle, WA 98124-2207

Re: Ecology Contingent Approval Algona Residential Neighborhood Vapor Intrusion Assessment Work Plan, dated June 13, 2013 - WAD 041337130, State FS ID: 2018

Dear Mr. Bet:

Thank you for submitting the draft revised Algona Residential Neighborhood Vapor Intrusion Assessment Work Plan (Work Plan), per the requirements of the Boeing-Auburn Agreed Order, (DE 01HWTRNR-3345 AO) and the Ecology May 22, 2013 comment letter.

The revised Work Plan is an improved document and Ecology thanks Boeing for incorporating many of Ecology's written comments. However, the document can be improved and Ecology has a number of revisions in Enclosure A. Many of our remarks relate to clarifying Ecology's expectations for Work Plan revision and/or the upcoming assessment. Ecology also received comments from the Washington State Department of Health (WDOH) and the City of Algona's consultant, ICF International (ICF). A number of WDOH's and ICF's comments have also been integrated into our enclosed required revisions. ICF's full set of comments is provided in Enclosure B.

Under the contingent approval, Ecology does not request nor is Boeing required to resubmit another revised Work Plan. Instead, the Ecology approved Work Plan consists of the following documents: June 13, 2013 revised VI work plan and this Ecology letter. The contingent approval process is the fastest and most cost efficient manner leading to an approved VI work plan that Boeing can implement quickly. Please implement this approved VI work plan.

Later, following this contingent approval of the Work Plan, Boeing will submit the building-specific sampling plans for Ecology review and approval. These building-specific sampling plans are incorporated by reference to the Work Plan.

If you have questions about today's letter or would like to schedule a conference call or meeting to discuss this letter, please contact me at (425) 649-7232 or by email at: robin.harrover@ecy.wa.gov

Sincerely,

Robin Harrover

Robin Harrover, LHG
Hydrogeologist
Hazardous Waste and Toxics Reduction Program

Enclosures
By certified mail: 7012 3460 0000 3272 0641

cc: Mayor David E. Hill, City of Algona
Gary Clendenin, ICF
Barbara Trejo, WDOH
Rhonda Kaetzel, Seattle-King County Health
Ken Lederman, Foster Pepper PLLC
Stephanie Weir, Foster Pepper PLLC
Dennis Johnson, Ed Jones, Dean Yasuda Ecology-NWRO
Dori Jaffe, Ecology AAG

ENCLOSURE A

**Revisions Required for Department of Ecology Contingent Approval:
Algona Residential Neighborhood Vapor Intrusion Assessment Work Plan for the Boeing Auburn site**

General:

1. In the future, it is important that deliverables to Ecology are submitted by Boeing and not the environmental consultant. Aside from the fact that the Agreed Order is between Ecology and Boeing only, it is important for Ecology have a clear understanding that the Landau document was reviewed and approved by Boeing, prior to submittal to Ecology. Ecology wants to be sure the deliverables received are "final ready for submittal", prior to investing Ecology review and comment time. This requirement is not meant to be a burdensome one, and Boeing may meet this requirement simply by having the Boeing Auburn project manager email the deliverable to Ecology with a short explanation of the nature of the attached deliverable, or Landau may mail the deliverable with a signed Boeing cover letter.

Specific: Referenced pages and sections are from the revisions incorporated into the revised Work Plan dated June 13, 2013.

2. Page 1-1, Section 1.0 Introduction: The Boeing Company refers to the terms "site" for the Boeing Auburn property and "offsite" for property outside of the Boeing Auburn property. As clarification, the term "site" as defined under the Model Toxics Control Act (RCW 70.105D) means any location where Boeing Auburn has caused contamination to come to be located. Therefore, a more appropriate set of terms for this revised work plan would be, "on Boeing Auburn property" and "off Boeing Auburn" property.

3. Page 1-2, Section 1.0 Introduction, First Paragraph, Last Sentence: Ecology understands that this last statement means that any vapor intrusion mitigation required at any home in Algona, will not be considered completion of the cleanup at the "site".

4. Page 2-1, Section 2.1 Algona Residential Screening Criteria, Last Paragraph, Third Sentence: Ecology agrees that confirmation sampling in the Winter shall be conducted at each of the Algona homes where vapor intrusion (VI) sampling is conducted in the Summer and mitigation is not required based on the Summer VI data. However, multiple lines of evidence (MLE)[1] including the Winter indoor air sample data shall be used to evaluate the vapor intrusion pathway and if further VI sampling is required.

5. Page 2-2, Section 2.1.1 Shallow Water Table Groundwater Preliminary Concern Levels, Third Paragraph, Last Sentence: Boeing correctly states that cis-1,2-DCE was detected

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[1] Includes at a minimum, sub-slab vapor and crawl space sampling data, if collected, all shallow groundwater data collected as of that time.

in the shallow groundwater samples collected in northern Algona. However, even though there are no current MTCA indoor air cleanup levels for cis-1,2-DCE, future toxicological research may result in the development of an indoor air cleanup level for this compound. Furthermore, the Washington State Department of Health (DOH) will include cis-1,2-DCE in any future health assessments. Therefore, Ecology does not approve the last part of this statement and the part of footnote 7 (and footnote 17) that reads, "…….and is not a vapor intrusion constituent of concern."

6. Page 2-2, Section 2.1.1 Shallow Water Table Groundwater Preliminary Concern Levels: Ecology's specific comment #2[2] from its May 22, 2013 response letter (regarding acetone) was not adequately addressed in the revised work plan as required in the Ecology response letter dated May 22, 2013. The Landau response letter did not but, should have stated that the acetone detections (6.2 – 13 µg/L) were from three shallow groundwater samples outside of the footprint where vapor intrusion sampling will occur this Summer. The previous Ecology specific comment #2 stated *that currently there is no MTCA Method B air cleanup level for acetone.*

7. Page 2-3, Section 2.1.1 Indoor Air Action Levels, First Paragraph, Fourth Sentence: Short term exposures of TCE-contaminated indoor air are established for current and future female women of child bearing age occupying the sampled home. Boeing shall verify if, short term exposure screening levels (2.0 µg/m^3 TCE) in indoor air are exceeded during indoor air sampling this Summer, in the following Winter, and any other subsequent sampling event, women of child bearing age inhabit the sampled home.

8. Figure 2: Within 7 calendar days of your receipt of this letter, Boeing shall submit a revised Figure 2 which includes the TCE/VC shallow groundwater preliminary concentration of concern (PCL) contour used to select the northern Algona homes for VI sampling this Summer.

9. Additional Figure: Per Ecology's Response Letter dated May 22, 2013, specific comment #35, Boeing shall submit an additional figure that shows all shallow groundwater volatile organic compounds detected (above the MDL). Boeing shall submit this additional figure within 7 calendar days of receipt of this contingent approval letter. The additional figure shall be incorporated by reference into the contingent approved Work Plan.

10. Page 2-5, Section 2.3.1 Tier II Assessment Sample Types, Paragraph 1: The text states that all air samples, associated with a particular resident, shall be collected on the same day. For homes where only crawl space or SSV[3], and indoor air samples are collected, this is Ecology's expectation. Boeing/Landau should schedule home sampling visits so

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[2] The Landau response letter dated June 13, 2013 stated that the methylene chloride detection was actually from an equipment rinsate blank and not from any groundwater sample.
[3] Refer to Section 3.1.1.1 for the sequencing of indoor air and SSV sampling in any home.

that this expectation is met. If there are insurmountable reasons that this expectation cannot be met, then Boeing shall notify Ecology before sampling in this home is conducted.

11. Page 2-5, Section 2.3.1 Tier II Assessment Sample Types, Paragraph 2, Fourth Sentence: The statement should read that crawl space samples are less likely to be contaminated by indoor chemicals. Boeing used the term "background chemicals" and Ecology is not sure of the meaning of this term.

12. Page 2-5, Section 2.3.1 Tier II Assessment Sample Types, Paragraph 2, Sixth Sentence: Ambient air samples shall be collected directly upwind of the sampled home and contemporaneous with indoor air samples of that same home.

13. Page 2-5, Section 2.3.1 Tier II Assessment Sample Types, Paragraph 3, Last Sentence: The statement should read, "*....inadequate soil gas zone above the capillary fringe.*" Ecology does not want Boeing to attempt to sample soil gas from within the capillary fringe.

14. Page 2-7, Section 2.3.2.2 Requesting Permission to Conduct Tier II Assessment, Paragraph 1, First Sentence: This statement references section 2.3.2.3 in the revised Work Plan. However, no such section exists. This referenced section is not required in order to implement the Work Plan and is therefore deleted, by reference. Most of the description on requesting owner/tenant permission is included in Section 2.3.2.2.

15. Page 2-8, Section 2.3.2.2 Requesting Permission to Conduct Tier II Assessment, Paragraph 3, Fifth Sentence: Ecology expects that temporal removal of indoor sources shall occur at least 48-hours prior to indoor air sampling.

16. Page 2-8, Section 2.3.3 Sample Location Evaluation: This statement references section 2.2.3.2 in the revised Work Plan. However, no such section exists. This referenced section is not required in order to implement the Work Plan and is therefore deleted, by reference. Boeing perhaps meant to reference Section 2.3.2.2 "Requesting Permission to Conduct Tier II Assessment."

17. Page 2-9, Section 2.3.3.1 Preliminary Conceptual Model of Algona Neighborhood, Paragraph 2, Last Bullet: Same as Ecology specific comment #13.

18. Page 2-10, Section 2.3.3.2 Building Survey and Building Specific Conceptual Model, Paragraph 2, Last Bullet: The text states that the owner will be asked permission if photographs maybe taken during the VI home visit. However, in many cases the tenant alone, not the owner, will be present and asked for permission to take photographs.

19. Page 2-10, Section 2.3.3.2 Building Survey and Building Specific Conceptual Model, Paragraph 3, Third Sentence: Ecology expects that the number of photographs taken during the VI home visit shall be minimized. However, Ecology expects not only potential sub-slab locations to be photographed (as described in the revised Work Plan), but also photographs of indoor chemical labels, and potential crawl space sample locations to be taken to assist in the preparation of each home specific Work Plan addendum.

20. Page 3-2, Section 3.1.1.1 Sub-slab Soil Gas Sampling, Paragraph 1: Installation of the Vapor Pin, sub-slab sampling, and decommissioning should be completed more than 24 hours before or after indoor air sampling; but no more than 2 days before or after indoor air sampling.

21. Page 3-2, Section 3.1.1.1 Sub-slab Soil Gas Sampling: Boeing shall use the Helium leak test method as described in the California Environmental Protection Agency Department of Toxic Substances Control (CalEPA/DTSC), Advisory Active Soil Gas Investigations Guidance, dated April 2012. Ecology does not believe that the "water dam" leak test method is as effective in identifying small leaks between the vapor pin and the floor hole. The water dam leak test also does not measure leaks in the sample train.

22. Page 3-2, Section 3.1.1.1 Sub-slab Soil Gas Sampling, Paragraph 6: Figure 5 shall be revised to have the He leak test shroud include all of the sampling train as possible (see CalEPA/DTSC 2012 guidance). Figure 5 shall be consistent with the CalEPA/DTSC helium leak test figure and resubmitted to Ecology as an addendum to the contingent approved Work Plan within 7 calendar days of your receipt of this letter. The helium leak test shroud shall also be in place when actual sub-slab vapor samples are collected in the Summa canister, and helium shall be analyzed in the sample. In addition, during the leak test, the sub-slab vapors shall not contain more than 5% of the Helium concentration in the shroud.

23. Page 3-3, Section 3.1.1.1 Sub-slab Soil Gas Sampling, Paragraph 2: Ecology did not see in the revised Work Plan what volume of purge gas will be collected prior to collecting the sub-slab soil vapor (SSV) sample. Ecology expects at least three(3) volumes (includes total volume of the sampling system), shall be purged prior to collecting the SSV sample.

24. Page 3-3, Section 3.1.1.1 Sub-Slab Soil Gas Sampling, Paragraph 3: Per the CalEPA/DTSC 2012 guidance, helium tracer compound in the shroud should be kept to +/- 10% of the target shroud concentration. The concentration of helium in the shroud should be at least 100 times that of the helium reporting limit of the helium field meter.

25. Page 3-4, Section 3.1.1.1 Sub-slab Soil Gas Sampling, Paragraph 2: The PID meter used to measure volatile constituents in the purged SSV sample should be sensitive enough to measure concentrations in the μg/m^3 range in order to maximize the usefulness of the data. If Boeing/Landau cannot locate and use a PID meter with this level of sensitivity, then Boeing shall report the results and sensitivity of the PID meter used in subsequent reports to Ecology.

26. Page 3-4, Section 3.1.1.2 Crawl Space Air Sampling, Paragraph 2, First Sentence: Ecology agrees that it is preferable to position the crawl space summa canister in a dry location. However, as a clarification, Ecology expects a crawl space sample shall be collected even if there is water present in the crawl space because TCE contaminated groundwater that has infiltrated the crawlspace in the wet season will be a source of indoor air contamination. Ecology also expects that Boeing will meet the following criteria when locating crawl space samples: placed near openings in the floor (if applicable), placed in areas below indoor air samples (if possible), and placed an adequate distance away (at least 10 feet) from crawlspace vents and crawlspace wall. This may or may not require confined space entry qualified personnel.

27. Page 3-5 Section 3.1.1.3 Indoor Air Sampling, Paragraph 2: Second Sentence: Boeing shall also position the summa canister inlet at the breathing height of the respective adult or child sleeping on a bed (for samples collected in bedrooms).

28. Page 3-5 Section 3.1.1.4 Ambient Air Sampling, Paragraph 1: Ecology assumes that Boeing understands this, but the ambient air samples shall be collected concurrently with indoor air samples at every home. Ambient air samples should be collected away from obvious outdoor air contaminant sources such as any combustion engine exhaust, to the extent possible, and at least 10 feet away from building walls or other barriers to ambient air flow.

29. Page 3-5 Section 3.1.1.4 Ambient Air Sampling, Paragraph 1, Last Sentence: Ecology agrees that the ambient air canisters should be labeled with a sign that indicates the purpose of the canister and that the canister should not be touched. But, there should be a statement that the canister is sampling ambient air for 24 hours and if there are questions one can contact either Boeing or Landau by phone. If there is a potential for a rain event, Boeing or Landau shall equip the ambient air summa canister with a downward facing inlet or other device to prevent the introduction of water in the sample.

30. Page 3-6 Section 3.1.1.4 Ambient Air Sampling, Paragraph 2: Ecology agrees with the criteria listed here for the collection of ambient air samples. However, Ecology also expects that Boeing/Landau will verify wind direction at the home on the day of sampling. If this wind direction is clearly significantly different from the weather station reported wind direction, Ecology expects that Boeing/Landau will locate the ambient air sample directly upwind of the sampled home, based on wind direction at the home. If

the direction changes after sampling has begun or is otherwise different than the direction at the start of sampling, the sampling report needs to note this and acknowledge the associated uncertainty in representativeness. In addition, Boeing/Landau shall indicate the location and address of the weather station on a revised Figure 1, to be resubmitted to Ecology.

31. <u>Page 3-7, Section 3.1.2.1 Sub-Slab Soil Gas Sample Handling and Analysis, Paragraph 1, Table of SSV reporting limits</u>: Ecology recommends that SSV samples achieve the same reporting limits (RLs) as indoor air samples. Ecology agrees that there will be some attenuation of sub-slab soil vapors in the vadose zone before entering any sampled home. However, the reduced SSV RLs will provide more information for Ecology and Boeing to re-evaluate the groundwater PCLs, as necessary.

32. <u>Page 3-8, Section 3.2.1 Sample Collection Procedures, Paragraph 2</u>: Ecology thanks Boeing for agreeing to use passive diffusion sampling devices as part of this VI assessment. However, Boeing shall collect passive diffusion samples concurrently and at all the same locations where indoor air and crawl space samples are collected via summa canisters. This is consistent with what Ecology and Landau told residents during VI house visits.

33. <u>Page 3-9, Section 3.2.1 Sample Collection Procedures, Paragraph 1, First Indented Paragraph</u>: Boeing/Landau should suspend the Radiello passive diffusion samples (centrally located and) above the floor of the crawl space to prevent contact with any water that may enter the crawl space during the 21-day sampling period.

34. <u>Page 3-9, Section 3.2.1 Sample Collection Procedures, Paragraph 1, First Bulleted Paragraph</u>: Same as Comment #30.

35. <u>Page 4-1, Section 4.0 Data Analysis and Mitigation Assessment, Paragraph 2, First Bullet</u>: Multiple lines of evidence (MLE) gathered after the Winter sampling event will be used to determine if further indoor air sampling is required. Some MLEs to consider are current shallow groundwater data, indoor air sample data approaching IAALs, and SSV and/or crawl space sample data.

36. <u>Page 4-1, Section 4.0 Data Analysis and Mitigation Assessment, Paragraph 2, Second Bullet, First Indented Paragraph</u>: Same as Ecology comment #35, above.

37. <u>Page 4-2, Section 4.0 Data Analysis and Mitigation Assessment, Paragraph 1, First Indented Paragraph</u>: Same as Ecology comment #35, above.

38. <u>Page 4-2, Section 4.0, Data Analysis and Mitigation Assessment, Paragraph 1, Second Bullet</u>: Ecology also expects that Boeing will consider the benefits of installation of a

home mitigation system under the following circumstances also (not just indoor air sample exceedances of the IAALs):

a. highly elevated SSV sample concentrations above SSV Table 1 screening levels even though indoor air sample concentrations are below IAALs. This situation indicates a potential for future indoor air exceedances, and installation of a home mitigation system may be more practical than continued routine indoor air and SSV monitoring; and
b. elevated crawl space sample concentrations above indoor air IAALs in Table 1 values even though indoor air sample concentrations are below IAALs. This situation indicates a potential for future indoor air exceedances, and installation of a home mitigation system may be more practical than continued routine indoor air and crawl space monitoring.

39. Page 4-2, Section 4.0, Data Analysis and Mitigation Assessment, Paragraph 1, First Bullet, Second Indented Paragraph: Boeing did not specifically explain what is meant by conducting "...... a background source evaluation" at the time of a second sampling event to confirm whether or not a home mitigation is required. Ecology expects that the ambient air sampling described in the Work Plan shall be implemented for any Ecology approved confirmation sampling. Ecology does not expect to use national background data or other background data. If Boeing's stated intent is to further examine the likelihood of home indoor sources contributing to contaminants in the indoor air, then Boeing shall clearly describe the steps taken and the results of this evaluation as part of the second round of sampling report.

40. Page 4-2, Section 4.0, Data Analysis and Mitigation Assessment, Paragraph 1, Fourth and Fifth Sentences: To the extent possible, Ecology's expectation is that removed indoor sources will stay out of the house for the full 21-days when Radiello passive diffusion samplers (PDS) are used.

41. Page 5-1, Section 5.0 Data Reporting and Distribution, Paragraph 1, First Sentence: The first sentence of Section 5.0 shall state: "Unless concentrations are elevated and require a more immediate communication, Boeing shall provide copies of the letter data report to Ecology within fifteen (15) days after the sample has been collected. Ecology and the WDOH will review the results and issue their response letter and cover letter to Boeing/Landau. Boeing/Landau shall deliver the data results and Ecology's letters to the homeowner and residents within 3 to 4 weeks of sampling.

42. Page 5-1, Section 5.0 Data Reporting and Distribution, Paragraph 1, Second Sentence (also Page 6-1, Section 6.0 Schedule, Paragraph 2, Eighth Bullet): As stated in the Ecology response letter dated May 22, 2013, the general format and content of these data letter reports sent to the resident shall be discussed by Ecology and Boeing prior to sending.

43. <u>Page 5-1, Section 5.0 Data Reporting and Distribution, Paragraph 3, Second Sentence</u>: Ecology is subject to compliance with the <u>Public Disclosure</u> Laws in Washington State...

44. Page 6-1, Section 6.0 Schedule, Paragraph 2, Eighth Bullet: The eighth bullet shall state: "Results distribution to property owners, and tenants, if applicable, within approximately 3 to 4 weeks after sampling, unless concentrations exceed TCE short-term action level that warrants immediate communication."

ENCLOSURE B

City of Algona (ICF) comments
Draft Revised Algona Residential Neighborhood Vapor Intrusion Assessment Work Plan for the Boeing Auburn site

Only one of ICF's original comments (which Ecology had incorporated into their May 22, 2013 comments) was not adequately addressed or explained by Boeing in the Revised VI Work Plan:

ICF Original Comment #3 (from May 15th comment letter submitted to Ecology) and Ecology Specific Comment #2 (from May 22, 2013 comment letter to Boeing):

- **Pg. 2-2, Sec 2.1.1 Shallow Water Table Groundwater PCLs:** There is no mention of acetone and methylene chloride in this section; however, both of these contaminants were detected in the recent direct-push groundwater samples. Acetone and methylene chloride were also identified as constituents of concern in the 2nd Revised Ecology Review Draft Remedial Investigation Report Boeing Auburn Fabrication Division Facility (dated April 10, 2009). A discussion needs to be added to address why PCLs for acetone and methylene chloride (and any other contaminants detected in the recent direct-push investigation) were not developed. This is particularly important for acetone, as it appears detections of this contaminant were observed in direct-push locations farthest to the west (P-5, P-16), where TCE and VC were not detected. If these detections exceed PCLs, additional homes in this area could require VI assessment.

We would appreciate an explanation why the comment above was not addressed in the Revised VI Work Plan.

Work Plan
Algona Residential Neighborhood Vapor Intrusion Assessment
Boeing Auburn Facility
Auburn, Washington

June 13, 2013

Prepared for

The Boeing Company
Auburn, Washington

Landau Associates
950 Pacific Avenue, Suite 515
Tacoma, WA 98402
(253) 926-2493

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FIGURES

TABLES

APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

μg/L	Micrograms per Liter
μg/m^3	Micrograms per Cubic Meter
AA	Ambient Air
ATD	At Time of Drilling
BGS	Below Ground Surface
Boeing	The Boeing Company
cis-1,2-DCE	cis-1,2-dichloroethene
COC	Chain of Custody
CSA	Crawl Space Air
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ft	Feet
HI	Hazard Index
HVAC	Heating, Ventilation, and Air Conditioning
IA	Indoor Air
IAAL	Indoor Air Action Level
ID	Identification
IRIS	Integrated Risk Information System
LLI	Eurofins Lancaster Laboratories, Inc.
LOQ	Limits of Quantitation
mL	Milliliter
MLE	Multiple Lines of Evidence
MTCA	Model Toxics Control Act
PCE	Tetrachloroethene
PCL	Preliminary Concern Level
PID	Photoionization Detector
QAPP	Quality Assurance Project Plan
RI	Remedial Investigation
SIM	Selected Ion Monitoring
SL	Screening Level
SSV	Sub-slab Soil Vapor
TCE	Trichloroethene
trans-1,2-DCE	Trans-1,2-dichloroethene
TWA	Time-weighted Average
VAF	Vapor Attenuation Factor
Vapor Pin	Cox-Colvin Vapor Pin™
VC	Vinyl Chloride
VOC	Volatile Organic Compound
WDOH	Washington State Department of Health

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1.0 INTRODUCTION

This document presents a vapor intrusion assessment work plan as part of additional remedial investigation (RI) activities associated with The Boeing Company's (Boeing) Auburn Fabrication Division facility (facility) located at 700 15th Street Southwest in Auburn, Washington (Figure 1). Boeing is currently conducting corrective action activities 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 the Washington State Department of Ecology (Ecology). The Agreed Order includes a requirement to conduct a RI of facility contamination impacts both within the facility (on site) and at downgradient properties (off site). After the RI is complete, a Feasibility Study (FS) will be conducted to identify appropriate cleanup actions, and a Cleanup Action Plan (CAP) will be developed and finalized. Cleanup will be conducted according to the cleanup plan.

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 site and have migrated off site. The plumes have affected shallow groundwater both on site and off site. Volatile organic compounds (VOCs) in shallow groundwater have the potential to impact indoor air via the vapor intrusion pathway. As a result, Boeing prepared a Vapor Intrusion Evaluation and Assessment Approach report[1] (Vapor Intrusion Approach report; Landau Associates 2013a) to be used during the RI.

A recent RI groundwater characterization event conducted in December 2012 included installation of new shallow groundwater monitoring wells in the northeastern portion of a residential neighborhood in Algona. TCE and the TCE breakdown product vinyl chloride (VC) were detected at the new wells at or above Ecology-approved residential vapor intrusion screening levels (SLs) for shallow groundwater. In accordance with the Vapor Intrusion Approach report, additional shallow groundwater data from the Algona neighborhood is necessary to more fully delineate the extent of TCE and VC to evaluate where vapor intrusion assessments (e.g., residential air sampling[2]) should be conducted. As a result, 49 direct-push shallow water table groundwater samples were collected in Algona during April 2013 in accordance with a direct-push drilling work plan (Landau Associates 2013b). The April 2013 direct-push shallow water table data is being used to evaluate which residences should be assessed for

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[1] The Vapor Intrusion report (Landau Associates 2013a) was submitted to Ecology on February 20, 2013, and Ecology provided comments on April 12, 2013 (Ecology 2013a). Landau Associates is currently revising the draft Vapor Intrusion Approach report and will submit a finalized version to Ecology; this work plan reflects Ecology's requested changes to the Vapor Intrusion Approach.

[2] Residential air sampling for a residence may include a combination of sub-slab soil gas sampling, crawl space air sampling, indoor air sampling, and ambient air sampling. The type of residential air sampling will be determined on a building-specific basis for each residence.

vapor intrusion. The initial[3] vapor intrusion assessments will be conducted generally between Chicago Avenue and Celery Avenue, between 11th Avenue North and 9th Avenue North, where the shallow water table results are at or above residential vapor intrusion screening levels. Ecology and Boeing have agreed to focus the initial vapor intrusion assessments on the 23 residences shown on Figure 2, as discussed in Section 2.2. If groundwater data suggests that the vapor intrusion risk may extend beyond the area of the initial vapor intrusion assessment residences, "step-out"[4] vapor intrusion assessments will be conducted. If the vapor intrusion assessment indicates that vapor intrusion is unacceptably impacting indoor air at a given residence(s), mitigation will be conducted at the impacted residence(s) as an interim action to minimize vapor intrusion and reduce indoor air concentrations of VOCs. Implementation of mitigation interim actions is independent of decisions on final site cleanup actions for the Boeing facility.

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[3] The initial vapor intrusion assessments address Ecology's requested Plan B approach (Ecology 2013a).

[4] The step-out vapor intrusion assessments address Ecology's requested Plan A approach (Ecology 2013a).

2.0 INVESTIGATION APPROACH

The vapor intrusion investigation approach for the Algona residential neighborhood is consistent with both the Vapor Intrusion Approach report and the associated Ecology comment letter (Ecology 2013a). The purpose of the vapor intrusion investigation is to identify where vapor intrusion is occurring in the Algona residential neighborhood so that decisions on what actions should be taken can be made. Algona residential screening criteria are presented in Section 2.1. The process for screening shallow groundwater data to assess which residences may be at risk for vapor intrusion (i.e., Tier I screening) is presented in Section 2.2. The process for evaluating a particular residence by conducting a building survey and sampling activities (i.e., Tier II assessment) is presented in Section 2.3.

2.1 ALGONA RESIDENTIAL SCREENING CRITERIA

In November 2012, Ecology approved of Boeing's vapor intrusion screening criteria for site-wide vapor intrusion assessments (Ecology 2012). The approved residential vapor intrusion screening criteria that are applicable to the Algona residential neighborhood consist of Model Toxics Control Act (MTCA) Method B indoor air cleanup levels (herein termed indoor air screening levels), shallow soil gas screening levels, and shallow groundwater screening levels for individual constituents TCE and VC; these criteria are presented in Table 1. The approved screening criteria were presented in Boeing's Vapor Intrusion Approach report, which was submitted to Ecology on February 20, 2013. On April 19, 2013 Ecology provided review comments on the Vapor Intrusion Approach report and requested that Boeing calculate additional Algona-specific screening criteria: preliminary concern levels (PCLs) for shallow (water table) groundwater VOCs and indoor air action levels (IAALs).[5]

PCLs are conservative, site-specific shallow groundwater screening levels that Ecology has required be used for initial vapor intrusion screening activities in Algona. Ecology requested that Boeing calculate the site-specific PCLs because groundwater is very shallow in the Algona residential neighborhood, which is a condition that is not specifically factored into the approved shallow groundwater screening levels. Therefore, the PCLs are to be used in Algona instead of the previously approved shallow groundwater screening levels because the PCLs are more conservative and may be more appropriate where groundwater is very shallow.

The IAALs will be used to evaluate indoor air and crawl space/basement air data in addition to the approved indoor air screening levels. The IAALs will be used to trigger an interim action such as prompt repeat sampling (if background source is suspected) or mitigation. During confirmation sampling

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[5] Ecology did not request revised shallow soil gas screening levels and in an April 19, 2013 conference call explained that the Ecology-approved soil gas screening levels for site-wide conditions would be applicable in Algona where sub-slab soil gas can be collected (Jones, E., 2013, personal communication).

during the winter, the approved indoor air screening levels will be used to determine if there is a need to further evaluate the vapor intrusion pathway. Also, Ecology requested that Boeing calculate crawl space/basement screening levels; since the current state of the practice assumes no attenuation between crawl space/basement and indoor air, Boeing will use indoor air screening criteria for crawl space/basement samples. The following two subsections present the calculated PCLs and IAALs for use during the Algona residential neighborhood vapor intrusion assessments.

2.1.1 SHALLOW WATER TABLE GROUNDWATER PRELIMINARY CONCERN LEVELS

The PCLs are calculated identically to the approved shallow groundwater screening levels except the PCLs use a more conservative vapor attenuation factor (VAF) of 1/667 (unitless) recommended by Ecology (Ecology 2013a). The Ecology-recommended VAF is intended to account for minimal vadose zone attenuation because groundwater is very shallow in Algona. The PCLs are calculated as follows:

$$PCL_{GW} = \frac{CUL_{IA}}{VAF \times UCF \ \times H_{CC}}$$

Where:

PCL_{GW}	Preliminary concern level in groundwater protective of indoor air, micrograms per liter (µg/L)
CUL_{IA}	MTCA Method B standard formula indoor air cleanup level, micrograms per cubic meter (µg/m^3)
VAF	Vapor attenuation factor (VAF; unitless); an Ecology recommended value of approximately 1/667
UCF	Unit conversation factor, 1000 liters per cubic meter (L/m^3)
H_{CC}	Henry's Law constant, unitless[6]

Per Ecology's comments, Boeing calculated residential shallow groundwater PCLs for TCE and VC. Additionally, because trans-1,2-dichloroethene (trans-1,2-DCE), a TCE breakdown product, has been detected in shallow groundwater in Algona and has a MTCA Method B indoor air cleanup level, Boeing has calculated a PCL for trans-1,2-DCE. The PCLs are presented in Table 1 and are summarized here:

Constituents:	TCE	Trans-1,2-DCE	VC
PCL (µg/L):	1.0	46	0.23

Boeing is using the PCLs to screen water table data in Algona from water table wells AGW225 and AGW226 and from the April 2013 direct-push borings; this is part of the Tier I screening process, which is described further in Section 2.2. At locations where water table concentrations exceed the PCLs, there will be a need to evaluate the potential for vapor intrusion within nearby residences. TCE,

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[6] Consistent with Ecology's draft vapor intrusion guidance (Ecology 2009), Henry's Law constants were adjusted to 13 deg C to better represent average Washington State groundwater temperatures.

trans-1,2-DCE, and VC have been detected at the two water table wells and from April 2013 direct-push boring groundwater samples; cis-1,2-DCE was also detected, but is not a vapor intrusion constituent of concern[7].

To-date, tetrachloroethene (PCE) has not been detected at either of the two water table wells or from the April 2013 direct-push boring groundwater samples. Therefore, PCE is not considered a risk driver for vapor intrusion in the Algona residential neighborhood and Boeing does not intend to have the laboratory report PCE for indoor air samples; this is in accordance with Ecology's comments (Ecology 2013a). If additional vapor intrusion constituents of concern are identified based on new shallow groundwater data in Algona, PCLs will also be calculated for those constituents.

2.1.2 INDOOR AIR ACTION LEVELS

As discussed in Section 2.1, IAALs are concentrations that trigger an interim action such as mitigation. In Ecology's recent comment letter regarding the Vapor Intrusion Approach report, Ecology asked that Boeing develop chronic exposure risk IAALs for vapor intrusion constituents of concern and that Boeing also use the TCE short-term exposure level of 2.0 $\mu g/m^3$ recently published by the U.S. Environmental Protection Agency (EPA) Region 10 (EPA 2012). Ecology's MTCA Method B cleanup levels account for long-term exposure to an individual constituent, whereas the requested chronic exposure IAALs account for the combined risk of multiple vapor intrusion constituents to an individual over long-term exposure. The short-term exposure level pertains to TCE (only), and is to be used when residential occupants include women of child bearing age, because it specifically represents a health-protective concentration of TCE to prevent fetal cardiac malformations (EPA 2012). The short-term level for TCE is presented in Table 1.

In accordance with Ecology's comments (Ecology 2013a), Boeing has identified chronic exposure IAALs. The chronic exposure IAALs are a cumulative potential cancer risk of $1x10^{-5}$ and a non-cancer hazard index (HI) of 1. A cumulative potential cancer risk will be calculated for each sample by summing the potential cancer risk of each detected constituent with carcinogenic effects (TCE and VC). The calculated cumulative potential cancer risk will be compared to the IAAL of $1x10^{-5}$. To support calculation of a non-cancer HI, the critical (health) effects of the three constituents of concern detected in shallow groundwater in Algona with available toxicity information (TCE; trans-1,2-DCE; and VC) were identified using the EPA Integrated Risk Information System (IRIS). The critical health effects are presented in Table 2. The additive non-cancer risk for individual samples will be calculated by summing the hazard quotients for critical effects that target the same functional system of the human body

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[7] Cis-1,2-DCE does not currently have a MTCA Method B indoor air cleanup level and is not a vapor intrusion constituent of concern. However, per Ecology's request (Ecology 2013a), it will be reported because it is a breakdown product of TCE.

for each detected constituent of concern. For example, both TCE and trans-1,2-DCE have immune system-related critical effects, so the additive risk to the immune system from these two constituents will be calculated if both constituents are detected in an indoor air sample. The calculated HI for each air sample for each critical effect based on detected concentrations of constituents will be compared to the allowable HI of 1.

2.2 TIER I SCREENING OF SHALLOW GROUNDWATER DATA

Shallow groundwater data primarily collected at the top of the water table within the Algona residential neighborhood is being used to determine which residences may be at risk for vapor intrusion. There are two shallow water table groundwater wells installed in the Algona neighborhood (AGW225 and AGW226) and one conventional[8] shallow well screened beneath the water table installed just downgradient of the Algona neighborhood (AGW228). TCE and VC are detected at all three of these wells at concentrations above the PCLs; trans-1,2-DCE has been detected at concentrations ranging between 0.4 µg/L and 0.7 µg/L, which is well below the PCL of 46 µg/L. The most recent TCE and VC concentrations at the three wells are shown on Figure 3. As identified in the Vapor Intrusion Approach report, the well data indicated the need for additional shallow groundwater characterization in the Algona neighborhood, which led to the April 2013 direct-push drilling program.

As indicated in Section 2.1.1, the vapor intrusion constituents of concern detected in the direct-push water table samples include TCE, trans-1,2-DCE, and VC. Only TCE and VC have exceeded PCLs. Figure 2 shows where TCE and VC in the April 2013 water table samples are: 1) not detected, 2) where one or both are detected, but concentrations are below PCLs, and 3) where one or both are detected at concentrations greater than or equal to the PCLs. The April 2013 direct-push boring groundwater data is presented in draft technical memorandum *Algona Neighborhood Direct-Push Boring Investigation*[9].

The April 2013 direct-push boring groundwater data was provided by the laboratory on a quick turnaround and was shared with Ecology throughout the drilling program on a weekly basis. Sharing of the data ahead of schedule enabled Boeing and Ecology to assess where initial vapor intrusion assessments should occur. Boeing submitted proposed residences for the initial vapor intrusion assessment to Ecology on April 22, 2013 based on areas where the shallow water table data exceeds PCLs for TCE or VC (consistent with the Tier I screening process in the Vapor Intrusion Approach report). Based on the PCL exceedances, a total of 23 residences were identified by Boeing and Ecology [with concurrence from Washington State Department of Health (WDOH)] as locations at which initial vapor intrusion assessments should be conducted; the 23 residences are shown on Figure 2. Step-out vapor

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[8] Conventional shallow groundwater wells are typically screened between 20 and 35 ft below ground surface.
[9] The direct-push results draft technical memorandum was submitted to Ecology on May 28, 2013 and is under review.

intrusion assessment residences will be discussed with and approved by Ecology after the initial vapor intrusion assessments are completed.

2.3 PROPOSED TIER II ASSESSMENT APPROACH

Tier II assessments will be conducted at residences in general accordance with the Vapor Intrusion Approach report. A brief description of the types of samples that may be collected during a Tier II assessment is presented in Section 2.3.1. Permission to conduct Tier II assessments must be granted by property owners (and tenants if applicable). The process for communicating with residents and requesting permission to conduct a Tier II assessment from a property owner is presented in Section 2.3.2. Procedures for evaluating sampling locations at individual residences for residential Tier II assessments are presented in Section 2.3.3.

2.3.1 TIER II ASSESSMENT SAMPLE TYPES

Tier II assessments include some combination of indoor air sampling with other types of samples including crawl space and/or sub-slab soil gas. Background ambient air samples will be collected in the neighborhood upwind of a given residence during Tier II sampling. All air samples associated with a particular residence will be collected on the same day.

The purpose of indoor air samples is to determine if VOCs found in the subsurface (in this case shallow groundwater) are present in indoor air where receptors may be exposed. The purpose of crawl space air samples is to provide results for comparison with indoor air results as another vapor intrusion line of evidence. Since there is assumed to be no attenuation from crawl space to indoor air, one might expect that the contribution of VOCs from vapor intrusion (if present) would be relatively similar between crawl space and indoor air. However, a crawl space sample is less likely to be impacted by background chemicals than an indoor air sample; therefore, the crawl space sample may be a more accurate indicator of vapor intrusion if indoor chemicals are impacting indoor air results. The purpose of collecting ambient air samples is to establish a background air quality condition that can be compared to the coupled-indoor air results. Having the ambient air sample can be useful for estimating the impact of outdoor air contamination on the indoor air sample. The purpose of sub-slab soil gas sampling is to confirm presence of TCE and/or VC in the sub-surface directly beneath a residence.

When indoor air is sampled, it is ideal to collect a co-located sub-slab soil gas sample to allow a comparison of VOCs in indoor air and below the building slab to support the vapor intrusion assessment. However, three conditions preclude the option of collecting sub-slab soil gas samples: 1) the presence of an unpaved crawl space beneath a residence, 2) wetted basements or foundations caused by shallow groundwater, and 3) inadequate capillary fringe to allow for collectable soil gas beneath a slab.

Therefore, the decision to collect sub-slab soil gas samples will be dependent on the findings from residential building surveys (see Section 2.3.3.2) and the information from the April 2013 direct-push groundwater investigation (Landau Associates 2013c).

2.3.2 COMMUNICATING WITH RESIDENTS AND REQUESTING PERMISSION TO CONDUCT TIER II ASSESSMENTS

Obtaining permission to conduct a Tier II assessment at a residence may be a multi-step process. The initial step is to communicate the purpose and process of the Tier II assessment to the property owners and tenants and to coordinate building surveys (Section 2.3.2.1). The subsequent steps include formally requesting permission to conduct Tier II sampling from the property owner and tenant and coordinating sampling activities (Section 2.3.2.2).

2.3.2.1 Communicating the Purpose and Process

Ecology plans to communicate the results of the April 2013 direct-push groundwater sampling and detailed information about vapor intrusion assessment at a public meeting that is scheduled for June 13. However, the initial vapor intrusion assessments under this work plan began prior to the June 13 public meeting and so it was important to communicate this work to the affected members of the Algona community. Ecology mailed a notification packet of information to each residence (and to property owners who do not occupy their Algona residence) that was selected for initial vapor intrusion assessments. The notification packet includes a cover letter and vapor intrusion fact sheet about the initial building surveys and indoor air testing, as well as a building visit appointment form, a scheduling information insert (which provides information on scheduling visits through Landau Associates), and a short-form version of the building survey form (provided by Landau Associates). The cover letter and fact sheet explain the general concept of vapor intrusion, why Ecology and WDOH are recommending that air sampling be conducted at the residences, the building survey process, the air sampling process, and mitigation (should it become necessary). If step-out vapor intrusion assessments become necessary, Boeing anticipates that Ecology will mail a similar packet of information to the tenant and property owner of each residence that is selected for step-out vapor intrusion assessments. Following distribution of the packets, Landau Associates began scheduling building surveys. Access agreements are needed for collecting indoor air, crawl space air, outdoor air, or sub-slab soil gas samples at each of the selected residences. Landau Associates will coordinate scheduling of sampling activities once an access agreement is obtained.

Aspects of the permission process pertaining to requesting and obtaining permission to conduct a Tier II assessment are further explained in the following section.

2.3.2.2 Requesting Permission to Conduct Tier II Assessment

It is anticipated that residents who are interested in allowing Boeing to conduct a vapor intrusion assessment of their residence will communicate with Landau Associates by following instructions provided by Ecology (see Section 2.3.2.3). In general, Boeing will mail or hand-deliver a permission request packet (Appendix A) to each of the selected residential properties either prior to a building survey or during a building survey. The packet will include: 1) an introduction letter, 2) an access agreement, 3) a scheduling/communication form, and 4) information sheets regarding air sampling and instructions for the resident; if mailed, a stamped and addressed return envelope to Boeing's consultant (Landau Associates) will also be included.

The introduction letter briefly explains the project and how to fill out and return the attached forms. Boeing has generated cover letters for the owner-occupied scenario and the tenant-occupied scenario. Additionally, there are versions of the letters that cover a scenario where air sampling and sub-slab sampling activities are proposed as well as a scenario where only air sampling activities are proposed. An example cover letter for the owner-occupied scenario where air and sub-slab sampling is proposed is provided in Appendix A.

The purpose of the access agreement is to formally document if the property owner (and tenant, if applicable) grants or denies Boeing and Landau Associates permission to conduct residential air sampling at their residence. The access agreement must be signed by the property owner (and tenant, if applicable) before sampling can be conducted. In accordance with Ecology's comments on the April 30, 2013 draft of this work plan (Ecology 2013b), Boeing has created four versions of the access agreement: 1) to property owner when air sampling, 2) to property owner when air and sub-slab soil gas sampling, 3) to tenant when air sampling, and 4) to tenant when air and sub-slab soil gas sampling. If access is denied, Ecology may follow-up with the property owner to better understand their reasoning for not allowing the sampling. A copy of final access agreements and declination forms will be mailed back to the residents for their records; alternatively, if in person, the resident can sign two and one can be kept for Boeing's records.

The scheduling and contact information form contained in Appendix A provides the property owner (and tenant, if applicable) with a Landau Associates scheduling phone number and contact. The form has a space for tenant and property owner information (if both apply) to help confirm Boeing and Ecology records.

The introduction letter asks that the access agreement and the scheduling and contact information form be returned within two weeks of receiving the letter using the enclosed return envelope. If the occupying resident (and property owner if non-resident) does not respond within 2 weeks, additional attempts to communicate will be made. The second attempt will involve a phone call (or email) if a phone number or email address can be located; if no phone number or email is located, a visit to the residence in Algona will take place to distribute a second packet in person. If no one is present at the time of the visit, the packet will be left at the front door, with a requested response time of one week. Phone calls may be necessary to evaluate the validity of mailing addresses listed in King County tax parcel records and Boeing and Ecology should share contact information to ensure we are communicating with the same people.

If the property owner (and tenant, if applicable) chooses to grant permission, they will fill out the scheduling and contact information form and will then return the scheduling and contact information form and access agreement to Landau Associates using the provided envelope or in person if completed during the building survey visit. If the property owner (and tenant, if applicable) chooses to decline access, Boeing will send them the declination form and Ecology may consult with them to try to better understand their reason for declining the vapor intrusion assessment.

As permission request responses are received, Boeing will compile a list of the permission approvals and rejections and will provide the list and copies of the responses to Ecology. Boeing will also create a file for each residence. As previously indicated, Landau Associates will coordinate scheduling building surveys and sampling activities with residents. For homes where only air sampling is anticipated, up to five site visits are anticipated: 1) building survey; 2) temporary removal of indoor sources (i.e., placing chemicals in totes and storing away from home); 3) air sampling equipment setup; 4) air sampling equipment take-down; and 5) support in returning indoor sources to resident. For homes where air and sub-slab sampling is anticipated, at least five site visits are anticipated: 1) building survey; 2) temporary removal of indoor sources (i.e,. placing chemicals in totes and storing away from home), utility locates, and installation of sub-slab soil vapor point; 3) air sampling equipment setup; 4) air sampling equipment take-down, then sub-slab sampling and sample port removal and floor patching; and 5) support in returning indoor sources to resident.

2.3.3 SAMPLE LOCATION EVALUATION

The sample location evaluation process will consist of creating a preliminary conceptual model of the Algona neighborhood (Section 2.3.3.1), and conducting building surveys and developing building-specific conceptual models for residential buildings where sampling permission has been granted (Section 2.2.3.2).

2.3.3.1 Preliminary Conceptual Model of Algona Neighborhood

The preliminary conceptual model provides a conceptual understanding of the potential pathways for vapor intrusion at residential buildings in the Algona neighborhood. A preliminary survey of building construction type in Algona has been conducted via a windshield survey and review of King County assessor records. It appears that the residences are generally either manufactured (i.e., mobile) or stick-built (i.e., wood-framed), and that some are slab-on-grade construction, some may have crawl spaces, and some have basements.

The depth to groundwater in the Algona neighborhood has been measured west of Chicago Avenue at 10th Avenue North (well AGW225), farther to the west along 11th Avenue North (AGW226), and northwest along Boundary Boulevard (AGW228). In March 2013, the depth to water was 2.72 feet (ft) below ground surface (BGS) at AGW225, 0.8 ft BGS at AGW226, and 3.87 ft BGS at AGW228. Direct-push groundwater sampling conducted during April 2013 confirms that the water table is close to ground surface in the Algona residential area. Given the depth to water measurements, it is anticipated that little to no vadose zone will be present during the planned Tier II assessments. Co-located sub-slab soil gas sampling is not possible if the following conditions exist at a residential building:

- Unpaved crawl spaces, with no slab
- Wetted slabs (basement or slab-on-grade) where shallow groundwater is immediately beneath the slab or has penetrated the slab causing standing water
- Inadequate capillary fringe to allow for collectable soil gas beneath a slab.

The depth to groundwater at time of drilling (ATD) measurements collected during the April 2013 direct-push groundwater sampling may help identify areas where the vadose zone is adequate to allow for sub-slab soil gas sampling as part of the Tier II assessments; in addition, evidence of wetted basements and standing water in the yards will be documented during building surveys and air sampling activities.

Given the types of anticipated residential construction, depth to groundwater, and the VOC concentration data, the preliminary conceptual model and cross section A-A’ have been developed (Figure 3); the location of cross section A-A’ is shown on Figure 2. Algona site-specific data collected during the April 2013 direct-push drilling such as ATD depth to water measurements and geologic characteristics in shallow soil will help to refine the vapor intrusion conceptual model; April 2013 direct-push data was presented in a separate technical memorandum in May 2013. Additionally, a utility map of the northern portion of the Algona residential neighborhood has been created to help identify preferential migration pathways (Figure 4).

2.3.3.2 Building Survey and Building-Specific Conceptual Model

Building surveys will be conducted at residential buildings where the residents have scheduled an appointment. A representative from Ecology and Landau Associates will participate in building surveys. Building surveys will be focused on filling out the building survey form, identifying potential indoor air sources, selecting tentative sampling locations, describing the sampling process (including instructions for pre-sampling and during sampling) to the resident, providing the resident with Boeing's notification and permission information packet and answering the resident's questions. With the resident's permission, photos of potential indoor air sources, building features that may represent preferential pathways, crawl spaces, and locations where sub-slab sample points may be installed will be taken; later, during air sampling, photos of air samples will also need to be collected.

Technical information that will be gathered during the building survey is outlined below:

- *Construction and structural details:* the foundation type and characteristics (slab-on-grade, footings and crawl space, or basement), any barriers to vapor intrusion, and features that could be potential preferential pathways for vapor (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:* typical receptor population exposure data (e.g., typical hours occupied, age of residents and other occupants, and typically occupied spaces within the building); resident will be interviewed to obtain information.
- *Background indoor air source inventory:* potential indoor air VOC sources (i.e., chemical products used indoors that contain VOCs); notes regarding typical use of potential indoor air VOC sources will be documented and photos of all potential indoor air sources will be taken (if permission is granted by property owner). After the building survey, material safety data sheets for identified potential background indoor air sources will be obtained from the internet and reviewed to identify TCE and VC content.

The above bulleted information and sketches of each residence will be documented on the building survey form (Appendix B)[10] and will be filed by residence. Boeing and Ecology will evaluate appropriate sampling locations during the building survey, and will discuss them after leaving the residence to develop consensus on the locations; therefore, Ecology will approve the number of samples and approximate locations with Boeing just after the building survey visit. The agreed upon sampling locations will be documented in the field with sketches; only potential sub-slab locations will be photographed during the building survey. Selection of sampling locations will consider the building spatial relationship to subsurface VOC impacts, an evaluation of potential preferential pathways for vapor

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[10] The building survey form is an adaptation of the "indoor air sampling questionnaire" from the *Vapor Intrusion Pathway: A Practical Guideline* (ITRC 2007).

migration, potential receptor exposure, indoor air circulation, and spaces occupied most by receptors; therefore, collectively, the completed building survey form and photos will serve as building-specific conceptual models. The conceptual model will contain applicable elements in accordance with Section 3.2 of Ecology’s draft vapor intrusion guidance (Ecology 2009).

After the initial vapor intrusion assessment building surveys have been completed, Boeing will provide one or more addenda to this work plan describing each residence and summarizing proposed sampling locations and sampling and analysis plan details not already covered in this work plan. If step-out vapor intrusion assessments are required, the step-out residences will be determined by Boeing and Ecology based on evaluation of initial vapor intrusion assessment sample results and neighborhood-wide utility corridors (i.e., preferential pathways). Addenda to this work plan will be submitted to Ecology for review and approval. After a work plan addendum is approved, Landau Associates will schedule and conduct sampling.

Another important use of the Tier II data from the initial vapor intrusion assessments is to re-evaluate the PCLs used to screen groundwater. In addition to the Tier II data, the re-evaluation will include analysis of building characteristics, the most recent groundwater data, information regarding soil type, and depth to water estimates. The re-evaluation of the PCLs will be presented in an Algona residential neighborhood initial vapor intrusion assessment summary data report; see Section 5.0 for information regarding how data will be reported.

3.0 FIELD ACTIVITIES

This section describes the field activities and provides sampling procedures and analytical procedures for sub-slab soil gas, crawl space air, indoor air, and ambient air sampling. Two types of samplers are proposed for application in this work plan: Summa canisters (for time-weighted average samples) and passive diffusive samplers (for longer duration, time-integrated samples). Time-weighted average samples collected using Summa canisters are the primary type of air and soil gas samples collected for the project; the most current sampling and laboratory procedures for using Summa canisters are presented in Section 3.1 of this work plan and in the current draft[11] SAP and QAPP. Time-integrated samples using passive diffusive samplers have not been collected for this project and are proposed for limited application as detailed in this work plan; sampling and laboratory procedures for the passive diffusive samplers are summarized in section 3.2 of this work plan. Field activities will be performed in accordance with the site health and safety plan (Appendix C). Field sampling forms are provided in Appendix D.

3.1 PROCEDURES WHEN USING SUMMA CANISTERS

The following three sub-sections present sample collection procedures, laboratory procedures, and sample labeling procedures when using summa canisters. Also, per discussion with Ecology during a meeting regarding this work plan on May 29, 2013, field duplicates will not be collected as part of this sampling program.

3.1.1 SAMPLE COLLECTION PROCEDURES

This section provides information regarding the collection of sub-slab soil gas, crawl space air, indoor air, and ambient air samples.

3.1.1.1 Sub-slab Soil Gas Sampling

If a residence has a paved crawl space/basement or slab-on-grade construction, and groundwater is not just beneath the pavement or slab, sub-slab soil gas samples should be collected. During sub-slab sampling activities, Boeing will make best efforts to minimize the introduction of soil gases into the residence. Sub-slab soil gas (i.e., vapor) samples will be collected from just beneath a slab[12] from a 5/8-inch-diameter core. The core will be drilled with a handheld rotary hammer style drill[13]. Immediately following coring, field staff will insert a photoionization detector (PID) into the drilled hole

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[11] The SAP and QAPP were recently updated and resubmitted to Ecology on 5/13/13 and 5/10/2013, respectively.

[12] The slab may be the slab-on-grade building foundation slab, basement slab, or crawl space slab.

[13] Some coring debris will remain at the bottom of the boring; therefore, drilling should extend beneath the bottom of the slab by approximately 4 to 6 inches to expose the soil before installing the Vapor Pin. A broom and dust pan will used to collect coring debris deposits on the ground surface; a shop vacuum will not be used.

to quickly check for VOCs, and will proceed with installing the sample point to minimize the introduction of soil gas into indoor air.

Sample points will be constructed by inserting a Cox-Colvin Vapor Pin™ (Vapor Pin) of approximately 3 inches in length into each core; see manufacturer's standard operating procedure provided as Appendix E. Vapor Pins are comprised of a barbed, stainless steel sample point fitted with an inert, compressible, silicon sleeve. Each Vapor Pin will be installed using a hammer and specialized installation tool to drive the Vapor Pin into place within the core. Driving the Vapor Pin into the core compresses the sleeve, creating a seal between the sample point and slab surface. Typically slabs are thicker than 3 inches, so the bottom of the Vapor Pin will rest within the slab core, above underlying soil.

After the Vapor Pin is installed, the end with a hose barb is exposed at the ground surface. A fitted cap will be attached to the barb to allow the sub-slab soil vapor to equilibrate without exposure to ambient air. The sample location will be left undisturbed for a minimum of 2 hours (Cal/EPA 2012) to allow for the soil vapor to equilibrate. To prevent the Vapor Pin from being tampered with or damaged, a small safety cone will be placed over the sampling assembly and tubing will extend through the top of the cone[14].

After the equilibration period is complete, a shut-in test and a leak test will be performed, immediately followed by sampling. There are two leak test options: 1) helium leak test following Cal EPA's advisory's guidance (Cal/EPA 2012), or 2) the water dam leak test method developed by Cox Colvin. The shut-in test from Cal EPA can be applied to both options.

Cal EPA's advisory guidance recommends that prior to purging or sampling, a shut-in test be conducted to check for leaks in the aboveground sampling system (Cal/EPA 2012). To conduct a shut-in test, assemble the aboveground valves, lines, and fittings downstream from the top of the probe. Evacuate the system to a minimum measured vacuum of about 100 inches of water using a purge pump. The test is conducted while the sampling canister, if used, is attached with its valve in the closed position. Observe the vacuum gauge connected to the system with a "T"-fitting for at least 1 minute or longer. If there is any observable loss of vacuum, adjust the fittings until the vacuum in the sample train does not noticeably dissipate. Following a successful shut-in test, the sampling train should not be altered. The vacuum gauge should be calibrated and sensitive enough to indicate a water-pressure change of 0.5 inch.

The first leak test option is the Cal EPA helium leak test. Cal EPA's advisory guidance (Cal/EPA 2012) recommends that in order to document a successful seal, a helium tracer test be performed prior to and during sample collection to show that the sub-slab soil gas sample does not contain more than 5 percent indoor air. A plastic shroud will be affixed over the sampling point, placed in such a way as to

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[14] Applicable field sampling procedures for sub-slab vapor sampling are presented in *Vapor Intrusion Pathway: A Practical Guideline* (ITRC 2007), and *Draft Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action* (Ecology 2009). Procedures in this work plan are consistent with these two guidance documents.

allow helium gas to be introduced to the air space surrounding the surface of the seal at the sampling point. The purpose of the helium will be to act as a highly mobile tracer gas that will indicate the extent of any leakage through the seal (i.e., the amount of ambient air being drawn from the surface to the subsurface during sampling). The tubing from the Vapor Pin will extend out of the shroud to the valve on the Summa canister, which is used to direct air flow either to the Summa canister or to a separate purging pump.

After the surface seal has set and the shroud is in place, a positive pressure of helium will be established beneath the shroud. The valve on the Summa canister will be set to direct air to a separate purging pump connected to a Tedlar bag. The tubing will then be purged of a minimum of three tubing volumes, with the purged air collected in the Tedlar bag. The purging and sampling rates will not exceed 200 milliliters per minutes (mL/min). A field measurement will then be performed on the air in the Tedlar bag to determine if helium is present in the purged air sample and to measure the concentrations of organic vapors. Helium concentrations beneath the shroud and within the purged air will be monitored using a portable helium meter (MARK Model 9822 Helium Detector, or equivalent). A helium leak test schematic is provided as Figure 5.

The Tedlar bag will be taken outside, away from entry points to the residences, to allow for helium assessment. If helium is detected in the Tedlar bag at concentrations greater than 5 percent of the concentration in the shroud, the probe will either be resealed or replaced, as appropriate. Once the seal integrity is verified through this procedure, purging will be concluded and a sample will be collected in the Summa canister. The final headspace concentration of helium beneath the shroud will be measured at the time of sample collection in the Summa canister.

The second leak test option is the water dam leak test. The water dam leak test consists of using a 2-inch diameter PVC coupler placed around the installed Vapor Pin. The PVC coupler is sealed to the slab using VOC-free modeling clay (or equivalent) rolled in a thin ribbon (approximately ½-inch thick) and applied to the leading edge of the PVC coupler. The coupler is then pressed tightly against the slab with the Vapor Pin at the center. The interior of the PVC coupler is then filled with distilled water to cover the connection between Vapor Pin and the tubing. Note the level of the water within the dam. If the water level stays stable, there are no leaks between the vapor pin and the slab and sampling can begin. A diagram and additional details about the water dam leak test procedure from Cox Colvin are provided in Appendix E.

Where sub-slab soil gas samples are co-located with indoor air samples, potential impacts to the indoor air samples related to sub-slab soil gas must be considered. In the case where samples will be collected with a Summa canister coupled with a 21-day passive diffusive sampler (i.e., Radiellos®), the sub-slab soil gas sample point will not be installed, purged, or disassembled less than 1 day prior to indoor air sampling. In the case where only a Summa canister is used for indoor air sampling, the sub-slab sample can be collected either at least one day before or after the indoor air sampling is completed.

Additionally, purged soil gas will be contained to the extent possible to prevent a release to indoor air. To prevent soil gas from entering indoor air, the sample purge volume will be pumped from the Vapor Pin through sample tubing to a new Tedlar bag. The Tedlar bag will later be taken outside and the PID will be used to check to see if the purge air volume has detectable levels of VOCs, which will be documented on the sample collection form. The air will be released from the Tedlar bag into the atmosphere away from the residence.

After the leak test and purging, a sub-slab soil vapor sample will be collected at each sampling location. Each sample will be collected in a 1-liter Summa (vacuum) canister fitted with a flow controller that includes a built-in 2-micron particulate filter. Each Summa canister will be connected to the sample tubing with a Swagelock® fitting. To collect a sample, the ball valve on the sample tubing will be opened first followed by the needle valve on the Summa canister. The flow controller will be calibrated by the laboratory to a flow rate not to exceed 200 milliliters (mL) per minute. The vacuum gauge on the flow controller will be monitored as the sample is collected. When the vacuum gauge reaches approximately 5 inches mercury (Hg)[15] the final vacuum pressure will be recorded, the canister valve and then the tubing ball valve will be closed, and the canister will be detached. The tubing ball valve will be closed to seal the slab penetration. After collecting the required samples at each location, the Vapor Pin and tubing assembly will be removed and the core hole patched with quick-set concrete to reseal the concrete slab.

3.1.1.2 Crawl Space Air Sampling

Residential crawl space air samples will be 24-hour, time-weighted average (TWA) samples. The TWA samples will be collected using integrated passive air samplers consisting of a 6-liter laboratory-certified evacuated Summa canister. Each Summa canister will be equipped with a pressure gauge and a calibrated critical orifice air flow controller.

Crawl space air samples will be collected in a dry location. Field personnel will place the canisters into the crawl space without entering the crawl space; if confined space entry is needed in order to place the canister, the associated building-specific procedure for placing the sample will be presented in the building-specific work plan addendum. Canisters will be clearly labeled with signs indicating the purpose of the canisters and that the canisters are not to be interfered with or moved.

The TWA Summa canisters will be evacuated to a vacuum pressure of 25 to 30 inches Hg by Eurofins Lancaster Laboratories, Inc. (LLI). A final vacuum pressure reading greater than ambient (i.e.,

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[15] It is important to close the canister valve with some vacuum pressure remaining because if the laboratory receives a Summa canister without vacuum (i.e., approximately 0 inches Hg) upon arrival at the laboratory, the laboratory might interpret that a possible leak from the canister that occurred during transport.

zero inches Hg) indicates a valid sample; however, canister closure will be targeted for a vacuum pressure of 5 inches Hg to provide a margin of safety. Canister pressures will be checked within 1 to 2 hours after beginning sampling to evaluate whether air flow controllers are functioning properly. Observed hourly pressure losses greater than one-twenty-fourth (1/24th) of the initial pressure will be considered indicative of a faulty flow controller. Any canisters observed to have a faulty flow controller will be replaced with a backup canister and flow controller.

3.1.1.3 Indoor Air Sampling

Residential indoor air samples will be 24-hour, TWA samples. The TWA samples will be collected using integrated passive air samplers consisting of a 6-liter laboratory-certified evacuated Summa canister. Each Summa canister will be equipped with a pressure gauge and a calibrated critical orifice air flow controller.

In order to sample receptor breathing space air, canister inlet valves height will be determined for each sample location based on anticipated receptors and receptor activity. For most locations, a height of approximately 3 to 5 ft aboveground surface is anticipated to approximate the breathing zone. Canisters will be clearly labeled with signs indicating the purpose of the canisters and that the canisters are not to be interfered with or moved.

The TWA Summa canisters will be evacuated to a vacuum pressure of 25 to 30 inches Hg by LLI. A final vacuum pressure reading greater than ambient (i.e., zero inches Hg) indicates a valid sample; however, canister closure will be targeted for a vacuum pressure of 5 inches Hg to provide a margin of safety. Canister pressures will be checked within 1 to 2 hours after beginning sampling and about 1 to 2 hours before the planned completion of sampling to evaluate whether air flow controllers are functioning properly. Observed hourly pressure losses greater than one-twenty-fourth (1/24th) of the initial pressure will be considered indicative of a faulty flow controller. Any canisters observed to have a faulty flow controller will be replaced with a backup canister and flow controller.

3.1.1.4 Ambient Air Sampling

Ambient air sample locations will 24-hour, TWA samples. The sample will be collected using a 6-liter laboratory-certified evacuated Summa canister. The Summa canister will be equipped with a pressure gauge and a calibrated critical orifice air flow controller for collection of the TWA samples. Canister inlet valves will be placed near HVAC inlets (if present), but more likely upwind of the houses, at a minimum height of 5 ft aboveground surface. If ambient air samples are placed upwind of the building of interest, the final location will be selected at time of sampling and the canister inlet valve will be placed at a height greater than or equal to 5 ft. The canister will be labeled with signs indicating its purpose and that the canister is not to be interfered with or moved.

The background sample Summa canisters will be evacuated to a vacuum pressure of 25 to 30 inches Hg by LLI. A final vacuum pressure reading greater than ambient (i.e., zero inches Hg) indicates a valid sample; however, canister closure will be targeted for a vacuum pressure of 5 inches Hg to provide a safety margin. Canister pressure will be checked within 1 to 2 hours after beginning sampling to evaluate whether the air flow controller is functioning properly. Observed hourly pressure losses greater than one-twenty-fourth (1/24th) of the initial pressure will be considered indicative of a faulty flow controller. If the canister is observed to have a faulty flow controller, it will be replaced with a backup canister and flow controller:

Atmospheric conditions during the sampling period, including temperature, barometric pressure, wind direction, wind speed, and precipitation totals, will be recorded using a combination of publicly available meteorological data from a weather station[16] (located within about 0.5 miles from the residences where sampling will occur), and information collected from the residents of specific houses regarding average household temperatures.

3.1.2 LABORATORY PROCEDURES

This section provides information regarding sample shipment and analysis for sub-slab soil gas samples and air samples (collectively crawl space air, indoor air, and ambient air samples).

3.1.2.1 Sub-slab Soil Gas Sample Handling and Analysis

At the end of the field day or on the following business day, Summa canisters will be shipped using the original shipping packaging under chain of custody (COC) procedures to Boeing’s contracted laboratory LLI West Coast Regional Air Toxics branch in Folsom, California; the previous LLI lab branch used for this project was in Pennsylvania, and the switch to the California branch is recent. Samples will be analyzed for concentrations of TCE, trans-1,2-DCE, cis-1,2-dichloroethene[17] (cis-1,2-DCE), and VC by EPA Method TO-15. An accelerated turnaround time of 3 days will be requested for initial vapor intrusion assessments.

Final data packages will be validated, and validated results will be entered in the site-wide database for inclusion in supplemental reports. The 2012 quality assurance project plan (QAPP; Landau Associates 2012) identified the Pennsylvania LLI air lab and included procedures pertaining to that particular division of LLI; Boeing is in the process of updating QAPP to reflect procedures pertaining to the LLI California Air Toxics lab branch. The LLI California Air Toxics lab branch has different limits

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[16] Data will be primarily obtained from the Celery Avenue meteorological station; station identification is KWAALGON3.

[17] Cis-1,2-DCE does not currently have a MTCA Method B indoor air cleanup level and is not a vapor intrusion constituent of concern. However, per Ecology’s request (Ecology 2013a), it will be reported because it is a breakdown product of TCE.

of quantitation (LOQ; i.e., the detection limit) than the Pennsylvania branch; the new LOQs for TCE, cis-1,2-DCE, trans-1,2-DCE, and VC by Method TO-15 are as follows:

Analyte	LOQ ($\mu g/m^3$)
Trichloroethene (TCE)	2.7
Cis-1,2-Dichloroethene (cis-1,2-DCE)	2.0
Trans-1,2-Dichloroethene (trans-1,2-DCE)	2.0
Vinyl Chloride (VC)	1.3

3.1.2.2 Air Sample Handling and Analysis

Summa canisters will be shipped using the original shipping packaging under COC procedures to Boeing's contracted laboratory LLI West Coast Regional Air Toxics branch in Folsom, California. Samples will be analyzed for total concentrations of TCE, trans-1,2-DCE, cis-1,2-DCE, and VC select VOCs by EPA Method TO-15 selected ion monitoring (SIM). An accelerated turnaround time of 3 days will be requested for initial vapor intrusion assessments.

Final data packages will be validated, and validated results will be entered in the site-wide database for inclusion in supplemental reports. The LLI California Air Toxics lab branch has different limits of quantitation (LOQ; i.e., the detection limit) than the Pennsylvania branch; the new LOQs for TCE, cis-1,2-DCE, trans-1,2-DCE, and VC by Method TO-15 SIM are as follows:

Analyte	LOQ ($\mu g/m^3$)
Trichloroethene (TCE)	0.11
Cis-1,2-Dichloroethene (cis-1,2-DCE)	0.079
Trans-1,2-Dichloroethene (trans-1,2-DCE)	0.40
Vinyl Chloride (VC)	0.026

3.1.3 SAMPLE LABELING

This section describes the creation of the sample identification (ID) number, which will be used for sub-slab soil vapor (i.e., soil gas), crawl space air, indoor air (includes basement air), and ambient air samples. Sample identification will be as follows:

- Location type: sub-slab soil vapor (SSV), crawl space air (CSA), indoor air (IA), or ambient air (AA)
- The sample number will be a three digit consecutive number
- Date of sample collection by year, month, and day (e.g., 20130603).

Thus, an indoor air sample collected at sample location 003 on June 3, 2013, would be assigned the following sample ID number:

IA003-20130603

IA	**003**	**20130603**
Location type (indoor air)	Sample number	Date– (yyyymmdd)

An example sample ID number for a sub-slab soil vapor sample, crawl space air sample, and an ambient air sample collected on the same day would be:

- SSV055-20130603 would represent the 55th sub-slab soil vapor sample collected during the RI to date, collected on the same day as the above indoor air sample.
- CSA002-20130603 would represent the 2nd crawl space air sample collected during the RI to date, collected on the same day as the above indoor air sample.
- AA015-20130603 would represent the 15th ambient air sample collected during the RI to date, collected on the same day as the above indoor air sample.

3.2 PROCEDURES WHEN USING PASSIVE DIFFUSIVE SAMPLERS

The following three sub-sections present sample collection procedures, laboratory procedures, and sample labeling procedures when using passive diffusive samplers.

3.2.1 SAMPLE COLLECTION PROCEDURES

Time-integrated air sample analytical results will be obtained in select homes over a 21-day period from indoor air and crawl space air (if a crawl space is present) using passive Radiello® samplers, specifically model Radiello® 130 (R130). A Radiello® sampler is a passive diffusive air sampler that consists of a diffusive protective body made of porous polypropylene in which a cartridge of adsorbent is inserted. Due to the narrow and cylindrical (radial) design of the adsorbent cartridge, the uptake rate is at least 3 times that of axial diffusive sampling designs. The type of adsorbent is selected based on analytic needs. All components of the Radiello® samplers appropriate for the collection of VOCs will be provided by the analytical laboratory.

Radiello® samplers will be used at select residences[18] (if permission is granted) closest to observed TCE concentrations at the water table. At a residence where permission has been granted to use the Radiello® samplers, one passive/diffusive sample will be collected from the ground floor. If the residence also has a crawl space or basement, one sample will also be collected from crawl space or basement air. Sample location and height will be identical to the Summa canister sampling location with which it is coupled. Sample collection will use the following protocol (additional instructions provided by the Radiello® sampler manufacturer are included in Appendix F):

- Immediately prior to placement at the planned sample location, the adsorbing cartridge will be removed from its protective packaging and placed in the previously assembled Radiello® supporting plate/diffusive body. The identification label associated with each adsorbing

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[18] Per Ecology and WDOH comments and meetings related to the work plan comments, approximately three residences were identified as candidates where use of passive diffusive samplers is of particular interest.

cartridge will be attached to the supporting plate and the identification information will be recorded in the field sampling notebook and on the sample collection form. During assembly, nitrile gloves will be worn to minimize any potential contamination of the adsorbing cartridge.

  - Crawl Space Samples: Crawl spaces will be accessed using available access points. The fully assembled Radiello® sampler will be placed on the floor as close to the center of the crawl space as possible, and the sampling start date and time (to the nearest minute) will be recorded on the sample label and field notes. After placing the Radiello® sampler, the access door will be closed. Field personnel will place the samplers as far into the crawl space as possible without entering; if confined space entry is needed in order to place the sampler, the associated building-specific procedure for placing the sample will be presented in the building-specific work plan addendum.
  - Basement Samples: Basements will be accessed using presently available access points. A Radiello® sampler will be placed in a central location within the main portion of the basement (to be determined in the field), and the sampling start date and time (to the nearest minute) will be recorded on the sample label and field notes. The height of the sampler will be determined for each sample location based on anticipated receptors and receptor activity.
  - Indoor Air Samples: The field team will place a Radiello® sampler within the house in a central location within the main living space, and the sampling start date and time (to the nearest minute) will be recorded on the sample label and field notes. The height of the sampler will be determined for each sample location based on anticipated receptors and receptor activity.

- Atmospheric conditions during the sampling period, including temperature, barometric pressure, wind direction, wind speed, and precipitation totals, will be recorded using a combination of publicly available meteorological data from a weather station[19] (located within about 0.5 miles from the residences where sampling will occur), and information collected from the residents of specific houses regarding average household temperatures.

After the sample period is complete, samplers will be retrieved from the sample locations. At the time of removal, the adsorbing cartridges will be placed back in the original protective tube and the adsorbing tube identification label will be placed on the protective tube, such that the barcode is parallel the axis of the tube. The sample stop date and time, to the nearest minute, will be recorded in the field sampling notebook or sample collection form. Samples will be kept cool, but do not need to be chilled on ice.

3.2.2 LABORATORY PROCEDURES

Completed sample containers will be shipped under COC procedures to Boeing's contracted laboratory (LLI West Coast Regional Air Toxics branch in Folsom, California). Radiello® R130 samplers will be submitted to the analytical laboratory for chemical analysis of TCE by gas

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[19] Data will be primarily obtained from the Celery Avenue meteorological station; station identification is KWAALGON3.

chromatography/mass spectrometry (GC/MS). The TCE reporting limit for the R130 analysis by GC/MS is 0.05µg/m^3.

An accelerated turnaround time of 3 days will be requested for initial vapor intrusion assessments. Final data packages will be validated, and validated results will be entered in the site-wide database for inclusion in supplemental reports.

3.2.3 SAMPLE LABELING

This section describes the creation of the sample identification (ID) number specific to samples collected using Radiello® samplers, which will be used for select crawl space air and indoor air (includes basement air) samples. Sample identification will be as follows:

- Location type: crawl space air (CSA) and indoor air (IA)
- The sample number will be a three-digit consecutive number
- R for Radiello®
- Date of sample collection by year, month, and day (e.g., 20130603).

Thus, an indoor air sample collected using a Radiello® sampler at sample location 003 on June 3, 2013, would be assigned the following sample ID number:

IA003-R-20130603

IA	003	R	20130603
Location type (indoor air)	Sample number	Radiello®	Date– (yyyymmdd)

An example of a sample ID number for a CSA sample collected on the same day would be: CSA002-R-20130603; this represents the 2nd CSA sample collected during the RI to date, collected on the same day as the above indoor air sample.

4.0 DATA ANALYSIS AND MITIGATION ASSESSMENT

Assessing the vapor intrusion pathway must always be based on utilizing multiple lines of evidence (MLE). The collected residential sub-slab soil gas, indoor air (basement and main floors), crawl space, and ambient air data are considered residential Tier II data[20]. In the context of this work plan, sub-slab soil gas samples and crawl space samples will be treated as secondary lines of evidence; indoor air samples are primary lines of evidence. The residential Tier II data will be evaluated using the screening levels in Table 1 and the IAALs identified in section 2.1.2. Depending on maximum concentration of the initial samples from a given residence, more sampling or mitigation planning may be conducted. Planned actions will be discussed with Ecology.

The evaluation of results will be conducted as described below:

Comparison of indoor air and crawl space concentrations to indoor air screening levels

- If the maximum detected concentrations from the initial sampling event are less than the indoor air screening levels, additional sampling during the cold weather season (October 2013 to May 2014) will be planned to confirm the results of the initial sampling event. If the maximum detected concentrations from the cold weather season sampling event are less than the indoor air screening levels, no further indoor air sampling will be conducted unless groundwater concentrations underlying the residence change, increasing the potential for vapor intrusion.
- If the maximum detected concentration of one or more constituents is equal to or greater than the indoor air screening level, the concentrations in ambient air will be subtracted from the reported results prior to further evaluation. The calculated results will be compared to the indoor air screening levels.
    - If the maximum calculated concentrations from the initial sampling event are all less than the indoor air screening levels, additional sampling during the cold weather season will be planned to confirm the results of the initial sampling event. If the maximum calculated concentrations from the cold weather season sampling event are all less than the indoor air screening levels, no further indoor air sampling will be conducted unless groundwater concentrations underlying the residence change, increasing the potential for vapor intrusion.
    - If a maximum calculated concentration is equal to or greater than the indoor air screening level, the cumulative carcinogenic risk and HI for that sample will be calculated as described in Section 2.1.2 and compared to the indoor air action levels as described in the following bullet.

Comparison of indoor air cumulative carcinogenic risk and HI to IAALs

- If the cumulative carcinogenic risk and HI from the initial sampling event are less than or equal to the IAALs, additional sampling during the cold weather season will be planned to confirm the results of the initial sampling event.

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[20] Ambient air samples often accompany collection of indoor air samples to verify background conditions. When ambient air is sampled during indoor air sampling, the indoor air concentration is commonly estimated to be the [max measured indoor concentration] – [representative measured, same-day, ambient air concentration] (Ecology 2009).

  - If the cumulative carcinogenic risk and HI from the cold weather season sampling event are less than or equal to the IAALs, VOC concentrations in groundwater will continue to be evaluated. No further indoor air sampling will be conducted unless groundwater concentrations underlying the residence change, increasing the potential for vapor intrusion.
  - If the cumulative carcinogenic risk or HI from the cold weather season sampling exceeds an IAAL, see the next bullet.
- If the cumulative carcinogenic risk or HI exceeds the indoor air action level for one or more constituents during either the initial or cold weather sampling event, the potential for the results to have been impacted by background sources or data quality problems will be considered.
  - If there is no reason to suspect that air sample results were impacted by background sources or data quality problems, Boeing will begin planning for mitigation and will contact the property owner and tenants, if applicable, to discuss mitigation options.
  - If there is reason to suspect that background sources of VOCs influenced the air sample results or if data is not of adequate quality for decision making, a second round of sampling will be conducted within about 2 weeks to verify the results. In addition, a background source evaluation will be completed at the time of the second sampling event to assist in distinguishing between concentrations from background sources and concentrations related to vapor intrusion of VOCs present in groundwater near the residence.

Comparison of indoor air TCE concentration to TCE short-term screening level

- If, after subtraction of ambient air results, the maximum calculated concentration of TCE in an indoor air sample exceeds the short-term indoor air screening level and there is a woman of child bearing age that lives in the residence, Boeing will provide temporary housing for her and her family while mitigation planning and implementation are conducted.

Results from the 24-hour TWA indoor air samples collected using Summa canisters will be compared with the available results from the following: indoor air samples collected using passive diffusive samplers and sub-slab samples and crawlspace samples collected using Summa canisters. The comparison will be considered in the evaluation of whether detected concentrations of VOCs in indoor air are likely to be a result of vapor intrusion. Because the passive diffusive air samples represent a 3-week period of time rather than 24 hours, they may provide information on longer-term average air concentrations. However, they may also be more likely to be impacted by background sources. The sub-slab and crawlspace results, if available, are less likely to be impacted by background sources than indoor air samples. If the results of the 24-hour TWA and the passive diffusive, crawlspace, or sub-slab samples are not consistent, Boeing will discuss with Ecology the potential reasons for the differences and appropriate further actions.

Depending on the initial sample results, the next step will be to: 1) conduct prompt repeat sampling to evaluate suspected background sources and confirm results, 2) conduct repeat sampling during the cold weather season, or 3) move to mitigation.

If the decision is made to mitigate a residence, the VOC data from the residence and the building survey documentation can be used to assess conceptually what vapor intrusion mitigation technique is most feasible. A mitigation decision tree presenting typical methodology by which mitigation designs are selected for a given residence is provided as Figure 6. Conceptual vapor mitigation scenarios for typical residences in the Algona neighborhood will be presented in a separate technical memorandum. If appropriate and agreed to by the property owner and tenant, if applicable, mitigation will be conducted as an interim action to minimize vapor intrusion and reduce indoor air concentrations of VOCs related to shallow groundwater impacted by the Boeing facility.

5.0 DATA REPORTING AND DISTRIBUTION

Boeing will send a copy of the official laboratory results to property owners, tenants, if applicable, and Ecology within approximately 3 to 4 weeks of sampling, unless concentrations are elevated and require a more immediate communication[21]. A data letter report will accompany the laboratory results with a brief comparison of the results to the residential screening and indoor action level criteria. Sample results that are below detectable laboratory limits or results that are below screening levels (MTCA Method B cleanup levels) or IAALs will be summarized briefly and repeat sampling during the cold weather season will be recommended. Sample results that trigger prompt repeat sampling or possible mitigation will be discussed in greater detail. If repeat sampling is recommended, the data letter report will explain that Boeing's consultant Landau Associates will call to schedule repeat sampling. If mitigation is recommended, an explanation of the most applicable conceptual vapor intrusion mitigation system for their residence will be attached. We understand that, following review of the data letter report, Ecology will respond to the property owners, tenants, if applicable, and Boeing.

In addition to the data letter reports, Boeing will prepare an initial vapor intrusion assessment summary technical memorandum that summarizes the overall results of all participating residences of the proposed 23. The data will be presented in such a way as to not directly link data results to a particular residence to provide some privacy. Re-evaluation of the PCLs will be included with this technical memorandum, as previously mentioned, as well as recommendations for any additional step-out vapor intrusion assessment work.

Ecology is the agency overseeing the RI activities, including evaluation of the vapor intrusion pathway. Ecology maintains copies of all RI-related documents which are subject to public disclosure under the Freedom of Information Act. Vapor intrusion results presented in the technical memorandum may also be posted on the Ecology project website; individual resident data letter reports will not be posted to the website to provide some level of privacy.

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[21] If, for example, the TCE concentration in indoor air is greater than the short-term TCE IAAL and women of child bearing age live at the residence, the results would be communicated to the property owner and resident immediately.

6.0 SCHEDULE

This tentative schedule includes the proposed shallow groundwater investigation, the second public meeting, the residential vapor intrusion assessments, and mitigation (if needed). The schedule is dependent on a number of factors, but is intended to occur generally within a two to three month period (if possible).

- Direct-push shallow groundwater sampling investigation (completed April 30th)
  - Results technical memorandum (draft submitted to Ecology May 28)
- Second public meeting (scheduled for June 13)
- Initial Vapor Intrusion Assessments (building survey visits started June 3)
- Any Necessary Step-out Vapor Intrusion Assessments (anticipated to begin after the initial vapor intrusion assessments technical memorandum is complete and additional residences have been selected by Boeing and Ecology).

The anticipated timeline for the residential vapor intrusion assessments for a case where the property owner is the resident is as follows; coordinating access for properties with tenants may result in longer timelines:

- Ecology sends property owner and resident notification packet.
- Resident contacts Landau Associates to schedule building survey visit.
- Building survey visits are conducted, during which the Boeing information packet is distributed and the access agreement may be signed by resident; if resident signs and mails the access agreement to Boeing later, Boeing will make a copy and send it to the resident. If resident is not the property owner, copy of the information packet and access agreement is mailed to property owner shortly after building survey visit.
- Boeing submits work plan addendum for the residence to Ecology for approval.
- After the addendum is approved, Boeing schedules sampling with resident.
- Boeing conducts sampling.
- Samples are submitted for analysis; the data will be returned on an approximate 3-day turnaround time.
- Results distribution to property owner and Ecology (approximately 3 to 4 weeks after sampling) unless concentrations exceed TCE short-term action level that warrants immediate communication.
- Mitigation (if needed; timeframe dependent on receptor and concentrations).

7.0 USE OF THIS REPORT

This work plan 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 Landau Associates. 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 Landau Associates, will be at the user's sole risk. Landau Associates 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.

This document has been prepared under the supervision and direction of the following key staff.

LANDAU ASSOCIATES, INC.

Lauren K. Knickrehm, EIT
Project Engineer

Charles P. Halbert, P.E.
Principal

LKK/CPH/emt

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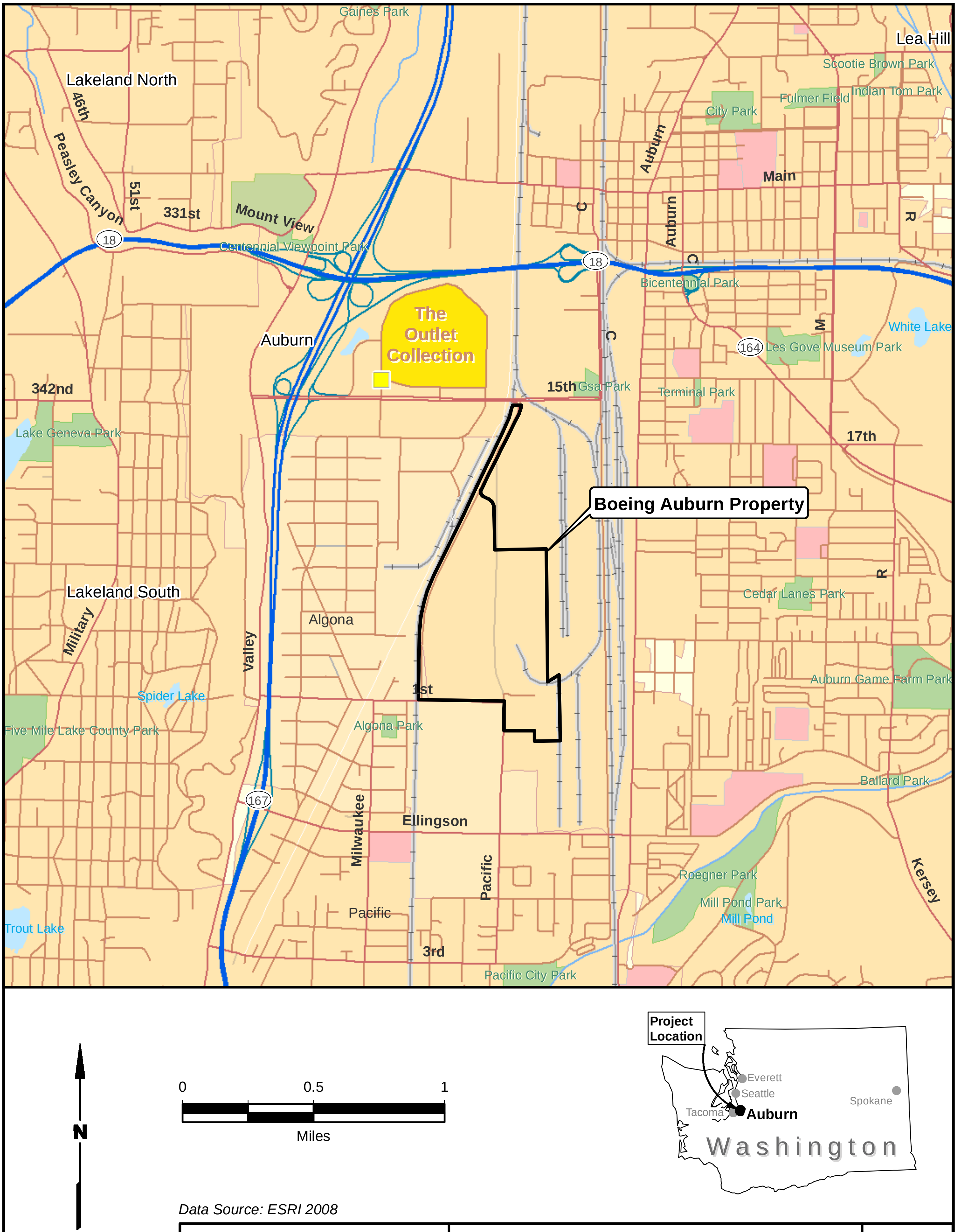


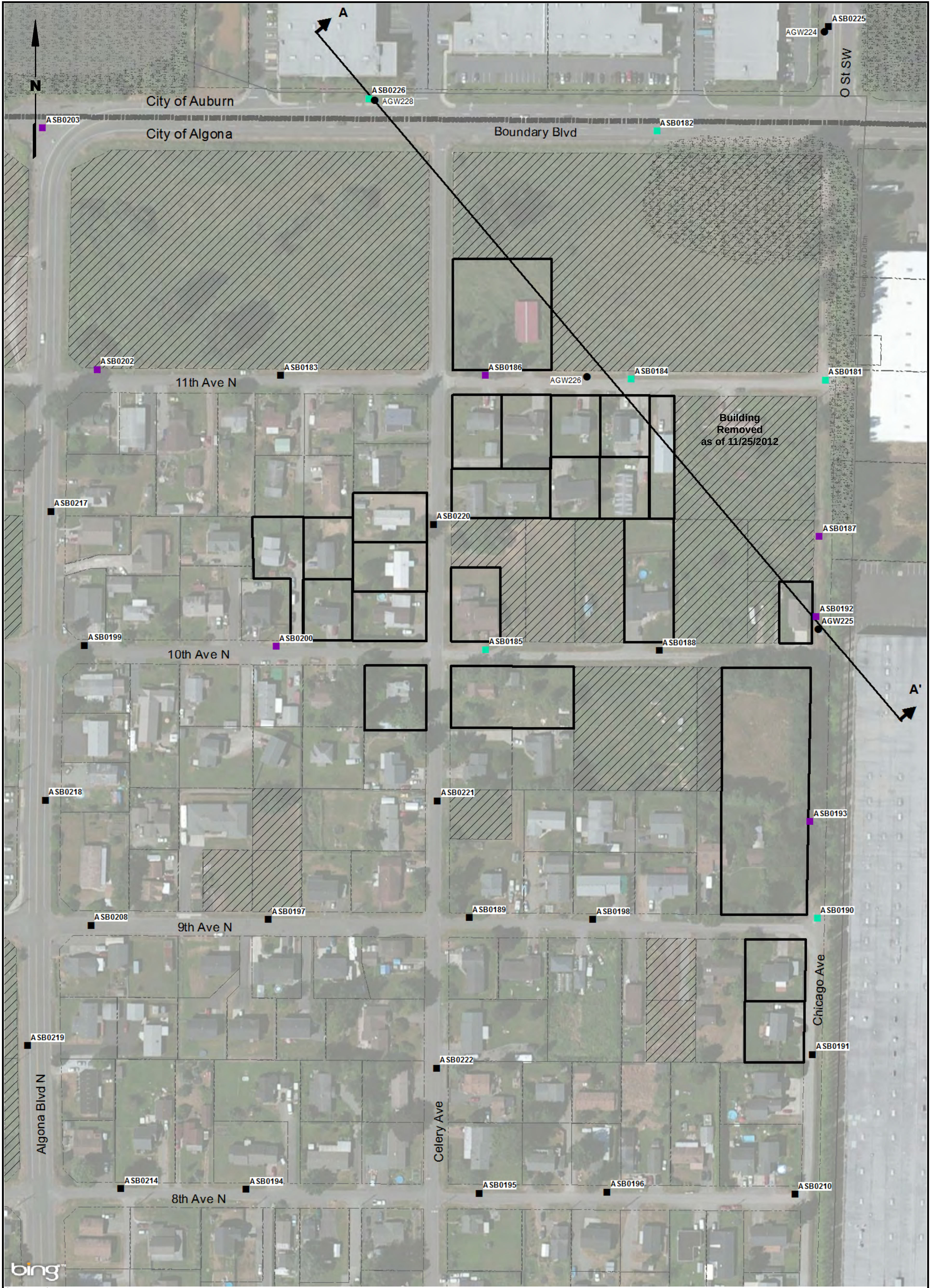
Data Source: ESRI 2008

Y:\Projects\025164\MapDocs\100\Figure 1 Vicinity Map.mxd 3/8/2013

LANDAU ASSOCIATES

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

Y:\Projects\025164\MapDocs\100\109\NorthernAlgona\Figure_2_Spring2013_Data_Shallow.mxd 5/28/2013 NAD 1983 StatePlane Washington North FIPS 4601 Feet



Legend

● Shallow Monitoring Well Location

April 2013 Direct Push Water Table VOC Concentrations

■ TCE or vinyl chloride exceed PCL

■ TCE or vinyl chloride are detected (neither exceed PCL)

■ TCE and vinyl chloride are non-detect

Cross Section A-A'

▨ Vacant Parcel

☐ Initial Vapor Intrusion Assessment Residences

Notes

1. Groundwater Preliminary Concern Levels (PCL):
   trichloroethene (TCE) ≥ 1 ppb
   vinyl chloride (VC) ≥ 0.23 ppb
2. All data from the April 2013 direct push drilling event is presented in a separate technical memorandum.
3. Cross Section A-A' provided on Figure 3.
4. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Data Source: Bing 2010, Parcel Data Source: King County GIS 2010

0 150 300
Scale in Feet

LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

Northern Algona Spring 2013 Water Table Data and Vapor Intrusion Assessment Area

Figure
2

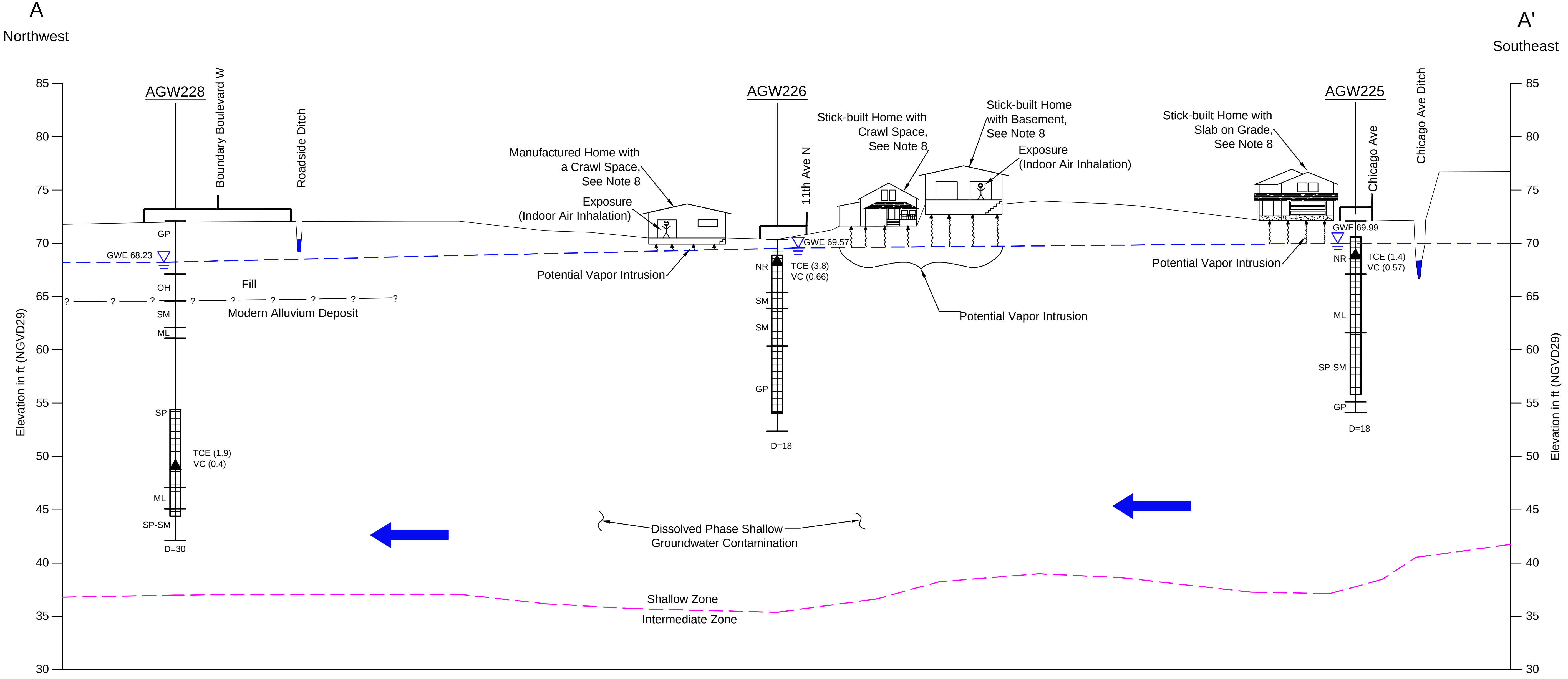
Legend

AGW228 — Exploration Designation
— Top of Exploration
— Groundwater Level
GP — USCS Symbol Designation
— Well Screen Interval
— Bottom of Exploration
D=30 — Total Depth of Boring (ft, BGS)

Groundwater Flow Direction
▲ Groundwater Sample Depth
Estimated Ground Surface
Aquifer Zone Break
Shallow Groundwater

Notes

1. Vertical datum is NGVD29.
2. Existing ground surface based on 2002 Puget Sound LiDAR Consortium, converted from NAVD88 to NGVD29, and modified based on site observations.
3. Groundwater elevations were collected in March 2013.
4. NR = No Recovery
5. Presence of fill unknown Shallow groundwater levels measured West of Chicago Avenue ditch are less than 5 ft below ground surface (BGS); therefore the vadose zone appears to be limited in the Algona neighborhood.
6. Trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), trans-1,2-dichloroethene (trans-1,2-DCE), and vinyl chloride (VC) concentrations are from March 2013 and are in Õg/L.
7. The provided TCE and VC concentrations exceed the Algona-specific shallow groundwater vapor intrusion preliminary concern levels (PCLs) of 1.0 Õg/L (TCE) and 0.23Õg/L (VC).
8. The scale of the houses has been exaggerated in order to make them easily visible.
9. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.



0 100 200
Horizontal Scale 1" = 100'
Vertical Scale 1" = 10'

LANDAU ASSOCIATES

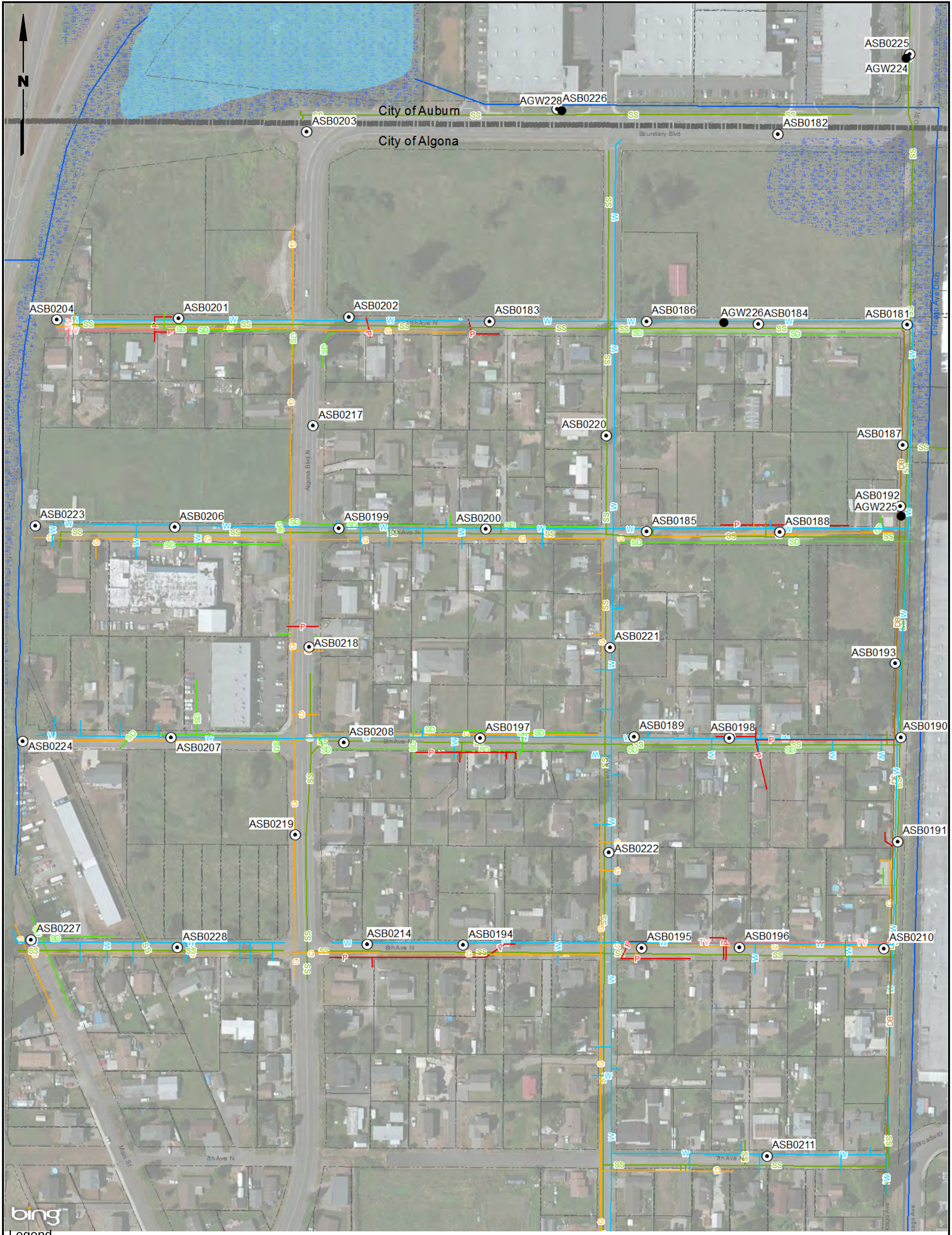
Boeing Auburn
Remedial Investigation
Auburn, Washington

Preliminary Residential Conceptual Model and Geologic Cross Section A-A'

Figure
3

Y:\025\164\T\CAD\CAD2013\SectionAA-JDE.dwg "Figure 3" 3/04/2013 | T:\025\164\T\CAD\CAD_2013\SectionAA-JDE.dwg (A) "Figure 3" 6/13/2013

Y:\Projects\025164\MapDocs\100\109\NorthernAlgona\Figure_4_UtiltyPlan.mxd 5/30/2013 NAD 1983 StatePlane Washington North FIPS 4601 Feet



Legend

⊙ Direct-Push Sampling Location

● Shallow Monitoring Well Location

—TV— Cable/TV

—DB— Duct Bank

—G— Gas Line

—P— Power Line

—SD— Stormdrain

—SS— Sanitary Sewer

—W— Water

Notes

1. A total of 49 direct push borings were conducted. Six of the 49 borings are south of 7th Ave N and are not shown here.
2. All boring locations sampled at the water table, and some at deeper intervals.
3. The City of Algona stormdrain system is an interconnected series of ditches and pipes
4. Typical Utility Depths According to Utility Services Providers:
    - Cable/TV - 18-24"
    - Duct Bank - Unknown
    - Gas Line - 24-44"
    - Power Line - 36-47"
    - Stormdrain - Varies
    - Sanitary Sewer - Varies
    - Water: 24-48"
5. The locations of all utilities are approximate and were documented in the field using utility locate markings. Some side-sewers were located near direct-push locations by running a video camera into the sewer line and observing side-sewer connections.
6. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Data Source: Bing 2010, Parcel Data Source: King County GIS 2010

0 200 400

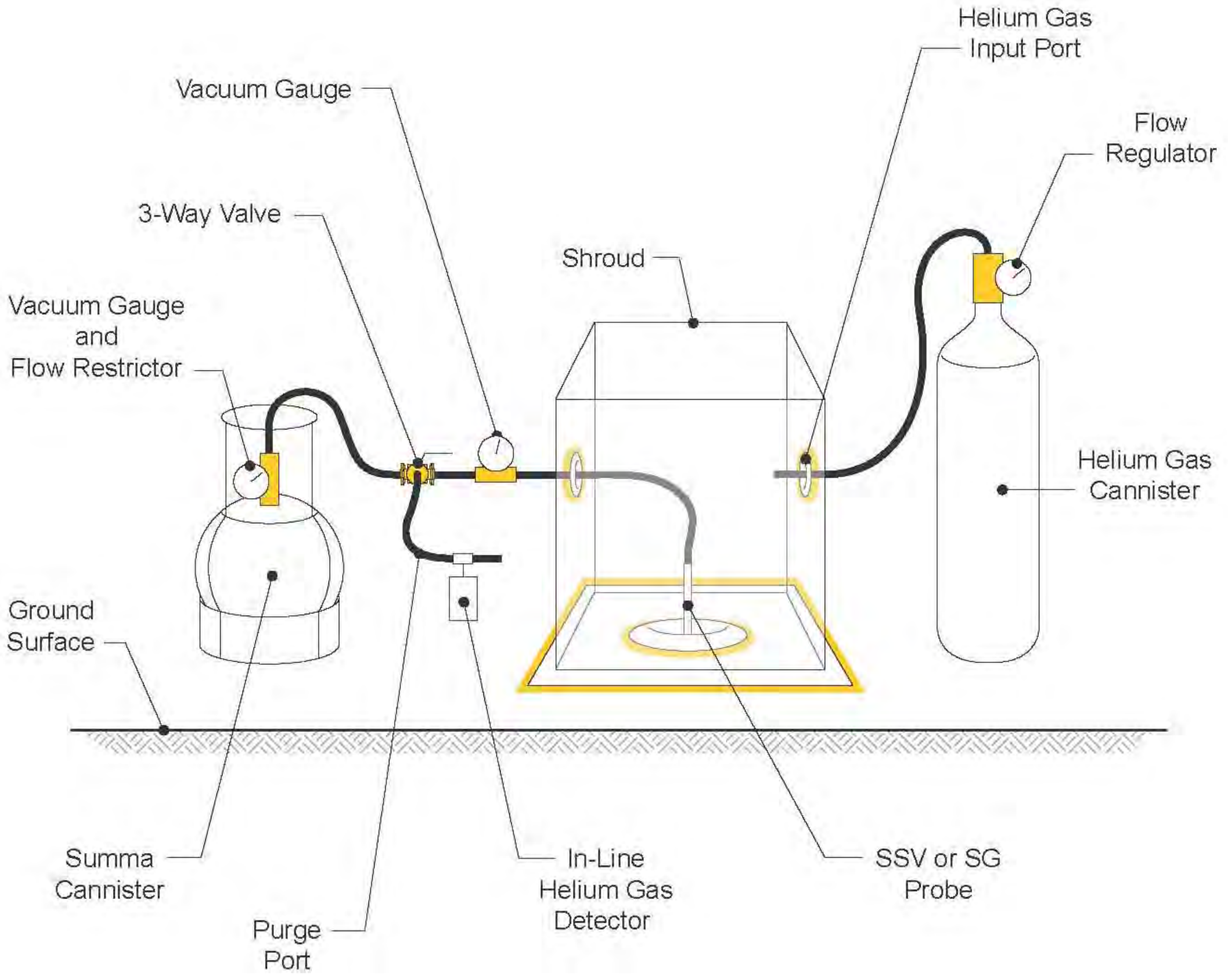
Scale in Feet

LANDAU ASSOCIATES

Boeing Auburn
Auburn, Washington

Northern Algona
Utility Location Map and April 2013
Direct-Push Boring Locations

Figure
4



Note:
Yellow shading indicates connections where leakage may occur. Attention to ensuring proper connections or seal is required.

Not to Scale

LANDAU ASSOCIATES

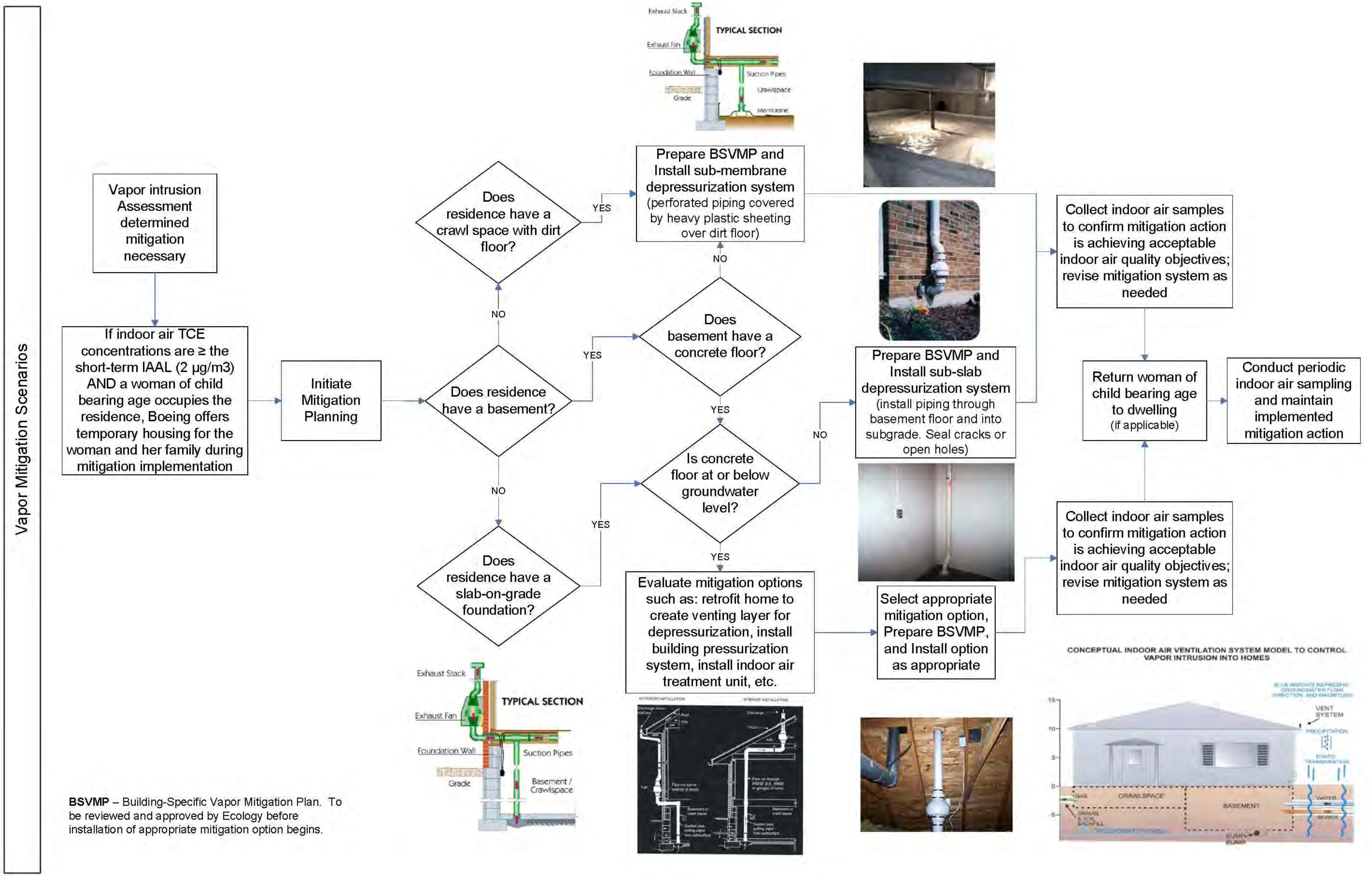
Figure provided by courtesy of URS.

Boeing Auburn
Auburn, Washington

Sub-slab Soil Gas Sampling
Helium Leak Test

Figure
5

6/7/13 \\TACOMA3\Project\025\164\R\Vapor Intrusion\2013\Res VI WP\2013 Res VI WP\Client Response to Comments Dr 060713\Figs\Backup Files\Figure 6 decision tree mitigation.docx



Vapor intrusion Assessment determined mitigation necessary

If indoor air TCE concentrations are ≥ the short-term IAAL (2 µg/m3) AND a woman of child bearing age occupies the residence, Boeing offers temporary housing for the woman and her family during mitigation implementation

Initiate Mitigation Planning

Does residence have a basement?

Does residence have a crawl space with dirt floor?

Does residence have a slab-on-grade foundation?

Does basement have a concrete floor?

Is concrete floor at or below groundwater level?

Prepare BSVMP and Install sub-membrane depressurization system (perforated piping covered by heavy plastic sheeting over dirt floor)

Prepare BSVMP and Install sub-slab depressurization system (install piping through basement floor and into subgrade. Seal cracks or open holes)

Evaluate mitigation options such as: retrofit home to create venting layer for depressurization, install building pressurization system, install indoor air treatment unit, etc.

Select appropriate mitigation option, Prepare BSVMP, and Install option as appropriate

Collect indoor air samples to confirm mitigation action is achieving acceptable indoor air quality objectives; revise mitigation system as needed

Return woman of child bearing age to dwelling (if applicable)

Conduct periodic indoor air sampling and maintain implemented mitigation action

Collect indoor air samples to confirm mitigation action is achieving acceptable indoor air quality objectives; revise mitigation system as needed

BSVMP – Building-Specific Vapor Mitigation Plan. To be reviewed and approved by Ecology before installation of appropriate mitigation option begins.

LANDAU ASSOCIATES

Figure provided by courtesy of Haley & Aldrich.

Boeing Auburn
Auburn, Washington

Decision Tree – Mitigation Decision Tree

Figure
6

TABLE 1
MTCA METHOD B SCREENING LEVELS, PRELIMINARY CONCERN LEVELS, AND TCE SHORT-TERM EXPOSURE INDOOR AIR SCREENING LEVEL
ALGONA RESIDENTIAL VAPOR INTRUSION ASSESSMENT
BOEING AUBURN

	Residential Screening Criteria					**Indoor Air Screening Level**
	Indoor Air (µg/m^3)		Soil Gas (µg/m^3)	Groundwater (µg/L)		**Indoor Air (µg/m3)**
Constituents	MTCA Method B Standard Formula Value CUL (Used as Indoor Air Screening Level)	Risk	Shallow Soil Gas SL Protective of Method B Air CUL (a)	Shallow Groundwater SL Protective of Method B Air CUL	Shallow Groundwater PCL Protective of Method B Air CUL (b)	**Short-term Exposure SL (c)**
TCE	0.37	Carcinogenic	12	1.6	1.0	2.0
VC	0.28	Carcinogenic	9.5	0.35	0.23	--
Trans-1,2-DCE (d)	27	Non-carcinogenic	907	69	46	--

red font = New constituents or screening criteria added for application to the Algona residential vapor intrusion assessment.
MTCA = Model Toxics Control Act
PCL = Preliminary Concern Level
TCE = Trichloroethene
VC = Vinyl Chloride
Trans-1,2-DCE = Trans-1,2-Dichloroethene
CUL = cleanup level
SL = screening level
µg/m^3 = micrograms per cubic meter
µg/L = micrograms per liter

(a) These shallow soil gas screening levels will be used for evaluation of Algona sub-slab soil gas measurements. Collection of soil gas samples outside of residential building footprints is not included in the Work Plan.

(b) Ecology approved indoor air CULs, soil gas SLs, and shallow groundwater SLs for TCE and VC in November 2012 (Ecology 2012). However, due to the very shallow groundwater conditions in Algona, Ecology requested revised shallow groundwater preliminary concern levels in their 4/12/2013 comment letter on Boeing's *Draft Vapor Intrusion Evaluation and Assessment Approach* (Ecology 2013a).

(c) The short-term exposure TCE SL comes from EPA Region 10 and will be used per Ecology's comments (Ecology 2013a).

(d) Ecology also requested that TCE chemical breakdown products with MTCA Method B air CULs be screened; one such chemical (trans-1,2-DCE) has been detected in shallow groundwater in Algona and, therefore, will be screened in air and gas samples.

TABLE 2
CRITICAL NON-CANCER EFFECTS FOR CONSTITUENTS OF CONCERN IN INDOOR AIR
ALGONA RESIDENTIAL VAPOR INTRUSION ASSESSMENT
BOEING AUBURN

	Critical Non-Cancer Effects (a)		
Constituents of Concern	Immune System	Heart	Liver
TCE	Development Immunotoxicity	Heart malformations	--
VC	--	--	Liver cell polymorphism
Trans-1,2-DCE	Decrease in anti-body forming cells	--	--

TCE = Trichloroethene
VC = Vinyl chloride
Trans-1,2-DCE = Trans-1,2-Dichloroethene

(a) From EPA ERIS, accessed 4/17/13.

APPENDIX A

Notification and Permission Information Packet

The Boeing Company
P.O. Box 3707
Seattle, WA 98124-2207

Resident
Algona, Washington 98001

Subject: Residential Air and Sub-Slab Soil Gas Sampling Permission Request

Dear Resident:

The Boeing Company (Boeing) is working with the Washington State Department of Ecology (Ecology) to conduct a groundwater contamination study related to historical chemical releases from the Boeing Fabrication Division Auburn site (the facility) located at 700 15th Street, SW, Auburn, Washington 98002. The chemical that was released is called trichloroethene (TCE). TCE and the TCE breakdown products vinyl chloride, cis-1,2-dichloroethene (cis-1,2-DCE), and trans-1,2-dichloroethene (trans-1,2-DCE) are present in shallow groundwater at the top of the water table in the northeastern portion of the Algona residential neighborhood.

These chemicals are part of a family of compounds known as volatile organic compounds or VOCs. VOCs can vaporize from the groundwater and have the potential to move through the overlying soil into buildings and affect indoor air quality; this is called vapor intrusion. Boeing is conducting sampling to determine if vapor intrusion is occurring in residential buildings in your neighborhood. Your residence has been selected because it is located in an area where VOCs in groundwater could potentially affect indoor air. You should have already received an information packet from Ecology explaining the work that Boeing and Ecology are currently conducting in your neighborhood.

In order to determine if vapor intrusion is occurring at your residence, with permission from you and the property owner, Boeing's contractor Landau Associates will collect air samples from inside your residence and in your basement or crawl space if you have one. Testing involves the placement of sampling equipment at your residence as described in the provided handout "Understanding Indoor Air Sampling and Instructions for Residents." In addition, Landau Associates would like to collect sub-slab soil gas samples from your residence. Soil gas samples will be collected on the day following collection of air samples as described below. Boeing will be responsible for costs related to collection and analysis of the air samples. More than one sampling event may be required dependent on the outcome of the initial sampling event.

In order to prepare for the initial sampling and to conduct sampling activities, a minimum of four visits to your residence is anticipated. During the initial visit Landau Associates will provide an access agreement to you, collect information about the construction of your residence, and identify potential air sampling locations. During this first visit Landau Associates personnel will be accompanied by staff from Ecology who will be available to answer sampling-related questions. As described in the Vapor Intrusion Fact Sheet sent to you by Ecology, many materials and substances commonly found in residential settings contain VOCs that may be detected during indoor air sampling as background contamination. These materials are also identified in the provided handout "Understanding Indoor Air Sampling and Instructions for Residents." During the initial visit, Landau Associates will provide information on actions you can take to limit the potential for background contamination; one action is having Landau Associates return to help temporarily relocate household chemicals away from your residence prior to sampling. We anticipate that the initial visit will take approximately one to two hours to complete. We will mail a copy of the information sent to you by Ecology and the information provided to you during the initial visit by Ecology and Landau Associates, including the access agreement, to the owner of your residence.

After the access agreement is signed by both you and the property owner, Landau Associates personnel will schedule the sampling. They will place the sampling equipment in your residence and return to remove the sampling equipment 24 hours later, at the end of the sample collection period. We anticipate that the visits to set up and remove the sampling equipment should take approximately 30 minutes each to complete.

Following removal of the sampling canisters, sub-slab soil gas samples will be collected. Prior to collection of sub-slab soil gas samples, Landau Associates will review the sampling locations with a private utility locator to identify and mark conductible utilities in the sampling area. When possible, the utility locate will be completed on the same day as the sampling. Collection of sub-slab soil gas samples requires drilling a small diameter (less than 1-inch) core through the floor slab. Following soil gas sample collection, the cores will be patched with concrete. We anticipate that the soil gas sampling can be completed within 4 hours.

The air and soil gas samples will be sent to an analytical laboratory to measure the concentrations of the VOCs TCE, vinyl chloride, cis-1,2-DCE, and trans-1,2-DCE. The data results will be provided to you and the property owner approximately four weeks after sample collection. If VOCs are not detected, or if the detected concentrations are below levels of potential concern, a second sampling event will be conducted during the winter months (between October 2013 and May 2014) to verify the initial sampling results.

In the event that VOCs are detected at levels of concern, and contaminated groundwater is likely to be the source, Boeing will work quickly with Ecology to install a mitigation system that will reduce or eliminate vapor intrusion into your residence. Mitigation systems are typically not intrusive. Boeing will be responsible for costs associated with the installation and operation of the mitigation system. In some cases, a second sampling event will be needed prior to mitigation to confirm the results of the initial samples (for example, if background contamination is suspected).

An access agreement is included with this letter as Attachment 1. Boeing requests that you review the materials provided by Ecology and the materials provided during the initial visit and respond within two weeks. Boeing will also obtain permission from the property owner for the air and soil gas sampling activities. If you decide that you would like to have the sampling conducted at your residence, please sign the access agreement and fill out the scheduling and contact information form attached to this letter. If you signed and returned the access agreement to Landau Associates during the initial visit, you do not need to return a second copy. For your convenience, a stamped and addressed return envelope is included.

Boeing realizes how important our work is to your community. We are committed to completing a thorough evaluation which will lead to effective mitigation of potential risks associated with vapor intrusion identified during this assessment. We appreciate your time and cooperation with this study. If you have any questions, please contact the undersigned.

Sincerely,

James Bet
Boeing EHS Remediation Group
Phone 206-679-0433
james.n.bet@boeing.com

Enclosures:

- Attachment 1: Access Agreement
- Attachment 2: Scheduling and Contact Information
- Attachment 3: Understanding Indoor Air Sampling and Instructions for Residents

ACCESS AGREEMENT
(PROPERTY OWNER)

The person signing below represents that he or she owns the property ("Property Owner") or is the authorized representative of the Property Owner of the property described below ("Property"). The person signing below authorizes The Boeing Company ("Boeing") and its authorized representatives access to the Property at reasonable times for the sole purpose of conducting the activities described below. Boeing and its contractor, Landau Associates, Inc. ("Landau") will be conducting a building survey and collecting data, primarily from soil gas beneath a building slab on the Property.

Subject to the terms and conditions of this Access Agreement, I agree to allow Boeing and its representatives to perform any of the following tasks on the Property:

- Conduct a building survey (for example, evaluate building slab and ventilation system);
- Collect sub-slab soil gas samples for analysis;
- Collect indoor air samples for analysis;
- Collect crawl space air samples for analysis; and
- Collect outdoor air samples for analysis.

In granting this access, we understand that Boeing and its contractors will do the following:

- Boeing's contractor, Landau, will contact the Property Owner by mail, telephone, email or in person no less than five (5) days before conducting any activities on the Property;
- Upon request of the Property Owner, sample results will be provided to the Property Owner for the sample or samples collected on the Property;
- Prior to collection of sub-slab soil gas samples, Boeing or Landau will visit the Property with a private utility locator to identify and mark conductible utilities in the sampling area. Collection of sub-slab soil gas samples requires drilling a small diameter (i.e. less than 1-inch) core through the floor slab. Following soil gas sample collection, the cores will be patched with concrete.
- Boeing does not anticipate their activities will result in damage to the Property and will make reasonable efforts to prevent their activities on the Property from resulting in damage to the Property. Boeing will be responsible for reasonable costs arising directly from the work or activities of Boeing's agents, employees, contractors and subcontractors (except to the extent caused by the Property Owner), and will repair such damage to substantially its condition prior to any such damage; and
- All work will be performed in compliance with applicable federal, state and local laws, and will comply with applicable health and safety requirements.

This Access Agreement commences on the date of signature by the Property Owner and continues for a period of two (2) years from the date of such signature or until December 31, 2015, whichever is later. Boeing shall have the option of requesting one (1) year extensions to this Access Agreement beyond the expiration date for additional data collection. Either party may terminate this Access Agreement without cause by providing sixty (60) days written notice to Landau specifying the effective date for such termination.

Please review and check the box below:

☐ Property Owner grants permission to Boeing and Landau to take photographs while completing the sampling activities outlined above.

The following person acknowledges that he or she is the Property Owner or is otherwise authorized to execute this Access Agreement of the property described below.

PROPERTY OWNER	**THE BOEING COMPANY**
Signature	Signature
Name	Name
Address	Address
Date	Date

When completed, please return this form in the enclosed self-addressed and stamped envelope to Landau at the following address:

Landau Associates, Inc.
950 Pacific Avenue
Suite 515
Tacoma, WA 98402
Attention: Jennifer Wynkoop

Questions or comments regarding the work to be conducted pursuant to this Access Agreement should be directed to:

Jennifer Wynkoop
950 Pacific Avenue
Suite 515
Tacoma, WA 98402
(253) 284-4879
jwynkoop@landau.com

James Bet
Boeing Environment, Health & Safety
PO Box 3707 MC 9U4-26
Seattle, WA 98124-2207
(206) 679-0433
james.n.bet@boeing.com

Robin Harrover
Washington State Department of Ecology
Northwest Regional Office
3190 160th Avenue S.E.
Bellevue, WA 98008-5452
(425) 649-7232

Scheduling and Contact Information

Return in self-addressed envelope by DATE to:

Landau Associates, Attn: Lauren Knickrehm
950 Pacific Avenue, Suite 515
Tacoma, Washington 98402

NAME (point of contact): ______________________________________

Property Owner or Tenant? (please circle one)

ADDRESS: ____
____

PHONE NUMBER(S): ____________________________(Home)
____________________________ (Cell/Other)

EMAIL ADDRESS: ____

If you are a tenant, please provide the property owner’s name, phone number, and address:

NAME (point of contact): ______________________________________

ADDRESS: ____
____

PHONE NUMBER(S): ____________________________(Home)
____________________________ (Cell/Other)

EMAIL ADDRESS: ____

BEST DAYS AND TIMES FOR A SITE VISIT (From June # to June #)

Day during business week: M Tu W Th Fri (please circle all that apply)

One-hour block start time: AM: 8 9 10 11
PM: 12 1 2 3 4 5 6

If you have any questions, or if you would prefer to schedule the appointment over the phone, please contact our project phone line at (253) 284-4883.

Understanding Indoor Air Sampling

for Vapor Intrusion Assessment Using Summa Canisters

INTRODUCTION

Air sampling is being conducted at your residence to determine if chemicals that are found in groundwater near your property are also present in your indoor air. The chemicals that have been found in the groundwater may travel through soil and into buildings, which is a process called vapor intrusion. The air samples will be collected using sampling containers called Summa canisters (see picture below). After sampling is complete, the canisters will be shipped back to the laboratory where they will be tested to see if the chemicals are in the air samples. The following sections explain what a Summa canister is and how it works.

SUMMA CANISTER BASICS

A Summa canister is a stainless steel container about the size of a basketball. Air flow into the canister is caused by setting the initial pressure inside the canister lower than the pressure in indoor air. A flow controller device will be attached to the canister to control the rate at which air flows into the canister. Also attached is a pressure gauge that enables them to monitor the flow rate. The canister does not make any noise.

The canister is provided by the laboratory for air sampling. The Landau Associates sampling personnel will place clean and empty canisters in your residence at sampling locations selected during the building survey. An attempt will be made to place the samplers in the breathing zone, typically about 3 to 5 feet above the floor. They will open an intake valve at the top of each canister to allow air to flow into the canister through the intake valve. Air will flow slowly and continuously into the canister over a period of 24-hours. After the sample period is complete, canisters will be retrieved from the sample locations.

.

SAMPLE QUALITY

There are a number of common household items that release chemicals into the air and such chemicals may be collected by the air sample. This is something we would like to avoid if possible. **Please do not smoke, or use or place any household items that may release chemical vapors near the Summa canister so we can collect a representative air sample.** A list of typical household items that release chemical vapors is provided on this sheet.

Occasionally Summa canisters collect air samples faster than intended due to equipment malfunction. To determine if this is happening, the Landau Associates sampling personnel will check the readings on the canister pressure gauge within the first 1 to 2 hours of sampling and during the final 1 to 2 hours of sampling.

CONTACT INFORMATION

We appreciate you allowing us to test the air at your residence. If you have any questions or concerns during sampling, please do not hesitate to call Landau Associates at **(253) 284-4883.**

COMMON HOUSEHOLD ITEMS THAT MAY RELEASE CHEMICALS TO INDOOR AIR

- Adhesives (automotive, household, craft, plumbing)
- Household cleaners
- Lubricants
- Bonders
- Adhesive removers
- Antistatic aerosols
- Automotive parts cleaners
- Paint strippers
- “Spot removers” for fabrics
- Jewelry polish
- Water repellents
- Spray paints
- Dry-cleaned materials (e.g., clothing)
- Caulks and sealants
- Cosmetics, including hair spray, nail polish, nail polish remover, and perfume/cologne
- Air fresheners and odor eliminators
- Insect repellents
- Cigarette smoke.

Instructions for Residents

in Preparation for Indoor Air Sampling (Summa Canister Sampling)

With your permission, representatives of Landau Associates will be collecting air samples from your residence in the near future. Your assistance is requested during the air sampling program in order to collect air samples representative of the typical indoor air quality of your residence. Additionally, your assistance will help to prevent impacts to the air samples from common background chemical vapors attributed to household activities and consumer products. Thank you for allowing us to evaluate your indoor air.

Please follow the instructions below starting at least 48 hours prior to and during the indoor air sampling event:

- Operate your furnace and whole house air conditioner as you normally would (e.g., appropriate for the current weather conditions).
- Do not use wood stoves, fireplaces or auxiliary heating equipment unless necessary to keep residence warm
- Do not open windows or keep doors open.
- Avoid using window air conditioners, fans or vents
- Do not smoke in the building
- Do not use air fresheners or odor eliminators
- Do not use paints or varnishes (up to a week in advance, if possible)
- Do not use cleaning products that may contain volatile organic compound chemicals (e.g., bathroom cleaners, furniture polish, appliance cleaners, all-purpose cleaners, floor cleaners)
- Do not store or apply cosmetics near the sampling locations (e.g. hair spray, nail polish remover, perfume, etc.)
- Avoid bringing freshly dry-cleaned clothes into the building
- Do not engage in hobbies indoors that use solvents
- Do not apply pesticides
- Do not store containers of gasoline, oil or petroleum-based or other solvents within the building or attached garages (except for fuel oil tanks)
- Do not operate or store automobiles in an attached garage
- Do not operate gasoline powered equipment within the building, attached garage or around the immediate perimeter of the building

As discussed during the building survey, there are certain household items (background sources) that can release chemical vapors into the air. Prior to sampling we would like to assist you in temporarily removing the following items and storing them in a location outside your residence (e.g., a detached garage or shed):

- Adhesives (automotive, household, craft, plumbing)
- Household cleaners
- Lubricants
- Bonders
- Adhesive removers
- Antistatic aerosols
- Automotive parts cleaners
- Paint strippers
- “Spot removers” for fabrics
- Jewelry polish
- Water repellents
- Spray paints
- Dry-cleaned materials (e.g., clothing)
- Caulks and sealants
- Cosmetics, including hair spray, nail polish, nail polish remover, and perfume/cologne
- Air fresheners and odor eliminators
- Insect repellents

Once air sampling is completed, the items may be returned to their original location.

If you have any questions about these instructions or would like assistance from a Landau Associates representative to temporarily remove and store any of the household items listed above, please contact:

Landau Associates
(253) 284-4883

Your cooperation is greatly appreciated.

LANDAU ASSOCIATES
ENVIRONMENTAL | GEOTECHNICAL | NATURAL RESOURCES

950 Pacific Avenue, Suite 515 • Tacoma, Washington 98402 • (253) 926-2493 • fax (253) 926-2531 • www.landauinc.com

Understanding Indoor Air Sampling

for Vapor Intrusion Assessment Using Passive Diffusive Samplers

INTRODUCTION

Air sampling is being conducted at your residence to determine if chemicals that are found in groundwater near your property are also present in your indoor air. The chemicals that have been found in the groundwater may travel through soil and into buildings, which is a process called vapor intrusion. The air samples will be collected using Summa canisters (see separate information sheet) and passive diffusive samplers (see picture below). After sampling is complete, the passive diffusive samplers will be shipped back to the laboratory where they will be tested to see if the chemicals are detected. The following sections explain what a passive diffusive sampler is and how it works.

PASSIVE DIFFUSIVE SAMPLER BASICS

Where trichloroethene (TCE) is detected in shallow groundwater (at the water table), sometimes 24-hour sampling with Summa canisters is supplemented with passive diffusive samplers. Passive diffusive samplers are relatively small and less noticeable than a Summa canister. Their primary advantage is their ability to measure longer-term, time-weighted average TCE concentrations. For example, they can collect an air sample for as long as three weeks.

The type of passive diffusive sampler that will be used at your residence is a "Radiello" sampler. This passive diffusive sampler consists of an adsorbent cartridge that is encased within a porous polypropylene shell for protection. The passive diffusive sampler is provided by the laboratory for air sampling. The Landau Associates sampling personnel will place new passive diffusive samplers in and outside of your residence at sampling locations selected during the building survey. An attempt will be made to place the samplers in the breathing zone, typically about 3 to 5 feet above the floor. After the sample period is complete, the passive diffusive samplers will be retrieved from the sample locations.

SAMPLE QUALITY

There are a number of common household items that release chemicals into the air and such chemicals may be collected by the air sample. This is something we would like to avoid if possible. **Please avoid smoking, or using or placing any household items that may release chemical vapors near the passive diffusive samplers so we can collect a representative air sample.** A list of typical household items that release chemical vapors is provided on this sheet.

CONTACT INFORMATION

We appreciate you allowing us to test the air of your residence. If you have any questions or concerns during sampling, please do not hesitate to call Landau Associates at **(253) 284-4883.**

LANDAU ASSOCIATES
ENVIRONMENTAL | GEOTECHNICAL | NATURAL RESOURCES

COMMON HOUSEHOLD ITEMS THAT MAY RELEASE CHEMICALS TO INDOOR AIR

- Adhesives (automotive, household, craft, plumbing)
- Household cleaners
- Lubricants
- Bonders
- Adhesive removers
- Antistatic aerosols
- Automotive parts cleaners
- Paint strippers
- “Spot removers” for fabrics
- Jewelry polish
- Water repellents
- Spray paints
- Dry-cleaned materials (e.g., clothing)
- Caulks and sealants
- Cosmetics, including hair spray, nail polish, nail polish remover, and perfume/cologne
- Air fresheners and odor eliminators
- Insect repellents
- Cigarette smoke.

Instructions for Residents

in Preparation for Indoor Air Sampling (Passive Diffusive Sampling)

With your permission, representatives of Landau Associates will be collecting air samples from your residence in the near future. Your assistance is requested during the air sampling program in order to collect air samples that are representative of the typical indoor air quality of your residence and that are not impacted by common background chemical vapors associated with resident activities and consumer products. Thank you for allowing us to evaluate the indoor air quality in your residence.

Please follow the instructions below starting at least 48 hours prior to and during the indoor air sampling event:

- Operate your furnace and whole house air conditioner as you normally would (e.g., appropriate for the current weather conditions).
- Avoid using wood stoves, fireplaces or auxiliary heating equipment unless necessary to keep residence warm.
- Avoid opening windows or keeping doors open.
- Avoid using window air conditioners, fans or vents.
- Avoid smoking near the sampling locations.
- Avoid using air fresheners or odor eliminators near the sampling locations.
- Avoid using paints or varnishes (up to a week in advance, if possible).
- Avoid using cleaning products that may contain volatile organic compound chemicals near the sampling locations (e.g., bathroom cleaners, furniture polish, appliance cleaners, all-purpose cleaners, floor cleaners).
- Avoid storing or applying cosmetics near the sampling locations (e.g. hair spray, nail polish remover, perfume, etc.).
- Avoid bringing freshly dry-cleaned clothes into the building.
- Avoid engaging in hobbies indoors that use solvents.
- Avoid applying pesticides.
- Avoid storing containers of gasoline, oil or petroleum-based or other solvents within the building or attached garages (except for fuel oil tanks).
- Avoid operating or storing automobiles in an attached garage.
- Avoid operating gasoline powered equipment within the building, attached garage or around the immediate perimeter of the building.

As discussed during the building survey, there are certain household items (background sources) that can release chemical vapors into the air. Prior to sampling we would like to assist you in temporarily removing the following items and storing them in a location outside your residence (e.g., a detached garage or shed):

- Adhesives (automotive, household, craft, plumbing)
- Household cleaners
- Lubricants
- Bonders
- Adhesive removers
- Antistatic aerosols
- Automotive parts cleaners
- Paint strippers
- “Spot removers” for fabrics
- Jewelry polish
- Water repellents
- Spray paints
- Dry-cleaned materials (e.g., clothing)
- Caulks and sealants
- Cosmetics, including hair spray, nail polish, nail polish remover, and perfume/cologne
- Air fresheners and odor eliminators
- Insect repellents

Once air sampling is completed, the items may be returned to their original location.

If you have any questions about these instructions or would like assistance from a Landau Associates representative to temporarily remove and store any of the household items listed above, please contact:

Landau Associates
(253) 284-4883

Your cooperation is greatly appreciated.

APPENDIX B

Vapor Intrusion Assessment Building Survey Form

Vapor Intrusion Assessment Building Survey

LANDAU ASSOCIATES

Project No.: 0025164.100.105

Client: The Boeing Company Date/Time:

Project Name: Boeing Auburn – Initial Vapor Intrusion Assessments - Algona

Location:

Weather Conditions (note wind direction/intensity):

Prepared By:

1. OCCUPANT:

Interviewed: Y / N

Last Name: First Name:

Contact Info:

Number of Occupants/persons at this location:

Age of Occupants:

Availability:

2. OWNER OR LANDLORD: (Check if same as occupant____)

Interviewed: Y / N

Last Name: First Name:

Address:

Contact Info:

3. BUILDING CHARACTERISTICS:

a. Type of Building: (Circle appropriate response)

Residential

Industrial

School

Church

Commercial/Multi-use

Other:

b. If the property is residential, type? (Circle appropriate response)

Ranch

Duplex

Raised Ranch

Contemporary

Townhouse/Condos

Mobile Home

Cape Cod
Apartment House
Split Level
Modular
Log Home
Colonial
Other:

c. If multiple units, how many?

d. If the property is commercial, what type?

Business Type(s):

Does it include residences (i.e., multi-use)? Y / N
If yes, how many?

4. OCCUPANT/OWNER QUESTIONAIRE

a. Typical hours home and rooms most occupied:

b. Building age:

c. Type of heating used in the building: (circle all that apply – note primary)

Heat Pump
Space Heaters
Hot Air Circulation
Radiant Floor
Steam Radiation
Hot Water Baseboard
Wood Stove
Electric Baseboard
Outdoor Wood Boiler
Other Stove:

d. Types of fuel used in the building:

Natural gas
Fuel oil
Kerosene
Electric
Propane
Solar
Wood
Coal

e. Boiler/furnace located in:

Basement   Outdoors   Main Floor

Other:

f. Ventilation:

Central Air   Window Units   Open Window

Heat Pump   Ceiling Fan   None

g. Is there a radon mitigation system for the building/structure?   Y / N

Date of Installation:

Is the system active or passive?   Active / Passive

h. If it is a non-residential building, do they know if the building is under positive or negative pressure?

i. Water Supply:

Public Water   Drilled Well   Driven Well

Dug Well   Other:

j. Sewage Disposal:

Public Sewer   Septic Tank   Leach Field

Dry Well   Other:

k. How is roof runoff/storm drainage routed?

- Downspouts directly to surface
- Directed to the surface away from the building
- Infiltrated
- Collected and reused

l. Is the basement/lowest level occupied?

Full-Time Occasionally Seldom

Almost Never

m. Does the garage have a separate heating unit? Y / N

n. Has the building ever had a fire? Y / N
When:

o. Is a kerosene or unvented gas space heater present? Y / N
Where & Type?

p. Is there a workshop or hobby/craft area? Y / N
Where & Type?

q. Is there smoking in the building? Y / N
Frequency?

r. Has painting/staining been done in the last 6 months? Y / N
Where & When?

s. Is there new carpet, drapes or other textiles? Y / N
Where & When?

t. Is there a clothes dryer? Y / N If yes, is it vented outside? Y / N

u. Has there been a pesticide/herbicide application? Y / N
When, type, & location?

v. Do any of the building occupants use solvents or volatile chemicals at work? (e.g., chemical manufacturing or laboratory, auto mechanic or auto body shop, painting, fuel oil delivery, boiler mechanic, pesticide applicator, cosmetologist, carpet installer) Y / N

If yes, what types of solvents are used?

If yes, are their work clothes stored at or washed at home? Y / N

w. Do any of the building occupants regularly use or work at a dry cleaning service? (circle appropriate response below):

- Yes, use dry-cleaning regularly (weekly)
- Yes, use dry-cleaning infrequently (monthly or less)
- Yes, work at a dry-cleaning service
- No
- Unknown

x. Ask them to review the Common Household Chemicals List (page 13) and to point out locations where these items are stored.

List specific locations/items that need further inspection based on responses to these questions:

5. BUILDING TOUR/INSPECTION

a. General

i. Review the Occupant/Owner Questionnaire and inspect associated locations of interest (e.g., heaters, HVAC unit, hobby area, etc.)

ii. Above grade construction:

Wood Frame Concrete Stone

Masonry/Bricks

iii. Are there air distribution ducts present? Y / N

iv. Describe the supply and cold air return ductwork; its condition where visible; whether there is a cold air return and tightness of duct joints. Indicate the locations on the floor plan diagram.

v. General use of each floor: (e.g., family room, bedroom, laundry, workshop, storage)

Basement/crawlspace:

1st Floor:

vi. Please describe any odors in the building:

b. Foundation (Circle all that apply):

Type:

Basement Slab Crawlspace

Other:

Basement is (if applicable):

Finished Unfinished Partially Finished

Floor material:

Concrete Dirt Stone

Other:

Foundation floor completion:

Unsealed Sealed Covered With:

Foundation walls material:

Poured Block Stone Other:

Not Applicable

Foundation walls completion:

Unsealed Sealed Sealed With:

Not Applicable

Moisture status:

Wet Damp Dry

Moldy

The basement is:

Finished Unfinished Partially Finished

If there is a crawlspace, is it vented? Y / N not applicable

Crawlspace vents are:

Always Open Always Closed Only Open Seasonally

Is a sump present (take photo)? Y / N

Construction details:

Is there water in the sump? Y / N

Basement/Lowest level depth below grade: (in feet)

Identify potential soil vapor entry points and approximate size: (e.g., cracks, utility ports, drains)

Note the general condition of the foundation:

c. Kitchen
   i. Is there an exhaust fan? Y / N
      If yes, where is it vented?

d. Bathroom(s)

   i. Is there an exhaust fan? Y / N
      If yes, where is it vented?

e. Garage

   i. Is the garage attached? Y / N

   ii. Are petroleum-powered machines or vehicles stored in the garage? (e.g., lawnmower, ATV, car)

      Y / N Please specify:

f. Floor Plans:

Draw a plan view sketches of the basement & upper floor(s) of the building (**use consistent orientation per plan)**.

Note any potential air sampling locations, preferential pathways, household chemicals, heating and ventilations elements, plumbing, doors, windows, and other items of interest.

i. Basement/Crawlspace:

Dir.
Arrow

ii. First Floor:

Note any potential air sampling locations, preferential pathways, household chemicals, heating and ventilations elements, plumbing, doors, windows, and other items of interest.

○

Dir.
Arrow

iii. Outdoor Plot:

Draw a sketch of the area surrounding the building being sampled. If applicable, provide information on spill locations; potential air contamination sources (industries, gas stations, repair shops, landfills, etc); outdoor air sampling location(s). Also indicate the locations of the well, septic, and drainage systems, if applicable; any known utilities; and a qualifying statement to help locate the site on a topographic map. **Note any standing water within the yard.**

○

Dir.
Arrow

g. Product Inventory Log:

Describe the condition of the product containers as **Unopened (UO)**, **Used (U)**, or **Deteriorated (D)**. Photographs of the front and back of the product containers can replace the hand written list of chemical ingredients; however, the photographs must be of good quality & ingredient labels must be legible.

Location	**Product Description**	**Size (units)**	**Condition (UO, U, D)**	**Chemical Ingredients**	**Field Instrument Reading (units)**	**Photo Y / N**	**To Be Removed Y / N**

Additional Notes/Comments:

Attachments: ____

Signed:____

Common Household Chemicals

- Adhesives (automotive, household, craft, plumbing)
- Household cleaners
- Lubricants
- Bonders
- Adhesive removers
- Antistatic aerosols
- Automotive parts cleaners
- Paint strippers
- “Spot removers” for fabrics
- Jewelry polish
- Water repellants
- Spray paints
- Dry-cleaned materials (e.g., clothes)
- Caulks and sealants
- Cosmetics including hair spray, nail polish, nail polish remover, and perfume/cologne
- Air fresheners and odor eliminators
- Insect repellants

Photograph Log

Roll No./Phone No.	Comments

APPENDIX C

Health and Safety Plan

WORK LOCATION PERSONNEL PROTECTION AND SAFETY EVALUATION FORM

Attach Pertinent Documents/Data
Fill in Blanks As Appropriate

Job No.:	025164.100.105	Revised:	June 10, 2013 by Kathryn Hartley
Prepared by:	Brett Borgeson	Reviewed by:	Christine Kimmel
Date:	April 25, 2013	Date:	April 25, 2013 / June 10, 2013

A. WORK LOCATIONS DESCRIPTION

1. **Project Name:** Boeing Auburn, Site Wide Corrective Action
2. **Location:** Algona, Washington
3. **Anticipated Activities:** Indoor air, ambient outdoor air, crawl space air, and sub-slab vapor sampling
4. **Size:** Approximately 42 acres
5. **Surrounding Population:** Mixed industrial, commercial, and residential
6. **Buildings/Homes/Industry:** Roadways, parking areas, residential areas
7. **Topography:** Flat concrete slab, unpaved surfaces, and interior of residential buildings
8. **Anticipated Weather:** 48-85 degrees Fahrenheit
9. **Unusual Features:** Potential to enter residential crawl spaces, which are considered non-permitted confined spaces. Field personnel entering crawl spaces will follow procedures identified in this health and safety plan (HASP) and will have the necessary equipment and training required for confined space entry. Non-permitted confined space entry requires one attendant in addition to the worker, and air monitoring prior to and during entry. Stairs will be involved to enter residential basements.
10. **Site History:** Various areas of the Auburn facility were designated Areas of Concern (AOCs) or Solid Waste Management Units (SMWUs) during the 1998 Resource Conservation and Recovery Act (RCRA) facilities assessment conducted by U.S. Environmental Protection Agency (EPA). Since 2004, Boeing has conducted a series of remedial investigation (RI) activities to define the nature and extent of volatile organic compound (VOC) contamination in groundwater at and north of the Boeing Auburn property. These activities defined two offsite VOC plumes. The primary constituents of concern in these plumes are trichloroethene (TCE) and vinyl chloride (VC). The VOC plumes extend offsite beneath the cities of Algona and Auburn where groundwater is relatively shallow in places. Based on the City of Algona's concerns, Washington State Department of Ecology (Ecology) has requested that residential indoor air and sub-slab vapor samples be collected to evaluate the presence of vapors as it pertains to the safety of the residential community. The purpose of this indoor air and sub-slab vapor investigation is to determine if nearby residential housing is impacted by TCE and VC plumes that are associated with releases from the facility.

B. HAZARD DESCRIPTION

1. **Background Review:** ☒ Complete ☐ Partial

If partial, why?

2. **Hazardous Level:** ☐ B ☐ C ☒ D ☐ Unknown

Justification: Existing data regarding site conditions

3. **Types of Hazards:** (Attach additional sheets as necessary)

A. ☒ Chemical ☒ Inhalation ☐ Explosive

☐ Biological ☒ Ingestion ☒ O2 Def. ☒ Skin Contact

Describe: Sampling surface potentially impacted by VOC's

B. ☒ Physical ☒ Cold Stress ☒ Noise ☐ Heat Stress ☐ Other

Describe: Slips, trips, and falls working around staircases leading to basement. Physical hazards associated with working in a confined or limited space area, including potential for oxygen deficiency, limited egress, and low clearance. Potential for insects and small animal encounters when placing and retrieving sampling equipment in a crawl space. Noise and physical hazards working around a rotohammer drill indoors. Potential for cold or hot temperatures. Chemical hazards from potential exposure to VOC-impacted air.

C. ☐ Radiation

4. **Nature of Hazards:**

☒ Air	Describe: Potential for volatile constituents to be released from contaminated soil or groundwater.
☒ Soil	Describe: Potential for contact with or ingestion of contaminated soil and hanta virus from animal droppings.
☐ Surface Water	Describe:
☒ Groundwater	Describe: Potential for contact with or ingestion of contaminated shallow groundwater.
☒ Other	Describe: Work will be conducted in confined space.

5. Chemical Contaminants of Concern ☐ N/A The primary chemical contaminants of concern VOCs. The table below lists information for these primary compounds and other potential contaminants.

Contaminant	PEL (ppm)	I.D.L.H. (ppm)	Source/Quantity Characteristics	Route of Exposure	Symptoms of Acute Exposure	Instruments Used to Monitor Contaminant
Trichloroethene	50	1,000/200	Present in shallow groundwater, max concentration of 12 µg/L	Inhalation, ingestion, dermal contact, ingestion, inhalation	Eye, nose, and throat irritation; headache, nausea	PID
Vinyl Chloride	1	--/5	Present in shallow groundwater, max concentration of 3.8 µg/L	Inhalation, ingestion, dermal contact	Weakness, abdominal pain (carcinogen)	PID
cis-1,2-Dichloroethene	200	4,000	Present in shallow groundwater, max concentration of 8.4 µg/L	Inhalation, ingestion, dermal contact	Dizziness, nausea, dermatitis, irritation of mucous membranes	PID

Notes:

PEL: Personal Exposure Limit
IDLH: Immediately Dangerous to Life and Health
-

6. Physical Hazards of Concern ☐ N/A

Hazard	Description	Location	Procedures Used to Monitor Hazard
Moving parts of rotohammer drill rig, flying objects	Drilling through concrete slab to collect vapor samples	Near rotohammer drill at sample locations	Alert observation of surroundings, minimize time spent near rotohammer drill, no loose clothing, and use of safety glasses, hard hat, and steel-toed boots.
Slip, trip, and fall	Hazards associated with staircases and uneven ground	Access to sampling locations	Alert observation of surroundings, extra care taken when walking up and down staircases.
Lifting Strain	Carrying rotohammer drill	Drill	Use proper lifting techniques with bent knees.
Non-Permitted Confined Space	Entry into confined space.	Residential home crawl spaces	Only personnel trained in confined space entry will conduct work in the identified confined space. Air monitoring before and during entry, attendant at access portal will keep sampling staff inline of sight .
Potential for insect or small animal encounters in crawl spaces	Personnel may enter a crawl space when placing and retrieving sampling equipment	Residential home crawl spaces	Use a flashlight to observe the inside of the crawl space prior to entering or placing and retrieving equipment. If necessary, use a stick or similar object to clear away cobwebs and insects prior to placing and retrieving sampling equipment. Do not place or retrieve equipment if small animals are observed in the crawl space. Wear respirator or dust mask while inside crawl space for hanta virus.

7. **Work Location Instrument Readings** ☐ N/A (For confined spaces, record instrument readings before entry in work area and at point of entry, during work with worker)

Location: __________

Percent O_2: __________ Percent LEL: __________

Radioactivity: __________ PID: __________

FID: __________ Other: __________

Other: __________ Other: __________

Other: __________ Other: __________

Location: __________

Percent O_2: __________ Percent LEL: __________

Radioactivity: __________ PID: __________

FID: __________ Other: __________

Other: __________ Other: __________

Other: __________ Other: __________

Location: __________

Percent O_2: __________ Percent LEL: __________

Radioactivity: __________ PID: __________

FID: __________ Other: __________

Other: __________ Other: __________

Other: __________ Other: __________

Location: __________

Percent O_2: __________ Percent LEL: __________

Radioactivity: __________ PID: __________

FID: __________ Other: __________

Other: __________ Other: __________

Other: __________ Other: __________

8. **Hazards Expected In Preparation For Work Assignment** ☒ N/A

Describe:

C. PERSONAL PROTECTIVE EQUIPMENT

1. Level of Protection

☐ A ☐ B ☐ C ☒ D

Location/Activity: All

☐ A ☐ B ☒ C ☐ D

Location/Activity: Upgrade to Level C PPE if ambient air conditions meet target monitoring level in Attachment A

2. Protective Equipment (specify probable quantity required)

Respirator ☐ N/A

☐ SCBA, Airline
☐ Full-Face Respirator
☒ Half-Face Respirator (Cart. organic vapor) (Only if upgrade to Level C)
☐ Escape mask
☐ None
☐ Other:
☐ Other:

Clothing ☐ N/A

☐ Fully Encapsulating Suit
☐ Chemically Resistant Splash Suit
☐ Apron, Specify:
☒ Tyvek Coverall (only if upgrade to Level C)
☐ Saranex Coverall
☐ Coverall, Specify
☒ Other: Dedicated field clothing; rain gear, as needed to avoid splash. Long shirts and pants will be worn.

Head & Eye ☐ N/A

☒ Hard Hat
☐ Goggles
☐ Face Shield
☒ Safety Eyeglasses
☒ Other: Hearing protection

Hand Protection ☐ N/A

☐ Undergloves; Type:
☒ Gloves; Type: Nitrile
☐ Overgloves; Type:
☐ None
☐ Other:

Foot Protection ☐ N/A

☐ Neoprene Safety Boots with Steel Toe/Shank
☐ Disposable Overboots
☒ Other: Steel-toed work boots

3. Monitoring Equipment ☐ N/A

☒ CGI
☐ O^2 Meter
☐ Rad Survey
☐ Detector Tubes (optional)

☒ PID
☐ FID
☐ Other

Type:

D. PERSONNEL DECONTAMINATION (ATTACH DIAGRAM)

☒ Required ☐ Not Required

Avoid hand to mouth contact, no eating/drinking in exclusion zone. Wash hands and face after egress from each confined space and after work shift.

EQUIPMENT DECONTAMINATION (ATTACH DIAGRAM)

☒ Required ☐ Not Required

If required, describe and list equipment:

Decontamination of non-dedicated sampling equipment with Alconox/tap water solution followed by tap water rinse and de-ionized water rinse

E. PERSONNEL

	Name	Work Location Title/Task	Medical Current	Fit Test Current
1.	Kristin Hooper	Site Geologist	☒	☒
2.	Lauren Knickrehm	Site Engineer	☒	☒
3.	Jennifer Wynkoop	Project Manager	☒	☒
4.	Sarah Weeks	Site Geologist	☒	☒
5.	Sierra Mott	Field Technician	☒	☒
6.			☐	☐
7.			☐	☐
8.			☐	☐
9.			☐	☐
10.			☐	☐

Site Safety Coordinator: **Lauren Knickrehm**

F. ACTIVITIES COVERED UNDER THIS PLAN

Task No.	Description	Preliminary Schedule
1	Indoor air and sub-slab vapor sampling.	2013

EMERGENCY FACILITIES AND NUMBERS

Hospital:
Auburn Regional Medical Center
202 N Division Street
Auburn WA 98001

Directions: Attachment B

Telephone: (253) 833-7711

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

Emergency Routes – Map (Attachment C)

Emergency Contacts:

	Offsite
Chris Kimmel	(206) 786-3801
Jennifer Wynkoop	(206) 617-3117
Jim Bet	(206) 679-0433
Fred Wallace	(206) 930-0461

<u>In the event of an emergency, do the following:</u>

1. Call for help as soon as possible. Call Boeing dispatch and 911. Give the following information:
   - WHERE the emergency is – use cross streets or landmarks
   - PHONE NUMBER you are calling from
   - WHAT HAPPENED – type of injury
   - WHAT is being done for the victim(s)
   - YOU HANG UP LAST – let the person you called hang up first.

2. If the victim can be moved, paramedics will transport to the hospital. If the injury or exposure is not life threatening, decontaminate the individual first. If decontamination is not feasible, wrap the individual in a blanket or sheet of plastic prior to transport.

HEALTH AND SAFETY PLAN
APPROVAL/SIGN OFF FORMAT

I have read, understood, and agreed with the information set forth in this Health and Safety Plan (and attachments) and discussed in the Personnel Health and Safety briefing.

Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
Lauren Knickrehm Site Safety Coordinator	Signature	Date
Christine Kimmel Landau Health and Safety Manager	Signature	Date
Jennifer Wynkoop Project Manager	Signature	Date

Personnel Health and Safety Briefing Conducted By:

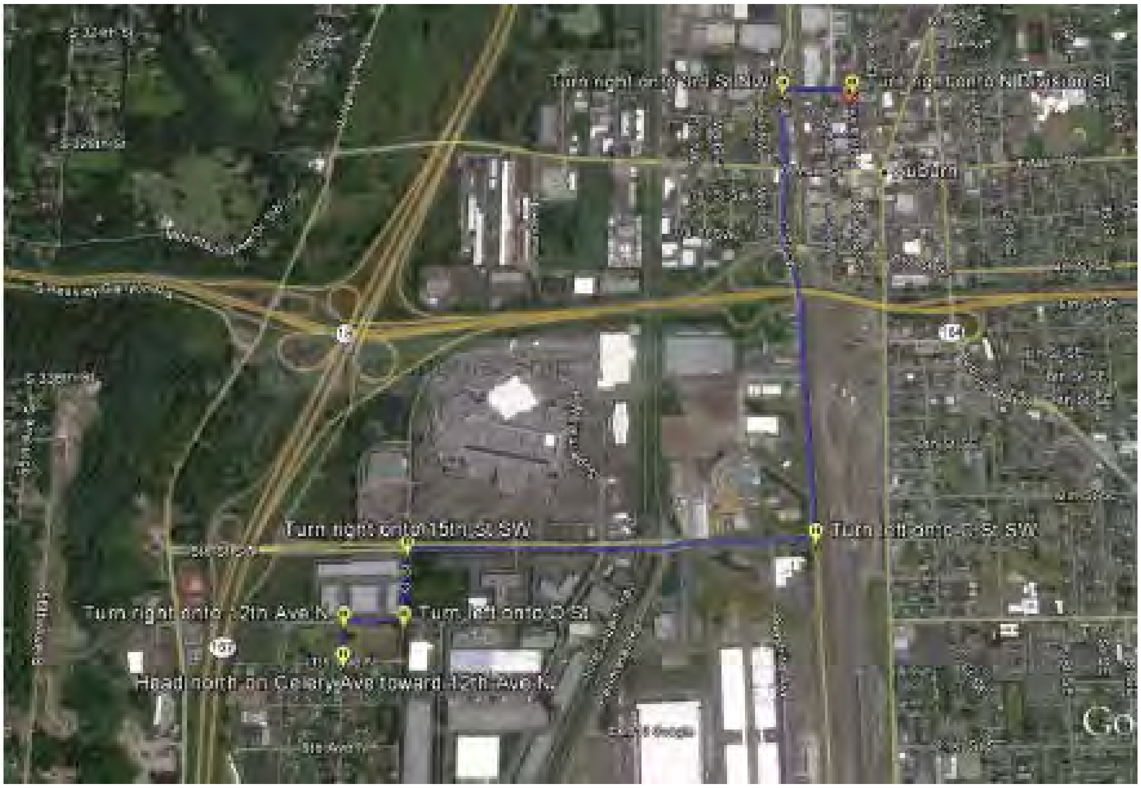
Name	Signature	Date

ATTACHMENT A

ACTION LEVELS FOR RESPIRATORY PROTECTION

Monitoring Parameter	Reading	Level of Protection
Organic Vapors	PID reading >15 ppm at point of operations for more than 1 minute	Establish 25-ft diameter exclusion zone around work area, monitor worker's breathing zone
	PID reading >15 ppm in worker's breathing zone for more than 1 minute	Evacuate area or upgrade to Level C half-face respirator with organic vapor/HEPA cartridge, establish contamination reduction zone with waste containers and decontamination fluids provided for personal decontamination and/or vent mixing tanks outside.
	PID reading >75 ppm in worker's breathing zone for more than 1 minute	Evacuate area and move upwind to allow vapors to dissipate, may resume work in Level C PPE after vapors dissipate.
	PID reading >150 ppm in worker's breathing zone for more than 1 minute OR >300 ppm instantaneous	Evacuate area and move outside. If elevated levels persist, cover sub-slab location. Notify onsite contact and Landau Associates health and safety manager.
Oxygen	19.5-23.5 %	No Entry outside of this range; if not 21.5% (normal), evaluate reasons for difference

Attachment B
Off Site Work - Route to Hospital



Start	Head NORTH on CELERY AVE toward BOUNDARY BLVD, From **Start Point (Celery Ave and 11th Ave N, Algona, WA)**
1	Go **0.1** miles and then TURN LEFT onto O ST
2	Go **0.1** miles and then TURN RIGHT onto 15th ST SW
3	Go **0.8** miles and then TURN LEFT onto C ST SW
4	Go **1.0** mile and then TURN RIGHT onto 3rd ST NW
5	Go **0.2** miles and then TURN RIGHT onto N DIVISION ST
End	Go **115** ft to **End Point on RIGHT (202 N Division St, Auburn, WA)**

APPENDIX D

Sample Collection Forms

Brief Indoor Air Sampling Questionnaire

Pre-Sampling Post-Sampling (please circle one)

Project No.: ______________________________

Client: ______________________________ Date/Time: __________

Project Name: ______________________________

Location: ______________________________

Prepared By: ______________________________

1. OCCUPANT:

   Interviewed: Y / N

   Last Name:______________________________First Name:______________________________

   Occupant Description (head of household, homeowner, etc):______________________________

   Contact Info.(phone & email:______________________________

2. Have cleaning products been used recently? Y / N

   When, Type, & Location?

3. Have cosmetic products been used recently? Y / N

   When, Type, & Location?

4. Has painting/staining been done in the last 6 months? Y / N

   When, Type, & Location?

5. Is there new carpet, drapes or other textiles? Y / N

   When, Type, & Location?

6. Have air fresheners been used recently? Y / N

   When, Type, & Location?

7. Has there been a pesticide/herbicide application? Y / N

   When, Type, & Location?

8. When is the last time you had any dry cleaning done?

   Where are those items stored?

Note any odors or activities that may impact the sample quality.

Common Household Chemicals

- Adhesives (automotive, household, craft, plumbing)
- Household cleaners
- Lubricants
- Bonders
- Adhesive removers
- Antistatic aerosols
- Automotive parts cleaners
- Paint strippers
- “Spot removers” for fabrics
- Jewelry polish
- Water repellants
- Spray paints
- Dry-cleaned materials (e.g., clothes)
- Caulks and sealants
- Cosmetics including hair spray, nail polish, nail polish remover, and perfume/cologne
- Air fresheners and odor eliminators
- Insect repellants

Page ____ of ____

LANDAU
ASSOCIATES

Air Sample Collection Form: Ambient / Indoor / Crawlspace

Project Name: ____________________ Project Number: ____________________

Client: ____________________ Sample Number: ____________________

Landau Rep: ____________________ Date/Time Collected: ____________________

Location Information: ____________________

SAMPLE TYPE

☐ Ambient Air ☐ Indoor Air ☐ Crawlspace ☐ Basement ☐ Other: ______________

WEATHER DATA

Rainfall < 1" in 24 hrs.? (YES or **NO**) Irrigation not w/in 5 hrs.? (YES or **NO**) Standing water near sampling location? (YES or **NO**)

Air Temperature ________ °F or °C Wind Direction __________ Wind Speed _________ mph Humidity __________ %

Barometric Pressure___________ in Hg or mBar Is sampling occurring after frontal system during stable pressure? (**YES** or NO)

SAMPLE COLLECTION DATA

Sample Container: ☐ Summa Canister, Size (liters) ______________ ☐ Tedlar Bag, Size (liters): ____________________

Canister number: ______________

☐ Passive / Diffusive ☐ Other: ________________________________

Manufacturer: _______________________

Sample Type: ☐ Grab ☐ Integrated (composite sample over time)

Height of Sample Above Floor/Ground: _________________ feet (to nearest tenth)

Ground/Floor Type: Soil, Wood, Carpet, Tile, Concrete Other: ____

Sample Collection/Purge Pump (if used): ______________________________________

Summa Canister, Pre-Sampling and Post-Sampling

Initial Vacuum: ________ in Hg Vacuum After Sample Collection: _____________ in Hg

LABORATORY ANALYSES:

____

____

Duplicate Sample Number(s): ____________________________________

Comments: ____________________________________

____

Signature: ______________________________ Date: ____________________

Page ____ of ____

LANDAU ASSOCIATES

Sub Slab Vapor / Soil Gas Sample Collection Form

Project Name: ______________________ Project Number: ______________________

Client: ______________________ Sample Number: ______________________

Landau Rep: ______________________ Date/Time Collected: ______________________

Location Information: ______________________

SAMPLE TYPE

☐ Sub Slab Vapor ☐ Soil Gas ☐ Other: ______________________

WEATHER DATA

Rainfall < 1" in 24 hrs.? (YES or **NO**) Irrigation not w/in 5 hrs.? (YES or **NO**) Standing water near sampling location? (YES or **NO**)

Air Temperature __________ °F or °C Wind Direction __________ Wind Speed __________ mph Humidity __________ %

Barometric Pressure __________ in HG or mBar Is sampling occurring after frontal system during stable pressure? (**YES** or NO)

SOIL GAS AND SUB SLAB INFORMATION AND AND PURGE DATA

Nature of Location: PERMENANT or TEMPORARY (circle one) ☐ Post-Run Tubing (PRT) ☐ Soil Gas Monitoring Well ☐ Other: __________

Installation Method : ☐ Direct Push Drill Rig ☐ Hollow Stem Auger ☐ Rotosonic ☐ Other: __________

☐ Hand Driven ☐ Rotohammer ☐ Vapor Pin Manufacturer:__________

If Permanent, Is Well Secure? (YES or NO or NA) Damaged (YES or NO) YES-Describe: __________

Materials: ☐ PVC Pipe ☐ Stainless Steel ☐ Teflon ☐ Nylon or Polyethylene Tubing ☐ Other: __________

Well/Hole Diameter: _______ inches Total Depth of Well: _______ ft Depth to Groundwater: _______ ft

Vacuum/Pressure of source (in. H_2O): __________ Time: __________

Purge Volume Calculation: ______________________

Purge: Begin Time __________ End Time __________ Casing Volume (ft^3): __________

Flow Rate (liter or ml/min): __________ Volume Purged (ft^3): __________

VOLUME EXAMPLES

Diameter (in)	OD (in)	ID (in)	Vol (ft^3/ln ft)
0.25 (tubing)	0.250	0.170	0.00016
1 (sch. 40)	1.315	1.029	0.006
1.25 (sch. 40)	1.660	1.380	0.010
2 (sch. 40)	2.375	2.067	0.020

Vol. Purged (ft^3)	Temp. (°F/°C)	PID (ppm)	Other	Comments/Observations

LEAK TEST OPTIONS

☐ Shut-in Test Starting Vacuum: _________ in H2O *(target 100 inches H2O)* Test Duration: _________ minutes *(target > 1 min)*

Ending Vacuum: __________ in H2O *(target no noticable vacuum decrease)* Result: PASS FAIL (circle one)

☐ Helium Shroud Design: ______________________ Helium Source Concentration:__________

Shroud Tracer Concentration Fluctuation: _________ % *(target ± 10%)* Tracer Equilibration Time: __________*(target min. 5 min)*

Sample Air Tracer Concentration: ________ % of Shroud Conc. *(target <5%)*

☐ Water Bath (vapor pins only)

SAMPLE COLLECTION DATA

Sample Container: ☐ Summa Canister, Size (liters) __________ Canister #:__________ ☐ Tedlar Bag, Size (liters): __________

☐ Passive / Diffusive Manufacturer:__________ ☐ Other: __________

Sample Type: ☐ Grab ☐ Integrated (composite sample over time)

Sample Collection/Purge Pump (if used): ______________________

Summa Canister, Pre-Sampling and Post-Sampling: Initial Vacuum: __________ in Hg Vacuum After Sample Collection: __________ in Hg

LABORATORY ANALYSES: ______________________

Duplicate Sample Number(s) and Comments: ______________________

Signature: ______________________ Date: __________

APPENDIX E

Vapor Pin Standard Operating Procedure

Cox-Colvin & Associates, Inc.
Environmental Services

Standard Operating Procedure
Installation and Extraction of the Vapor Pin™

May 20, 2011

Scope:

This standard operating procedure describes the installation and extraction of the Vapor Pin™[1] for use in sub-slab soil-gas sampling.

Purpose:

The purpose of this procedure is to assure good quality control in field operations and uniformity between field personnel in the use of the Vapor Pin™ for the collection of sub-slab soil-gas samples.

Equipment Needed:

- Assembled Vapor Pin™ [Vapor Pin™ and silicone sleeve (Figure 1)];
- Hammer drill;
- 5/8-inch diameter hammer bit (Hilti™ TE-YX 5/8" x 22" #00206514 or equivalent);
- 1½-inch diameter hammer bit (Hilti™ TE-YX 1½" x 23" #00293032 or equivalent) for flush mount applications;
- ¾-inch diameter bottle brush;
- Wet/dry vacuum with HEPA filter (optional);
- Vapor Pin™ installation/extraction tool;
- Dead blow hammer;
- Vapor Pin™ flush mount cover, as necessary;
- Vapor Pin™ protective cap; and
- VOC-free hole patching material (hydraulic cement) and putty knife or trowel.

Figure 1. Assembled Vapor Pin™.

Installation Procedure:

1) Check for buried obstacles (pipes, electrical lines, etc.) prior to proceeding.

2) Set up wet/dry vacuum to collect drill cuttings.

3) If a flush mount installation is required, drill a 1½-inch diameter hole at least 1¾-inches into the slab.

4) Drill a 5/8-inch diameter hole through the slab and approximately 1-inch into the underlying soil to form a void.

5) Remove the drill bit, brush the hole with the bottle brush, and remove the loose cuttings with the vacuum.

6) Place the lower end of Vapor Pin™ assembly into the drilled hole. Place the small hole located in the handle of the extraction/installation tool over the Vapor Pin™ to protect the barb fitting and cap, and tap the Vapor Pin™ into place using a

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[1] Cox-Colvin & Associates, Inc., designed and developed the Vapor Pin™; a patent is pending.

dead blow hammer (Figure 2). Make sure the extraction/installation tool is aligned parallel to the Vapor Pin™ to avoid damaging the barb fitting.

Figure 2. Installing the Vapor Pin™.

For flush mount installations, unscrew the threaded coupling from the installation/extraction handle and use the hole in the end of the tool to assist with the installation (Figure 3).

Figure 3. Flush-mount installation.

During installation, the silicone sleeve will form a slight bulge between the slab and the Vapor Pin™ shoulder. Place the protective cap on Vapor Pin™ to prevent vapor loss prior to sampling (Figure 4).

Figure 4. Installed Vapor Pin™.

7) For flush mount installations, cover the Vapor Pin™ with a flush mount cover.

8) Allow 20 minutes or more (consult applicable guidance for your situation) for the sub-slab soil-gas conditions to equilibrate prior to sampling.

9) Remove protective cap and connect sample tubing to the barb fitting of the Vapor Pin™ (Figure 5).

Figure 5. Vapor Pin™ sample connection.

10) Conduct leak tests [(e.g., real-time monitoring of oxygen levels on extracted sub-slab soil gas, or placement of a water

dam around the Vapor Pin™) Figure 6]. Consult your local guidance for possible tests.

Figure 6. Water dam used for leak detection.

11) Collect sub-slab soil gas sample. When finished sampling, replace the protective cap and flush mount cover until the next sampling event. If the sampling is complete, extract the Vapor Pin™.

<u>Extraction Procedure:</u>

1) Remove the protective cap, and thread the installation/extraction tool onto the barrel of the Vapor Pin™ (Figure 7). Continue turning the tool to assist in extraction, then pull the Vapor Pin™ from the hole (Figure 8).

Figure 7. Removing the Vapor Pin™.

Figure 8. Extracted Vapor Pin™.

2) Fill the void with hydraulic cement and smooth with the trowel or putty knife.

3) Prior to reuse, remove the silicone sleeve and discard. Decontaminate the Vapor Pin™ in a hot water and Alconox® wash, then heat in an oven to a temperature of 130° C.

The Vapor Pin™ to designed be used repeatedly; however, replacement parts and supplies will be required periodically. These parts are available on-line at www.CoxColvin.com.

Replacement Parts:

Vapor Pin™ Kit Case - VPC001
Vapor Pins™ - VPIN0522
Silicone Sleeves - VPTS077
Installation/Extraction Tool - VPIE023
Protective Caps - VPPC010
Flush Mount Covers - VPFM050
Water Dam - VPWD004
Brush - VPB026

APPENDIX F

Radiello® Manufacturer Guidance

how does the diffusive sampler work?

The diffusive sampler is a closed box, usually cylindrical. Of its two opposite sides, one is "transparent" to gaseous molecules which cross it, and are adsorbed onto the second side. The former side is named diffusive surface, the latter is the adsorbing surface (marked with ***S*** and ***A*** in the figure).

Driven by the concentration gradient ***dC/dl***, the gaseous molecules cross ***S*** and diffuse towards ***A*** along the path ***l***, parallel to the axis of the cylindrical box. The molecules, which can be trapped by the adsorbing material, are eventually adsorbed onto ***A*** according to the equation:

$$\frac{dm}{dt} = D\,S\,\frac{dC}{dl} \qquad [1]$$

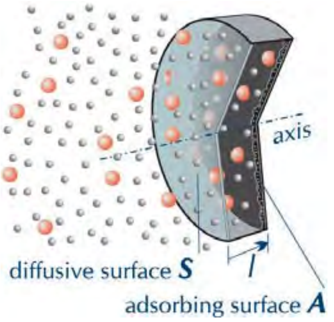
where ***dm*** is the adsorbed mass during time ***dt*** and ***D*** is the diffusion coefficient.

Let ***C*** be the concentration at the diffusive surface and C_0 the concentration at the adsorbing surface, the integral of [1] becomes

$$\frac{m}{t} = D\frac{S}{l}\,(C\text{-}C_0) \qquad [2]$$

If the concentration at the adsorbing surface is negligible, the equation can be approximated to

$$\frac{m}{t\,C} = D\frac{S}{l} = Q \quad \text{and then} \quad C = \frac{m}{t\,Q} \qquad [3]$$



In the diffusive sampler, the adsorbing and the diffusive surfaces are two opposing plane of a closed box. Driven by the concentration gradient, the gaseus molecules (coloured in the figure) pass through the diffusive surface and are trapped from the adsorbing surface.

Q is the ***sampling rate*** and has the dimensions of a gaseous flow (if ***m*** is expressed in µg, ***t*** in minutes and ***C*** in $\mu g \cdot l^{-1}$, ***Q*** is expressed in $l \cdot min^{-1}$).

Therefore, if ***Q*** is constant and measured, to calculate the ambient air concentration you need only to quantify the mass of analyte trapped by the adsorbing material and to keep note of the time of exposure of the diffusive sampler.

To improve the analytical sensitivity the collected mass ***m*** should be increased by enlarging ***Q***. As ***D*** is a constant term, one can only try to improve the ***S/l*** ratio, namely the ***geometrical constant*** of the sampler. Unfortunately, in the common axial simmetry sampler, if ***S*** is enlarged, the adsorbing surface ***A*** must be enlarged too, in order to keep the two parallel surfaces at a fixed distance. Since the analytes can be recovered from the axial sampler only by solvent extraction, any increase of ***A*** lead to a proportional increase of the extraction solvent volume, thus the improvement of ***Q*** is canceled out by the effect of dilution.

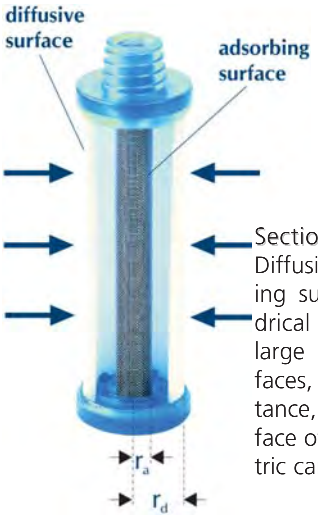
The value of distance ***l*** could also be reduced, but under the critical value of about 8 mm the diffusion law is no longer valid in the case of low air velocity values, since adsorption rate becomes higher than supplying rate of analyte molecules at the diffusive surface.

Cannot we improve ***Q*** then?

The answer is to improve the sampler geometry to a ***radial*** design.

From this idea the **radiello** sampler has been developed, its cylindrical outer surface acting as diffusive membrane: the gaseus molecules move axially parallel towards an adsorbent bed which is cylindrical too and coaxial to the diffusive surface.

When compared to the axial sampler, **radiello** shows a much higher diffusive surface without increase of the adsorbing material amount. Even if the adsorbing surface is quite smaller then the diffusive one, each point of the diffusive layer faces the diffusion barrier at the same distance.



Section of **radiello**. Diffusive and adsorbing surfaces are cylindrical and coaxial: a large diffusive surface faces, at a fixed distance, the small surface of a little concentric cartridge.

As $S=2\pi rh$ (where h is the height of the cylinder) and the diffusive path is as long as the radius r, we can then express equation [1] as follows

$$\frac{dm}{dt} = D\,2\pi\,h\,r\,\frac{dC}{dr} \qquad [4]$$

The integral of equation [4] from r_d (radius of the diffusive cylindrical surface) to r_a (radius of the adsorbing surface) becomes

$$\frac{m}{t\,C} = D\,\frac{2\pi\,h}{\ln\frac{r_d}{r_a}} = Q \qquad [5]$$

the ratio

$$\frac{2\pi\,h}{\ln\frac{r_d}{r_a}}$$

is the geometrical constant of **radiello**. The calculated uptake rate [5] is therefore proportional to the height of the diffusive cylinder and inversely proportional to the logarithm of the ratio of diffusive *vs* adsorbing cylinder radii.

The microporous sintered polyethylene diffusive barrier of **radiello** photographed at the electrton microscope; the path length is much longer than the membrane thickness due to the tortuosity of the pores.

While r_a can be easily measured, r_d can only be calculated by exposure experiments. Actually the diffusive membrane has been designed with a thick tubular microporous layer. The actual diffusive path length is therefore much longer than the distance among the diffusive and adsorbing surfaces due to the tortuosity of the path through the pores. A diffusive cylinder of external diameter 8 mm, thickness 1.7 mm and average porosity of 25 µm, coupled to an adsorbing cartridge with radius 2.9 mm creates a diffusive path of 18 mm instead of the straight line path estimation of (8-2.9) = 5.1 mm.

The sampling rate Q is function of diffusive coefficient D, which is a thermodynamic property of each chemical substance. D varies with temperature (T) and pressure (p); therefore also the sampling rate is a function of those variables according to

$$Q = f\,(T, p)$$

Q values that will be quoted in the following have been measured at 25 °C and 1013 hPa. As a consequence, they should be corrected so as to reflect the actual sampling conditions.

The correction of Q for atmospheric pressure is usually negligible since its dependence is linear and very seldom we face variations of more than 30 hPa about the average value of 1013 hPa. In the worst case, if corrections for pressure are ignored you make an error of ±3%, usually it is within ±1.5%.

On the other hand, Q depends exponentially on temperature variations, therefore more relevant errors can be introduced if average temperature is significantly different from 25 °C. Moreover, when chemiadsorbing cartridge are used kinetic effects (variations of reaction velocities between analyte and chemiadsorbing substrate) can be evident, apart from thermodynamic ones (variation of D).

It is therefore very important to know the average temperature in order to ensure accuracy of experimental data. See how you can perform on-field temperature measurements on page B3.

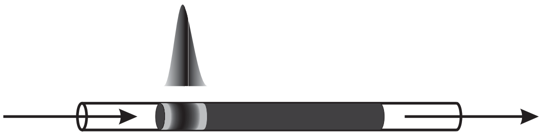
Even if some cartridges adsorb large quantities of water when exposed for a long time in wet atmosphere, generally this does not affect sampling by **radiello**. Some consequences, neverthless, can sometimes be felt on the analysis. As an example, a very wet graphitised charcoal cartridge could generate ice plugs during cryogenic focusing of thermally desorbed compounds or blow out a FID flame.

It is therefore important to protect radiello from bad weather. See page B1 how this can be easily done.

why is *radiello* so *special?*

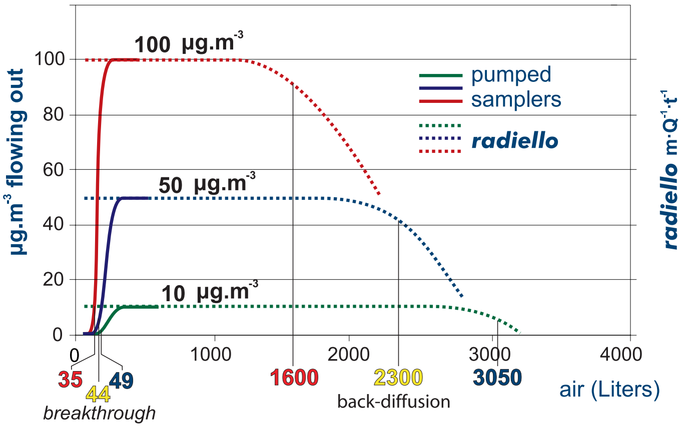
The diffusive sampling does not involve the use of heavy and encumbering pumping systems, does not have energy power supply problems, does not require supervision, is noiseless, is not flammable and does not represent an explosion hazard, can be performed by everybody everywhere and with very low costs.

Moreover, it is not subject to the breakthrough problem, which can be serious when active pumping is performed.



In pumped sampling the adsorbed compound behaves as a chromatographic peak (top): air flow displaces it along the adsorbent bed and its concentration is distributed as a gaussian function. Eventually, the compound comes out from the opposite end. When its concentration in the outlet air is 10% of the concentration in the sampled air we say that the ***breakthrough*** *has been reached or, with a misleading expression, that the tube has been saturated. Any further pumping leads to a loss of analyte and a consequent underestimation of the environmental concentration. The extent of this phenomenon depends weakly on the concentration of target compound but rather on the value of air flow, the overall sampling volume and the chemical compound involved.*

In the graph the case of benzene is displayed, sampled at 25 °C onto an activated charcoal adsorbent bed of the same volume of a code 130 ***radiello*** *cartridge. The breakthrough is reached after 35, 44 or 49 liters of sampled air depending on benzene concentration in air (10, 50 or 100 µg·m^{-3} respectively).*



An apparently similar phenomenon is shown by ***radiello*** *also. In this case, however, we cannot speak of breakthrough, since no actual air flow is involved, but rather of* ***backdiffusion****. This consists of a decrease of the value of m·Q^{-1}·t^{-1} (which is equal to the measured concentration, see eqn. [3] on page A1). This term is constant and equal to the actual concentration until the adsorbed mass of analyte is far from the maximum amount allowed by the adsorbing medium capacity. The extent of backdiffusion depends on concentration and exposure time but a decrease of 10% in the m·Q^{-1}·t^{-1} term is observed along with equivalent sampling volumes of magnitude bigger than those seen before: 1600, 2300 and 3050 liters at the concentration of 10, 50 and 100 µg·m^{-3}.*

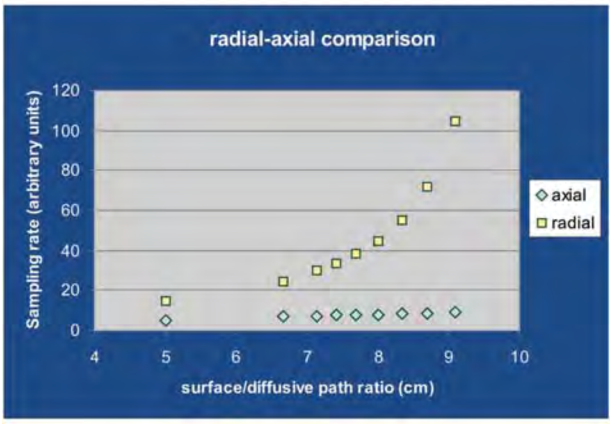
Why diffusive sampling has not been so extensively adopted up to now?

This is due to the fact that the traditional axial symmetry sampler has generally poor sensitivity and reproducibility because of the limits set by its geometry. On one side, uptake rate values are generally low, on the other, they often vary depending on environmental conditions.

These limitations have been overcome by ***radiello***.

By virtue of radial symmetry, uptake rate is:

✓ **high**, since it does not vary linearly but exponentially with the ratio diffusive surface *vs* diffusive path length (see eqn. [5]). With the same dimensions, radiello's uptake rate is at least three times higher than that of any axial diffusive sampler;



For a traditional axial symmetry sampler the uptake rate increases linearly with tha ratio of diffusive surface vs diffusive path length, while for the radial simmetry sampler, the corresponding increase is exponential. This means that, let the diffusive surface vs diffusive path length ratio be 8:1, for the axial sampler the uptake rate value is 8 (regardless of dimensions) while for the radial one it is 45.

- ✓ **constant**, due to the great adsorbing capacity of the adsorbing cartridge;
- ✓ **reproducible**, by virtue of the stiffness of the diffusive membrane and the cartridge and of the close tolerances characterizing all the components of ***radiello***;
- ✓ **invariable with air speed**, due to the tortuosity of the diffusive path inside the microporous diffusive cylindrical surface;
- ✓ **precisely measured**, because it is not calculated but experimentally measured in a controlled atmosphere chamber in a wide range of concentration, temperature, relative humidity, air speed conditions and with or without interferents....

Moreover, ***radiello***

- able to work properly also with bad weather conditions due to the water-repellent diffusive body
- has blank values lower than three times the instrumental noise due to the complex conditioning procedures of the bulk adsorbing (or chemiadsorbing) materials and to the repeated quality controls along the whole production
- has low detection limits and high adsorbing capacities that allow exposure time duration from 15 minutes to 30 days and concentration measurements from 1 ppb to over 1000 ppm
- offers high precision and accuracy over a wide range of exposure values

- allows thermal desorption and HRGC-MS analysis without interferents
- is suited to the sampling of a vast range of gaseous pollutants
- is though and chemically inert, being made of polycarbonate, microporous polyethylene and stainless steel
- is indefinitely reusable in all of its components apart from the adsorbing cartridge; the latter can be recovered if thermal desorption is employed
- it comes from the efforts of one of the main European scientific research institutions that produces it directly by high technology equipment and continuously submits it to severe tests and performs research and development in its laboratory in Padova

All the images in the manual concern the Environmental Research Center of Padova of the Fondazione Salvatore Maugeri-IRCCS

the components of *radiello*

The essential parts of ***radiello*** are the adsorbing cartridge, the diffusive body, the supporting plate and the adhesive label with the bar code indication. Apart from the adsorbing cartridge, if not differently stated, all of the other components can be repeatedly used for several sampling experiments.

The adsorbing cartridge

Depending on the polluting compound to be sampled, many different adsorbing or chemiadsorbing cartridges have been developed. Their dimensions are neverthless the same for all: 60 mm length and 4.8 or 5.8 mm diameter.

They are contained in glass or plastic tubes wrapped up in a transparent polyethylene thermowelded bag.

The code number, printed onto the bag along with the lot number and expiry date indicates the kind of cartridge.

Apart from the thermal desorption cartridges, all of the other kinds are for single use only. See the application section at the back for codes relevant to the different analytes.

Available in 20 pieces per package.

The cartridge has to be introduced into the diffusive body.

The supporting plate

It is identified by the **code 121**. Made of polycarbonate, it acts both as closure and support for the diffusive body, which has to be screwed onto the thread. It comes along with a clip and a transparent adhesive pocket to hold the label. The three parts are to be assembled before use (see page A6).

Available in 20 pieces per package.

code 121

The diffusive body

Four kinds of diffusive bodies are available, with like outer dimensions: 60 mm height and 16 mm diameter.

The **white** diffusive body, **code 120**, of general use, is made of microporous polyethylene 1.7 mm thick and average porosity 25 ± 5 µm. Diffusive path length is 18 mm.

The **blue** diffusive body, **code 120-1**, has the same properties of the white one but is opaque to light: it is suited to the sampling of light-sensitive compounds.

The **yellow** diffusive body, **code 120-2**, should be used whenever the sampling rate must be reduced; it is made of microporous polyethylene 5 mm thick and average porosity 10 ± 2 µm. Diffusive path length is 150 mm.

The **permeative** diffusive body, **code 120-3**, is a 50 µm thick silicone membrane strengthened by a stainless steel net and a microporous polyethylene cylinder. It is employed for anaesthetic gases and vapours sampling.

Available in 20 pieces per package.

The diffusive body has to be screwed onto the supporting plate.

code 120 **120-1** **120-2** **120-3**

code 190

The label

Self-adhesive, with printed barcode number. Since each barcode number has been printed in only one copy, it allows an unmistakable identification of the sampling tube on field and in the laboratory for the subsequent analysis.

Each package of 20 adsorbing cartridges contains also 21 labels.

If the labels are ordered separately, they are shipped in 198 pieces per package.

how to use radiello

before sampling

assembling the supporting plate

Before using ***radiello***, you have to assemble the supporting plate with the clip, necessary to suspend it, and the adhesive label pocket.

insert the clip strip in the slot, with the peg facing upwards

ply the strip and insert the peg into the hole

peel off the transparent pocket

and place it onto the plate in a central position; if you prefer, the pocket can be applied to the rear of the plate, but **BE CAREFUL**, always with the label insertion slot on the side (otherwise, if it starts raining the label can get wet)

user tip

Assemble the supporting plate in your laboratory before the sampling campaign to save time in the field

on-field
to start the sampling

open the plastic bag, draw the cartridge out from the tube and put it in the diffusive body. ***Keep the glass or the plastic tube and stopper in the original plastic bag.***

The lower part of the diffusive body holds a seat for the central positioning of the cartridge. **A correctly centered cartridge should not stick out even by half a millimeter. If it does, the cartridge is not correctly positioned and out of axis.**
BE CAREFUL: do not hold the diffusive body horizontally when you screw it onto the plate, otherwise the cartridge could come out from its seat and stick out.
As a consequence, when the diffusive body is screwed onto the supporting plate the cartridge is bent, the geometry of the sampler is disturbed and the results obtained become unreliable. ***To place the cartridge centrally you need only to tap on the diffusive body.***

Insert a label in the pocket without peeling it off. Keep note of the date and time and expose ***radiello***. Sampling has started.

Keeping the diffusive body in a vertical position, to screw it onto the support plate

user tip

Do not touch the cartridge with your fingers if possible, particularly if it is impregnated with reactive

user tip

even if you can write date and time of the sampling start and end on the adhesive label, we suggest you to keep note of these parameters also separately: after a week exposure with bad weather conditions, your writing might have become illegible!

DO NOT USE MARKER PENS to write on the label: they contain solvents that are sampled by ***radiello***!

after the sampling

Keep note of the date and time of the end of exposure.

Place the cartridge into the tube, peel off the label and stick it onto the tube **such that the barcode is parallel to the axis of the tube.**

If you have performed the sampling of different polluting compounds at the same time, ***BE CAREFUL NOT TO MIX UP THE TUBES***: place the exposed cartridge in its original tube, identified by the code printed on the plastic bag.

IMPORTANT

Always stick the label such that the barcode is parallel to the axis of the tube: any other position will compromise the barcode automated reading by the optic reading device.

radiello
maintenance

When exposed outdoors or in a workplace environment, the diffusive body may get dirty from airborne dust. Fine particles (PM_{10}) are especially harmful to yellow diffusive bodies since they can obstruct the pores. When the diffusive bodies are dirty you can wash them as follows.

Immerse the diffusive bodies in a beaker with a soapy solution (e.g. dish detergent) and sonicate them for 20 minutes. As the diffusive bodies float, you may make them sink by putting a smaller beaker on them, with water inside enough to dip it a few centimeters. Rinse the diffusive bodies with plenty of water and then deionized water; let them finally dry in the air.

IMPORTANT: NEVER USE SOLVENTS TO CLEAN THE DIFFUSIVE BODIES!!!

After four or five washings, diffusive bodies need to be replaced: repeatedly adsorbed dust may have penetrated the so deeply that they cannot be removed by washing anymore.

The following table shows the advised washing schedule:

PM_{10} concentration ($\mu g \cdot m^{-3}$)	<30	40	>50
Washing after days of exposure	45	30	15

radiello-ready-to-use

The ready-to-use version may be advantageous when you prefer not to assemble all of the components on field. It can be purchased as it is or in separate parts to be assembled by the customer.

In the ***ready-to-use version*** the adsorbing cartridge is already contained in a diffusive body closed with a polycarbonate screw-thread cap. The whole is closed in a polypropylene airtight container. Just before use draw the diffusive body out of the container and fit it to the special snapping vertical adapter fixed to the supporting plate. After the end of exposure, the diffusive body with its content is placed again in the polypropylene airtight container to be shipped to the laboratory for analysis. The ***ready-to-use radiello*** (polycarbonate cap, glass or plastic tube, special snapping vertical adapter, barcode label and polypropylene container) is available for the sampling of the following compounds:

code	**sampling of**	**contains**
123-1	BTEX and VOCs	white diffusive body and cartridge code 130
123-2	BTEX and VOCs	yellow diffusive body and cartridge code 145
123-3	NO_2, SO_2 and HF	blue diffusive body and cartridge code 166
123-4	aldehydes	blue diffusive body and cartridge code 165
123-5	ozone	blue diffusive body and cartridge code 172
123-6	hydrogen sulfide	white diffusive body and cartridge code 170
123-7	ammonia	blue diffusive body and cartridge code 168
123-8	HCl	white diffusive body and cartridge code 169

on top:
to the right, ***radiello-ready-to-use***
to the left, the diffusive body with the polycarbonate cap and the adsorbing cartridge inside
at the bottom: the special snapping adapter

see left: the supporting plate with the vertical snapping adapter

IMPORTANT: for the ***ready-to-use*** version ***the supporting plate needs to be ordered separately. The ready-to-use samplers are stable for 3 months.***

If you prefer ***to assemble it by yourselves***, you should order:

- ✓ diffusive bodies (of the required type, see following chapters)
- ✓ adsorbing cartridges (of the required type, see following chapters)
- ✓ polycarbonate caps, **code 124-1**
- ✓ special snapping adapters, **code 122-1**
- ✓ polypropylene containers, **code 124-2**
- ✓ supporting plates, **code 121**

user tip

the ***ready-to-use*** version of ***radiello*** is very useful in the workplace sampling campaigns but is not advised if very low concentrations in outdoor or domestic environments are to be measured

Fit the diffusive body to the adapter by pushing it till you hear a clicking sound

Draw the diffusive body by tilting it with decision

Volatile organic compounds (VOCs)

chemically desorbed with CS_2

Radiello components to be used:

White diffusive body code 120
Supporting plate code 121
Vertical adapter code 122 (optional)
Adsorbing cartridge code 130

Or: *radiello-ready-to-use* code 123-1 (also see page A8)

Principle

Code 130 cartridge is a stainless steel net cylinder, with 100 mesh grid opening and 5.8 mm diameter, packed with 530 ± 30 mg of activated charcoal with particle size 35-50 mesh. Volatile organic compounds are trapped by adsorption and recovered by carbon disulfide displacement, analysis is performed by FID gas chromatography.

Sampling rates

The table on page D2 lists sampling rate values at 298 K (25 °C) and 1013 hPa, experimentally measured in a standard atmosphere chamber. For other compounds, whose diffusion coefficient[1] is known, sampling rate can be calculated according to equation [5] on page A2, taking into account that white diffusive body and code 130 cartridge give the geometric constant of radiello the value of 14.145 ± 0.110 cm. Several experiments performed in the standard atmosphere chamber demonstrate that the calculated sampling rates seldom deviate by more than ± 10% from the experimentally measured values.

Effect of temperaure, humidity and wind speed

Sampling rates varies from the value at 298 K on the effect of temperature (in Kelvin) as expressed by the following equation

$$Q_K = Q_{298}\left(\frac{K}{298}\right)^{1.5}$$

where Q_K is the sampling rate at the temperature **K** and Q_{298} is the reference value at 298 K. This produces a variation of ± 5% for 10 °C variation (upwards or downwards) from 25 °C.

Sampling rate is invariant with humidity in the range 15-90% and with wind speed between 0.1 and 10 $m \cdot s^{-1}$.

---

[1] Lugg G.A.: Diffusion Coefficients of Some Organic and Other Vapours in Air. *Anal. Chem*. **40-7**:1072-1077 (1968).

Calculations

The listed sampling rate values already take into account for the desorption efficiency with carbon disulfide. **The average concentration over the exposure time interval is therefore calculated from the mass of analyte found onto the cartridge and exposure time without introducing any corrective factor**, apart from corrections due to average temperature different from 25 °C.

Average concentration over the whole exposure time is calculated according to the following expression

$$C\,[\mu g \cdot m^{-3}] = \frac{m\,[\mu g]}{Q_K\,[ml \cdot min^{-1}] \cdot t\,[min]}\ 1{,}000{,}000$$

where:
m = mass of analyte in µg
t = exposure time in minutes

Sampling rate values Q at 25°C (298 K)

	Q_{298} ml·min^{-1}	linearity range µg·m^{-3}·min	uncertainty at 2σ %	notes
acetone	77	10,000-600·10^6	7.0	**a**
acetonitrile	73	10,000-6·10^6	8.2	**b**
acrylonitrile	75	1,000-50·10^6	2.2	
benzyl alcohol	37	1,000-800·10^6	6.5	
amyl acetate	52	1,000-800·10^6	3.4	
benzene	80	500-500·10^6	1.8	
bromochloromethane	70	50,000-1,000·10^6	1.4	
butanol	74	1,000-500·10^6	5.0	
sec-butanol	64	1,000-300·10^6	5.2	
tert-butanol	62	1,000-300·10^6	5.5	
butyl acetate	60	1,000-1,000·10^6	3.0	
2-butoxyethanol	56	1,000-100·10^6	5.7	
2-butoxyethyl acetate	41	1,000-100·10^6	5.5	
carbon tetrachloride	67	100,000-60·10^6	9.0	
cyclohexane	54	500-500·10^6	4.5	
cyclohexanone	68	5,000-120·10^6	4.2	
cyclohexanol	54	5,000-120·10^6	4.5	
chlorobenzene	68	1,000-1,000·10^6	3.6	
chloroform	75	100,000-60·10^6	9.7	**a**
n-decane	43	500-1,000·10^6	1.1	
diaceton alcohol	43	500-1,000·10^6	4.5	
1,4-dichlorobenzene	51	1,000-1,000·10^6	7.7	
1,2-dichloroethane	77	1,000-500·10^6	8.2	
1,2-dichloropropane	66	500-250·10^6	4.5	
dichloromethane	90	500-60·10^6	8.7	
N,N-dimetylformamide	82	1,000-200·10^6	14.5	**c**
1,4-dioxane	68	1,000-600·10^6	5.5	
n-dodecane	8	1,000-1,000·10^6	4.7	
n-heptane	58	5,000-1,500·10^6	3.0	
n-hexane	66	1,000-1,000·10^6	2.5	
1-hexanol	52	5,000-120·10^6	5.5	
ethanol	102	10,000-500·10^6	7.5	**a-b**
diethyl ether	78	5,000-500·10^6	12.0	**a**
ethyl acetate	78	1,000-1,000·10^6	1.5	
ethylbenzene	68	1,000-1,000·10^6	2.4	
2-ethyl-1-hexanol	43	5,000-500·10^6	10.1	
2-ethoxyethanol	55	500-50·10^6	6.7	**b**
2-ethoxyethyl acetate	54	10,000-100·10^6	2.5	
ethyl-***tert***-butyl ether (ETBE)	61	500-200·10^6	3.0	
isobutanol	77	1,000-300·10^6	2.5	
isobutyl acetate	63	1,000-1,000·10^6	5.2	
isooctane	55	500-1,000·10^6	3.2	
isopropanol	52	10,000-400·10^6	12.0	**b**
isopropyl acetate	66	1,000-1,000·10^6	9.9	
isopropylbenzene	58	1,000-1,000·10^6	2.7	
limonene	43	1,000-1,000·10^6	10.0	
methanol	125	10,000-250·10^6	9.2	**a-b**
methyl acetate	80	1,000-1,000·10^6	12.0	
methyl-***ter***-butyl ether (MTBE)	65	500-200·10^6	2.5	

	Q_{298} ml·min^{-1}	linearity range µg·m^{-3}·min	uncertainty at 2σ %	notes
methylcyclohexane	66	1,000-1,000·10^6	6.5	
methylcyclopentane	70	1,000-1,000·10^6	2.5	
methylethylketone	79	1,000-500·10^6	1.6	
methylisobutylketone	67	1,000-250·10^6	8.7	
methyl metacrylate	68	1,000-500·10^6	2.5	
2-methylpentane	70	1,000-1,000·10^6	2.5	
3-methylpentane	70	1,000-1,000·10^6	2.5	
2-methoxyethanol	35	5,000-100·10^6	11.0	**b**
2-methoxyethyl acetate	56	2,000-100·10^6	3.0	
1-methoxy-2-propanol	55	1,000-350·10^6	6.0	
1-methoxy-2-propyl acetate	60	2,000-350·10^6	6.2	
naphthalene	25	1,000-1,000·10^6	7.0	
n-nonane	48	1,000-1,000·10^6	5.4	
n-octane	53	500-1,000·10^6	3.2	
pentane	74	1,000-1,000·10^6	1.9	
α-pinene	53	1,000-1,000·10^6	7.0	
propyl acetate	65	500-1,000·10^6	7.5	
propylbenzene	57	1,000-1,000·10^6	2.9	
styrene	61	1,000-500·10^6	3.0	
tetrachloroethylene	59	10,000-500·10^6	2.5	
tetrahydrofuran	74	2,000-250·10^6	11.0	**b**
toluene	74	500-1,000·10^6	1.5	
1,1,1-trichloroethane	62	5,000-1,000·10^6	5.5	
trichloroethylene	69	5,000-1,000·10^6	2.4	
1,2,4-trimethylbenzene	50	500-1,000·10^6	6.6	
n-undecane	24	1,000-1,000·10^6	10.0	
m-xylene	70	500-1,000·10^6	2.5	
o-xylene	65	500-1,000·10^6	2.5	
p-xylene	70	500-1,000·10^6	2.5	

Notes:

a = weakly adsorbed compound. If its concentration is higher than the TLV for the workplace environments it may be partially displaced by other compounds that are more strongly trapped if their concentration is also high. If this is the case, it is advisable to reduce sampling time under 8 hours.

b = prolonged exposure of charcoal cartridges at relative average humidity higher than 80% causes adsorption of up to 100 mg of water. Water does not interfere with adsorption mechanisms but is displaced by carbon disulfide and gives raise to a separate layer. Some very water soluble polar compounds will distribute between the two solvents, thus provoking an underestimation of the actual air concentration since only the carbon disulfide is injected in the gas chromatograph. When the concentration of polar compounds has to be determined, the calibration curve should be prepared by spiking 50 µl of water in each tube containing the cartridge and the 2 ml of carbon disulfide standard solution (see Analysis).

c = better reproducibility obtained by use of methanol as extraction solvent instead of carbon disulfide.

Limit of quantitation

The limit of quantitation depends on the instrumentation and on the analytical conditions. The minimum revealable environmental concentration can be estimated on the basis of the equation on page D1, where ***m*** is the minimum revealable mass, experimentally measured for each compound. Under the analytical conditions described on page D4, the limit of quantitation for 7 days exposure usually ranges from 0.05 to 1 µg·m^{-3}, depending on the compound.

Exposure

Code 130 cartridge has a very large loading capacity: about 80 mg, corresponding to an overall VOCs concentration of 3,000-3,500 mg·m^{-3} sampled for 8 hours or 70,000-80,000 µg·m^{-3} sampled for 14 days. Neverthless, if the quantified overall adsorbed mass should be near 80 mg, sampling rate could have deviated from linearity. If this is the case, it is advisable to repeat the sampling experiment reducing exposure time.

Workplace environment

In workplace environments complex mixtures of airborne solvent vapours are often found at concentrations of 2,000-3,000 mg·m^{-3}. The outstanding adsorbing capacity of code 130 cartridges allows you to sample them for the whole working shift of 8 hours. On the other hand, the very high values of sampling rates for a variety of compounds allow you to perform accurate concentration measurements even after very short exposures. For example, 15 minutes are enough to measure 0.1 mg·m^{-3} of benzene.

radiello can therefore be employed to evaluate both *TWA* and *STEL* concentrations.

Other indoor sampling experiments and outdoor campaigns

High sampling rates of ***radiello*** ensure very low limits of detection also for short exposure time intervals. For example, you may measure benzene concentrations as low as 2 µg·m^{-3} with an error not exceeding 4% after 8 hours of exposure. If ***radiello*** is exposed for 7 days, limit of quantitation becomes 0.1 µg·m^{-3}.

Generally speaking, we suggest exposure time duration ranging from 8 hours to 30 days, the ideal value being 7 days.

Storage

The activated charcoal cartridges have undergone a complex conditioning process that ensures an outstanding chromatographic blank level, never exceeding three times the instrumental noise of a FID detector at the lowest attenuation.

Kept in a cool place and away from volatile organic compounds, the cartridges mantain unchanging blank level and adsorbing capacity for at least two years. Expiry date and lot number are printed onto the plastic bag wrapping each cartridge: its integrity stands as warranty seal.

After exposure the cartridges, well capped and kept in a cool and solvent-free place, mantain their content unaltered for at least six months.

Analysis

Extraction

Introduce 2 ml of CS_2 and 100 µl of internal standard solution (see next page) directly in the ***radiello*** glass tube without drawing out the cartridge. **Always use class A volumetric pipettes or dispensers.** Stir from time to time for 30 minutes. If analysis is not performed soon after, draw out the cartridge and discard it.

Calibration

Outdoor environment sampling

If benzene, toluene, ethylbenzene and xylenes (BTEX) have to be analyzed, prepare three or four standard solutions in CS_2 having decreasing concentrations of the analytes in the following ranges (in mg·l^{-1}):

benzene	0.04-17.6	ethylbenzene	0.04-17.7
toluene	0.09-34.8	m-xylene	0.04-17.2
o-xylene	0.04-17.6	p-xylene	0.04-17.2

It is advisable to proceed via consecutive dilutions, starting for example from a stock solution containing 1 ml of each compound in 100 ml. Always use class A volumetric glassware. Introduce 2 ml of each standard solution, along with 100 µl of internal standard, onto a blank code 130 cartridge in its glass tube.

IMPORTANT

always use high purity grade CS_2, for example Fluka Cat. No. 84713 or Aldrich Cat. No. 34,227-0

BE CAREFUL

even refrigerated, CS_2 permeates the tube plastic cap: its volume decreases by 4-5% a day. If the internal standard has been added, it is only matter of unpleasant odour...

Analysis of unknown samples

Identify the sample that has been exposed for the longest time or at the highest expected concentration. Introduce 2 ml of CS_2 but do not add the internal standard, stir and let the sample stand for 30 minutes. Without discarding the cartridge, inject the CS_2 solution in the gas chromatograph with FID detector (see below), identify the compounds appearing in the chromatogram and make an estimation of the order of magnitude of their concentrations.

Prepare a CS_2 solution of the identified compounds with doubled concentration with respect to the sample. Dilute this solution in order to obtain standard solutions of concentration respectively about 0.1, 0.5 and 1 times the concentration estimated in the sample. Introduce 2 ml of each standard solution onto a blank code 130 cartridge in its glass tube, along with the chosen internal standard solution.

The chosen **internal standard** should have a retention time that does not interfere with other compounds in the chromatogram. Compatibly with this requirements, we suggest to employ a solution of **2-fluorotoluene** (e.g. Aldrich F 1,532-3 or Fluka 47520) in CS_2 with concentration of 100 $\mu l \cdot l^{-1}$ for outdoor samples and 2 $ml \cdot l^{-1}$ for workplace samples. Add 2 ml of CS_2 and the internal standard to all of the samples, stir, let the samples stand for 30 minutes and discard the cartridges prior to the analysis.

USER TIP

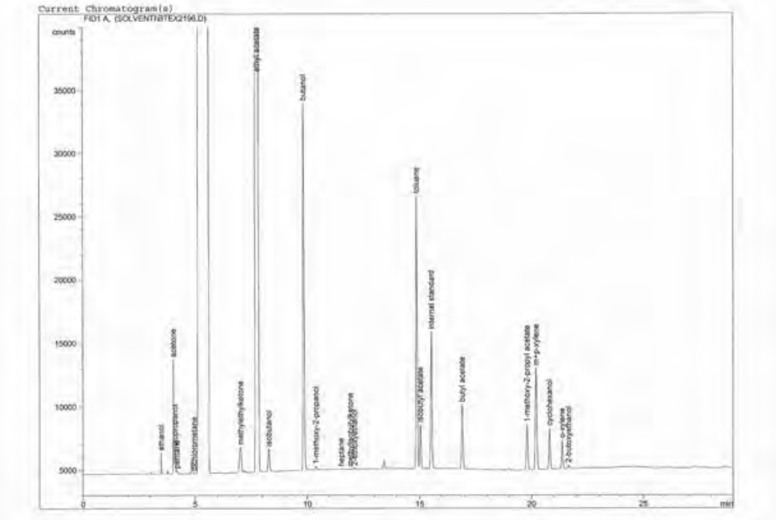
For a very accurate calibration we offer the **preloaded cartridges code 405** (outdoor environment) and **code 406** (workplace environment).

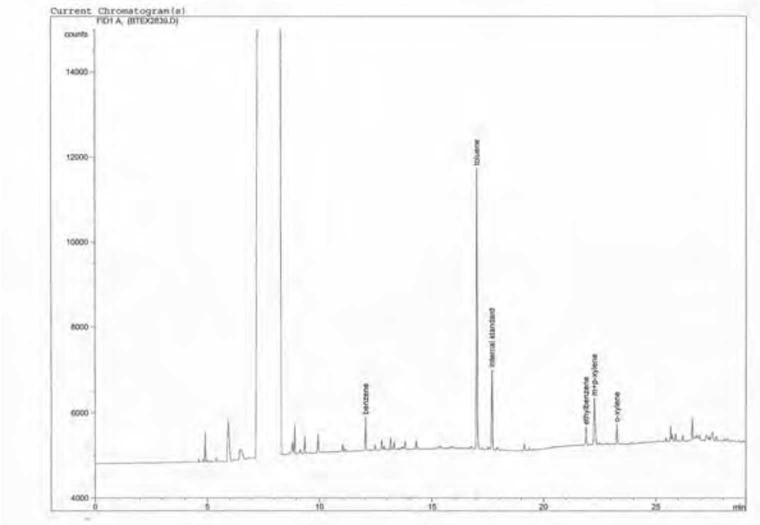
Instrumental analysis (advised)

Capillary gas chromatography with FID detection

outdoor environment samples: 100% dimethylpolysiloxane column 50m x 0.2mm, film thickness 0.5 µm; (e.g. Petrocol DH 50.2, Supelco Cat.No. 24133-U) split injection of 2 µl; split ratio 25:1; nitrogen carrier gas at constant pressure of 20 psi; injector temperature 240 °C; oven initial temperature 35 °C for 5 minutes, 5 °C/min up to 90 °C, maintain for 3 minutes, 10 °C/min up to 220 °C, final isotherm for 5 minutes.

workplace samples: 100% dimethylpolysiloxane column 0.2 mm·50 m, film 0.5 µm; split injection of 3 µl, split ratio 100:1; carrier N_2 at constant pressure of 20 psi; injector temperature 240 °C; oven initial temperature 50 °C for 5 minutes, 5 °C/min up to 80 °C, 15 °C/min up to 135 °C, 20 °C/min up to 220 °C, final isotherm 10 minutes. Total time: 29 minutes. The retention times for several compounds analyzed under the described conditions are listed in the table on next page.





On top: *FID chromatogram of a real workplace sample*

on the left: *chromatogram of a real urban outdoor sample*

USER TIP

If you perform several analyses, a barcode reader will greatly improve productivity in your laboratory and will also minimize the possibility of errors in the copying of sample labels.

Please contact us to help you in the implementation of the reader.

We have also developed software solutions for the analytical data processing and automated production of analysis reports.

What makes the code 130 cartridge incomparable?

	retention time (minutes)
methanol	4.834
ethanol	5.340
acetone	5.712
isopropanol	5.835
pentane	6.121
methyl acetate	6.346
dichloromethane	6.405
2-methylpentane	7.559
methylethylketone	7.719
3-methylpentane	7.941
ethyl acetate	8.331
n-hexane	8.402
isobutanol	8.763
methylcyclopentane	9.350
1,1,1-trichloroethane	9.636
butanol	9.956
isopropyl acetate	9.978
benzene	10.203
1-methoxy-2-propanol	10.424
cyclohexane	10.580
1,2-dichloropropane	11.285
trichloroethylene	11.625
isooctane	11.667
2-ethoxyethanol	11.831
propyl acetate	11.868
n-eptane	12.068
1-ethoxy-2-propanol	12.775
methylcyclohexane	12.912
methylisobutylketone	13.258
isobutyl acetate	14.005
toluene	14.055
butyl acetate	15.279
n-octane	15.435
tetrachloroethylene	15.601
diaceton alcohol	15.915
1-methoxy-2-propyl acetate	16.609
ethylbenzene	16.997
m+p-xylene	17.241
cyclohexanone	17.436
cyclohexanol	17.436
styrene	17.716
o-xylene	17.832
2-buthoxyethanol	17.880
n-nonane	18.186
α-pinene	19.129
n-decane	20.334
n-undecane	22.142

the container

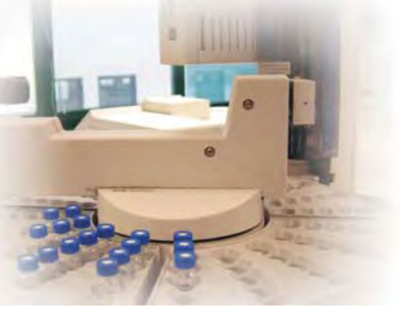
The container is made of stainless steel cloth AISI 316 with 100 mesh grid opening. It is electric welded with no supply of foreign materials. It has tolerance of ± 0.05 mm diameter and of ± 0.1 mm length.

the contents

The cartridge is packed with vegetal activated charcoal with a very large adsorbing surface. Its exceptionally low blank is obtained by conditioning it in a nitrogen stream fluidised bed at 450 °C for 16 hours. The fluidised bed technique does not only guarantee the thorough purification of adsorbing material but also performs an accurate selection of its granulometry, by ventilation separations of the fraction under 50 mesh and over 35 mesh.

the production

The cartridge is filled up with charcoal by a very complex automated apparatus that was designed and realised in our laboratory. It avoids any contamination of the adsorbing material during the delicate process of cartridge production and ensures a very accurate dosing of the material itself, providing a variability of less than 2% of the weight of the activated charcoal among the cartridges.



the quality control

Each cartridge batch undergoes statistical quality control of the blank level. If amounts higher than 20 ng of each of the BTEX compounds are found, the entire lot is discarded.

the sampling rate measurements

The sampling rate is measured in a standard atmosphere chamber unique in Italy (and one of the few found all over Europe) that allows the dynamic generation of high flows of controlled concentration gas mixtures from 1 µg·m^{-3} to 1,000 mg·m^{-3} (dynamic range from 1 to 10^6) of each investigated compound alone or mixed with others. The chamber allows temperature control from -20 to 60 °C, relative humidity control from 5% to 100% and air speed variation from 0.1 to 10 m·s^{-1}.

All of the gas flows are measured as mass flows and have therefore the properties of primary standards. All of the operating parameters (gas flows, temperature, relative humidity, ...) are recorded and the records are available along with the certification documents.