Indoor Air and Soil Vapor Sampling Plan, Rev. 3

Fox Ave Building Site

Seattle, Washington

Prepared for:
Fox Ave Building LLC

Prepared by: CALIBRE
Systems, Inc. Project No.

July 28, 2023 (as Rev 3)

Table of Contents

List of Exhibits

List of Tables

List of Figures

Acronyms

1,1-DCE	1,1-dichloroethene
AO	Agreed Order
CAP	Cleanup Action Plan
CCD	Cascade Columbia Distribution
cis-1,2DCE	cis-1,2-dichloroethene
CLARC	Cleanup Levels and Risk Calculation
CMP	Compliance Monitoring Plan
COC	Chemical of Concern
CULs	Cleanup levels
dCAP	draft Cleanup Action Plan
DQOs	Data quality objectives
Ecology	Washington State Department of Ecology
EDR	Engineering Design Report
ERD	Enhanced Reductive Dechlorination
FS	Feasibility Study

GIS	Geographic information system
GWC	Great Western Chemical
LCS	Laboratory control samples
MTCA	Model Toxics Control Act
PCE	Tetrachloroethene
PID	Photoionization detector
POC	Points of compliance
QAPP	Quality Assurance Project Plan
QA	Quality assurance
QC	Quality control
RPD	Relative percent difference
SBW	Seattle Boiler Works
SDG	Sample delivery group
SOP	Standard operating procedures
SVE	Soil vapor extraction
TCE	Trichloroethene
TO-15	Toxic organics – 15
USTs	Underground storage tanks
VC	Vinyl chloride
VI SAP	Vapor intrusion sampling and analysis plan
VOC	Volatile organic compounds
$\mu g/m^3$	Microgram per cubic meter

Addendum to:
Indoor Air and Soil Vapor Sampling Plan, Rev 2
Fox Ave Building Site, Seattle, Washington

The new/revised copy of the work plan with this addendum includes **Rev 3** in the title, with an updated issue date of **July 28, 2023**.

The corrections/adjustments below are based on comments provided by Seattle Boiler Works.

1. **The work plan incorrectly described the break room in the SBW Pipe Shop as unheated.**

   The actual condition of break room in the SBW Pipe Shop is a heated and enclosed space. The indoor air in this area will be sampled.

2. **An employee-occupied heated and enclosed office space is present at the SE corner of the Pipe Shop (adjacent to Fox Avenue).**

   The indoor air in this identified space (office space present at the SE corner of the Pipe Shop adjacent to Fox Avenue) will be sampled.

3. **Groundwater in the area is subject to tidal fluctuations, this changing water level will impact vapors in the vadose zone and may potentially influence vapor intrusion.**

   The 7-hour sampling interval for collection of indoor air samples will be selected so that it includes a high tide cycle.

1.0 INTRODUCTION

This indoor air sampling and analysis plan (SAP) has been developed for the Fox Ave Building Site, Facility Site ID#: 2282. This SAP has been prepared as requested by Washington State Department of Ecology (Ecology). The purpose of this SAP is to describe the sample collection, handling, and analytical requirements planned for the monitoring work and has been prepared following relevant Ecology guidance for characterization and evaluation of vapor intrusion.

1.1 History/Background

A solvent release was identified in 1989 when Great Western Chemical (GWC) closed six underground storage tanks (USTs) in place. The same year, GWC also decommissioned and removed ten other USTs. As part of an overall remodel, GWC retained the services of Hart-Crowser to provide engineering assistance in the removal of the tanks. GWC filed for bankruptcy protection in 2001 and Fox Avenue Building LLC acquired ownership of the property in 2003. Multiple phases of Agreed Orders, Site investigations and interim actions were implemented between 1991 and 2007.

In 2009, Ecology entered into an Agreed Order (DE 6486) with Fox Avenue Building LLC requiring the following activities:

1. Perform an interim measure to control the discharge of tetrachloroethylene (PCE) in the groundwater plume from the Site to the Lower Duwamish Waterway. Bioremediation using Enhanced Reductive Dechlorination (ERD) to degrade the Site COCs is identified.
2. Perform a pilot test to see how effective ERD may be in degrading contaminants in soils in the source area for the plume
3. Do a source area data gap investigation to better identify the measures and cost needed to clean up this area
4. Collect air samples to find whether PCE vapors are reaching the office part of the Fox Avenue Building facility. If so, evaluate restarting the existing soil vapor extraction (SVE) system to control vapor intrusion.
5. Prepare a new Feasibility Study (FS) to enable a site cleanup action to be selected in accordance with the MTCA.
6. Prepare a draft Cleanup Action Plan (dCAP) with the proposed cleanup action for addressing the contamination present on Site.

Based on the FS and dCAP, Ecology issued the final CAP in 2012 (Ecology 2012). Following Ecology's completion of the CAP, a new Agreed Order (DE 8985) was entered requiring Fox Avenue to continue site cleanup by implementing the CAP. These remedial actions included:

1. Thermal treatment via Electrical Resistive Heating in the Main Source Area followed by ERD.
2. ERD in the Downgradient Groundwater Plume.
3. ERD and Soil Vapor Extraction in the Northwest Corner Plume.
4. Confirmation and performance monitoring as required under the CAP.

Prior to initiating work on the remedial actions in the CAP, an Engineering Design Report (including Operation and Maintenance Plan and Compliance Monitoring Plan) was submitted to Ecology for review and approval.

1.2 Requirements from the CAP

The media impacted at the site are soil, groundwater, and air, with air compliance measured by indoor air. Following the MTCA procedures from WAC 173-340-70, and documented in the CAP, the Site Cleanup Standards are based on two components;

- Cleanup levels (CULs) and
- Points of compliance (POC)
- Other regulatory requirements based on site applicable state and federal laws

The CULs establish the concentration based criteria which do not threaten human health or the environment and the POC designate the Site location(s) where the CULs must be met. The CULs/POC are combined to define the Site Cleanup Standards and corresponding performance criteria. The CAP also describes additional regulatory requirements which apply to the Site restoration/cleanup actions because of the specific type of actions and Site location. The additional requirements in the CAP include approximate restoration timeframes where the different phases of the remedial actions are to be implemented based on progress towards meeting the Cleanup Standards.

1.2.1 Indoor Air Cleanup Standards

The consideration of cross-media pathways, specifically soil-to-groundwater and soil /groundwater-to-indoor air were included in the FS and CAP[1], as required under WAC 173-340-702. The CAP details that soil CULs protective of both groundwater and indoor air will not be numerical values but instead a direct empirical demonstration which confirms that soil concentrations remaining will be protective of the other exposure pathways (i.e., soil-to-groundwater and soil/groundwater-to-indoor air), as described under MTCA (WAC 173-340-747(3)(f)). Other Ecology guidance (Ecology 2022a) includes screening criteria that may be relevant for consideration but they are generally intended to screen-out a pathway and are therefore not relevant to demonstrate compliance. Direct measurement of the potential indoor air exposure levels and comparison with the CULs established in the CAP is the best method (i.e., most direct, most certain) to

---

[1] From the CAP:

1. *Soil leaching contaminants to groundwater. This is a cross-media pathway that concerns all site soil that is a potential source of chemicals to groundwater. Compliance will be demonstrated empirically by directly comparing groundwater concentrations at the Fox Avenue conditional point of compliance (CPOC) following source area remediation to the groundwater remediation and cleanup levels. If groundwater at the CPOC meets the groundwater cleanup levels, this pathway will be empirically demonstrated to be in compliance.*
2. *Soil in the vadose zone causing vapor intrusion. For protection of this cross-media pathway, the POC is from the surface to the uppermost groundwater table (approximately 10 feet bgs at the Site). Compliance will be demonstrated empirically by direct sampling of indoor air following source area remediation. If indoor air is in compliance with the indoor air cleanup levels, then this pathway will be empirically demonstrated to be in compliance.*

evaluate residual risk and demonstrate compliance with the CAP objectives. This direct measurement of indoor air exposure levels was defined in the CAP and further described in the Engineering Design Report.

The POC for air CULs is site-wide, including indoor and outdoor/ambient air. Sampling for compliance with air CULs has focused on indoor air because vapor intrusion can cause higher concentrations in indoor air than outdoor air. By definition, vapor intrusion to indoor air, can only occur in enclosed spaces and structures such as the CCD office, or the SBW buildings overlying the downgradient plume. All indoor air sampling has also included ambient air sampling.

The CAP notes that active remedial actions proposed for the source areas are intended to reduce soil concentrations and the resultant residual soil and groundwater concentrations following active remediation are anticipated to be protective of indoor air site-wide (within all structures). Compliance is to be demonstrated by measuring indoor air in the CCD office, the downgradient SBW buildings, and other potentially impacted structures before and after active remediation of soil and groundwater. Compliance monitoring data for indoor air has been previously collected and submitted to Ecology; the summary of results (including sampling from both the SBW and CCD properties) indicated compliance with their respective indoor air cleanup levels.

1.2.2 Indoor Air CULs for CCD

The CAP establishes that MTCA Method C levels are applicable on the Fox Ave Building property (the structure that CCD operates within) based upon the commercial/industrial use of the property.

1.2.3 Indoor Air CULs for SBW

The CAP presents modified MTCA Method B levels (as described under WAC 173-340-705 (2)) applicable considering the current industrial use of the SBW property. The modified MTCA Method B levels are described as “trigger levels” in the CAP and, in the future, standard MTCA Method B levels for indoor air are necessary to free the property of any future development restrictions. The CAP defines the following exposure/frequency adjustments to MTCA Equation 750-2 to set the trigger levels for SBW property:

1. Reduce worker exposure from the standard 30 years to 15 years (based in the restoration time frame to achieve standard MTCA Method B cleanup levels in 15 years in SBW) and
2. Reduce the exposure frequency to reflect worker exposure (i.e., 8 hours per day, for 5 days per week, for 49 weeks per year).
3. If the SBW site use is converted to residential use, the contingency trigger will be revised downward to the standard MTCA Method B cleanup level.

These exposure/frequency adjustments to MTCA Equation 750-2 are similar to the recent CLARC additions for *Vapor Intrusion Screening Levels for Workers* (Ecology 2022b).

The initial CAP (Ecology 2012a) did not identify vinyl chloride as a COC for indoor air (it had not been detected exceeding applicable standards in prior sampling) and did not include an indoor air CUL for vinyl chloride. The CAP was amended in 2013 (Ecology 2013) noting that; “ *Indoor air samples collected by URS at the Seattle Boiler Works facility in December 2010 and by Floyd!Snider in December 2012 indicate that PCE, TCE and vinyl chloride are below both Method C and the Modified Method B concentrations used to trigger* *contingency measures at Seattle Boiler."* The 2013 CAP amendment set the MTCA Method C indoor air criteria at 2.8 µg/m^3 and Method B criteria at 0.28 µg/m^3.

1.2.4 Restoration Timeframes

The relevant restoration timeframes presented in the CAP are as follows:

- Indoor air at CCD (Method C) 1 year—using thermal and SVE to meet the CULs.
- Indoor air at SBW (modified Method B) during and after thermal treatment (no restoration timeframe specified, but contingency actions[2] required if trigger levels are exceeded.
- Indoor air at SBW (Method B) 10–15 years of post-thermal ERD to meet the standard Method B CULs.

As the CAP was being prepared EPA updated the relevant toxicity factors for both PCE and TCE and the cleanup levels in the CAP were subsequently updated in an amended order (Ecology 2013). The project has also considered the potential for adverse effects from short-term TCE exposure[3].

1.3 Purpose

The objective of this VI SAP is to define data collection procedures for sampling to evaluate whether vapor intrusion of PCE and its primary degradation products present in the shallow groundwater beneath the Site is affecting indoor air quality within and down-gradient of the Fox Ave Building Site. The purpose of this SAP is to describe the sample collection, handling, and analytical requirements to be used during the monitoring work. The objectives, number of samples, analyses planned, documentation and schedules associated with these monitoring elements are described in detail in the subsequent sections.

1.4 Property and Building-Specific Details

The Fox Ave Building Site is located at 6900 Fox Avenue S. and encompasses downgradient properties under which a VOC plume travels and eventually discharges to the Lower Duwamish Waterway (LDW). Cascade Columbia Distribution (CCD) operates on the property located at 6900 Fox Ave S. and occupies approximately 2.5 acres. The area is zoned for heavy industry and several commercial and industrial operations are located on nearby and adjacent properties. CCD warehouses, packages, and distributes bulk chemicals for the aerospace, electronics, food manufacturing, personal care, water treatment, and metal plating industries. CCD operates in the warehouse that covers 35,650 sq. ft.

---

[2] If indoor air levels are found to exceed Modified MTCA Method B CULs at Seattle Boiler Works during active remediation (thermal and ERD), or exceed standard MTCA Method B CULs following active remediation, or if land use at any time changes to residential then contingency measures as described in Section 6.6 of the CAP will be evaluated and implemented. Modified MTCA Method B concentrations account for worker exposure based on 8 hours per day exposure for 5 days per week for 49 weeks per year for 15 years. The expected restoration time frame for indoor air to achieve standard MTCA Method B CULs is 15 years.

[3] Potential health effects from breathing TCE depends on concentrations in indoor air, length of exposure, and when a person is exposed. Women in the first 8 weeks of pregnancy are most sensitive to TCE exposures because of the potential to increase the risk of heart malformations in the developing fetus. Presently, Ecology has adopted EPA's TCE action level of 2 micrograms per cubic meter (µg/m^3) for pregnant women that may be exposed in their home. The short-term action level for commercial exposures is 7.5 (µg /m^3).

The building was built in 1959 and construction includes a slab-on-grade, concrete tilt-up wall panels, and a wood frame roof. Designed as a warehouse with the slab at a truck-loading height, the building includes multiple loading docks and large roll-up doors for materials and forklift access. Daily operations at the facility is as a warehouse with delivery trucks arriving at loading docks, materials moved in and sorted/stored and materials moved out for regional delivery, all trucks are at loading docks with rollup doors and the facility cannot operate with the rollup doors closed. The building includes a two level office area (covering approximately 2,300 sq. ft) and a small break room (< 300 sq. ft). In the larger warehouse area, multiple forklifts (up to 8) with internal combustion engines are in operation at all times and the large roll-up doors are always open for ventilation during operations. The larger warehouse area is unheated and the area labeled *old warehouse building*, a subarea within the warehouse with a different roof structure, is an integrated/open part of the warehouse. The Alkaline Shed and Flammables Shed areas are open-sided. The Production area is a containment area with an elevated roof structure and is also open-sided.

The 2009 indoor air sampling at CCD included co-located subslab-indoor air samples; two were in the office plus an additional location in the enclosed breakroom in the warehouse. Added samples were collected in the upstairs of the office (without a subslab co-located sample) and one more in the open warehouse (labeled as an ambient air sample AA-4, and also without a co-located subslab sample). These data and maps are included in Appendix A and the sampling results are summarized in the CAP (also in Appendix A)

Based on the 2009 sampling results, the Engineering Design Report (Floyd-Snider 2012) established the continued indoor air samples (co-located subslab-indoor air samples); two were in the office plus an additional location in the enclosed breakroom in the warehouse. This sampling was completed in 2013 at the time that the thermal heating was underway.

Prior work plans for vapor intrusion sampling were submitted to Ecology and existing vapor intrusion sampling has therefore focused on the office area and break room because of the ventilation requirement that the rollup doors are always open when occupied. See Figure 1 for indoor air and sub-slab sample locations at CCD.

The SBW property is an approximate 4.5 acre parcel comprised of several buildings under approximately 65,000 square feet of roof. The SBW facility is an industrial fabrication shop primarily engaged in fabrication and assembly of various industrial equipment such as boilers, pressure vessels, tanks, heat exchangers, and other industrial equipment. Current facility operations primarily consist of assembly of various components that are manufactured elsewhere. The building addressed in this work plan is commonly referred to as the Pipe Shop Building. This building was constructed in the late 1940's and consists of a slab on grade with wooden frame exterior walls covered with glass fiber and metal sheets and a concrete floor. The building is unheated. The Form Shop and Burn Shop buildings are connected by an overhead crane system (to move equipment/boilers) and each building has an opening roughly 25 feet wide by 40 feet tall (they are not enclosed buildings). The Wooden building is a former office building; it is not used and in a state of disrepair. Prior air sampling in 2012 included collection of a grab sample within the office building crawl space.

The Pipe Shop building is actively used by SBW for parts and equipment assembly. The building is approximately two stories high and is open from the floor to the roof. In the present condition, the building can best be described as well ventilated as there are multiple holes in the siding of the building, some broken windows and with large sliding doors which do not seal. The Fabrication Shop building is actively used by SBW for equipment fabrication/assembly. Prior indoor air sampling and sub-slab vapor sampling found levels much lower than the Pipe Shop (see data from the CCR included in Appendix A). All prior sampling locations in SBW were based on a facility walkthrough with Ecology.

Within the Pipe Shop, a smaller partially enclosed lunch room is located on the southwest corner of the building. The planned indoor air and sub-slab sampling locations for the SBW buildings are shown on Figure 2.

2.0 SUMMARY OF EXISTING VI SAMPLING

As noted previously, prior VI sampling has been completed at the Site and this Section summarizes the results from that prior sampling.

2.1 Prior Indoor Air Sampling at CCD

The initial indoor air and sub-slab sampling at CCD was completed in March 2009 and was included as a specific requirement under the 2009 Agreed Order. The soil vapor/indoor air investigation included soil vapor sampling from three sub-slab soil vapor ports inside the CCD office area. The larger warehouse area is unheated and with the rollup doors always open when occupied, the prior vapor intrusion sampling has focused on the enclosed office area and break room. As noted in the CAP (Ecology 2012a) and other site documents, indoor air sampling in the CCD building was competed on March 26 2009. This was a requirement under the 2009 Agreed Order and Ecology approved all details of the plan prior to implementation. The 2009 data (as presented in the CAP) are included in Appendix A. The 2009 sampling also included 1 sample from within the warehouse area (sample spot labeled AA-4), this sample location detected PCE but at levels more than an order-of-magnitude lower than the indoor air samples from the office area of CCD (see data in the CAP and included in Appendix A).

The 2009 soil vapor results indicated the presence of PCE and TCE in soil gas at concentrations greater than Ecology's screening levels for commercial land use. Four indoor air samples, averaged over a 6-hour period, were collected from inside the CCD office and break room, plus added ambient air samples. The 2009 indoor air sampling results indicated the presence of PCE and TCE in indoor air at concentrations greater than MTCA Method C (industrial use) cleanup levels.

Operation of an existing SVE system in the Main Source Area was tested as an engineered control for VI and no appreciable effect was observed in sub-slab location beneath the CCD office exposure area. An interim mitigation measure (as an engineering control) was implemented which included upgrading the ventilation fan in the men's bathroom with a higher capacity fan that is wired to run continuously during the workday. This engineering control was completed in May 2011 and, since that time, the higher capacity exhaust fan operating continuously has resulted in an increased indoor air turnover rate in the office area CCD building. This engineered control as a mitigation measure is one of the three examples listed in current (2022) Ecology guidance as recommended mitigation measures. Subsequent sampling (4/15/2013, 9/15/2013) has been used to evaluate the effectiveness of this engineered control (combined with other Site remedial actions).

After completion of the CAP, implementation of remedial actions included operation of an SVE system in the Northwest Corner area, along with thermal treatment in the Main Source area. The SVE system performance data demonstrated a 95% reduction in the targeted soil-vapor VOC concentrations All SVE monitoring data are included in the Construction Completion Report (Floyd-Snider 2013). Sub-slab vacuum measurements within and near CCD office collected near the SVE operations area did not observe appreciable vacuum (i.e., they were outside of the anticipated radius of influence); however VOC concentrations in these sub-slab areas declined. Following the Interim Action for indoor air, plus the remedial actions in the CAP, two indoor-air sampling events were completed in CCD (on April 15, 2013 and September 5, 2013). The sampling results (copied from the Construction Completion Report   Floyd-Snider 2013) are included in Appendix A. This 2013 sampling indicated all VOCs in indoor air were below MTCA C criteria for Site COCs. All TCE levels measured in indoor-air levels at CCD (both before and after the start of remedial actions) have been below short-term exposure limits set by EPA and adopted by Ecology, see results in Table 2.1 and Appendix A. In the Construction Completion Report (Floyd-Snider 2013), the summary of indoor air sampling at CCD noted;

> *Based on a review of both soil vapor and indoor air data collected after SVE and thermal operations were discontinued, there is no evidence of vapor intrusion at levels greater than the applicable cleanup levels at Cascade Columbia. PCE and TCE concentrations in indoor air have decreased significantly compared to the 2009 pre-remediation data. All concentrations were in compliance with the MTCA Method C cleanup levels.*
>
> *No further activities are planned at this time. Monthly field screening with a PID of the vapor points at the Cascade Columbia facility will be discontinued, and no further indoor air sampling will be performed because the cleanup levels have been achieved.*

2.2 Prior Indoor Air Sampling at SBW

The initial indoor air sampling at SBW was completed in 2010 by URS Corporation (URS), on behalf of the SBW. As noted in the CAP (Ecology 2012a) and other Site documents, indoor air sampling in the SBW buildings was initiated on December 12, 2010. The 2010 data (as presented in the CAP) are included in Appendix A.

As specified in the Engineering Design Report (EDR Floyd-Snider 2012), the approach for subsequent soil vapor and indoor air samples at SBW was developed with, and approved by, Ecology. Team representatives, including Ecology and the property owner, inspected the SBW property and buildings in December 2012. Based on the site walk, and discussions with Ecology, the Pipe Building and Fabrication Building were identified as buildings with the highest potential for vapor intrusion.

The SBW office was found to be constructed above grade (the office buildings is elevated on blocks and the ambient air is open beneath the floor). Based on these conditions the “crawl space” was identified for testing and results from this “crawl space” sample would identify the need for follow-up testing inside the elevated office building. The remaining buildings at the facility were inspected and found to have low risk of vapor intrusion due to their distance from the plume, unoccupied nature, or permanent open-air status (open sheds).

The crawl space area was sampled one time (12/14/2012) and indicated VOCs concentrations below the ambient background in that sampling event. Sampling of indoor air in the Fabrication Building did not identify any VOCs above the established indoor air CULs.

Based on a review of both soil vapor and indoor air data collected at SBW, the only building with evidence of vapor intrusion is the Pipe Building. Sampling data prior to the CAP is reported in the CAP and all indoor air sampling is reported in the Construction Completion Report (see Appendix A). In the Construction Completion Report (Floyd-Snider 2013), the summary of indoor air sampling at SBW noted;

> *Based on a review of indoor air data collected during thermal operations, there is no evidence of vapor intrusion impacting indoor air at levels greater than cleanup levels at SBW. Continued sampling of indoor air is not necessary, as all concentrations were either non-detect or much less than the current MTCA Method B cleanup levels.*

Soil vapor/indoor air investigation activities included the following:

The initial soil vapor/indoor air sampling at SBW started in October 2010 with collection of four sub-slab soil vapor samples from inside the Pipe Shop and Fabrication Shop buildings at SBW. The soil vapor results indicated the presence of PCE and TCE in soil gas at concentrations exceeding Ecology's screening levels for unrestricted land use. In December 2010, three indoor air samples, averaged over an 8-hour period, were collected from inside the Pipe Shop building, and one from an upwind outdoor ambient location. The indoor air sampling results indicated the presence of PCE and TCE in indoor air at concentrations greater than MTCA Method B cleanup levels but less than MTCA Method C (industrial use) cleanup levels when corrected for ambient concentrations. The sample for ambient air also contained PCE and TCE at concentrations greater than the Method B level.

Subsequent to completion of the CAP and starting site remedial actions, three indoor air sampling events were completed in SBW in 2012 and 2013. All samples were below the Cleanup Standards established in the CAP (as modified MTCA B levels based on the present land use) and the latter 2 sampling events (April and July 2013) indicated all COCs below the standard MTCA B levels. The sampling results (copied from the Construction Completion Report Floyd-Snider 2013) are included in Appendix A. All measured TCE levels from indoor air at SBW (both before and after the start of remedial actions) have been below short-term exposure limits set by EPA and adopted by Ecology.

Continued ERD actions have been implemented since the timeframe of the 2013 indoor air sampling at SBW. The analytical results from the 2022 groundwater sampling indicate all sampling locations within SBW in and around the Pipe Shop building are below the Site CULs for groundwater. In addition, all 2022 groundwater samples in the SBW property (i.e., 100% of the samples from the July/August 2022 sampling in the SBW property), all samples in Myrtle street area, plus all seep samples are below the CLARC groundwater screening levels[4] for protection against vapor intrusion in a commercial worker scenario (see data in Appendix C).

2.3 Summary of Existing Indoor Air Sampling Results and Calculation of Building-Specific VAFs

The indoor air and sub-slab sampling completed before and under the CAP have included multiple sampling events from March 2009 to September 2013. Samples were collected from multiple locations within the CCD and SBW buildings during the sampling events.

---

[4] In 2022, within CLARC, Ecology established, new groundwater screening levels for protection against vapor intrusion in a commercial worker scenario (Ecology 2022b). All new levels in CLARC, both indoor air criteria, and groundwater screening levels, are based on revised exposure/frequency adjustments to MTCA Equation 750-2 reflecting typical exposure in a workplace setting.

Indoor air sampling at CCD identified PCE ranging from 1.7 to 75 µg/m^3 and TCE ranging from 0.13 to 1.2 µg/m^3. The sub-slab sample results for PCE ranged from 2,440 to 47,000 µg/m^3 and TCE ranged from 153 to 2,000 µg/m^3. The building-specific VAFs for the office portion of the CCD building ranged from 0.0001 to 0.0052. After the initial 2009 sampling at CCD identified PCE exceeding MTCA Method C criteria, mitigation measures were implemented followed by SVE in the source area with the CAP. All subsequent indoor air samples have been below the Cleanup Standards in the CAP. A summary of indoor air sampling previously completed at the CCD building is presented in Table 2.1 and Appendix A. The building-specific VAFs (for the office space in the CCD building) are an order- of-magnitude lower than the default VAF (0.03) used in the Ecology's 2022 indoor air guidance to consider as screening levels (Ecology 2022a).

Indoor air sampling at SBW identified PCE ranging from 0.2 to 2.5 µg/m^3 and TCE ranged from 0.1 to 0.43 µg/m^3. The sub-slab sample results for PCE ranged from 1,800 to 27,800 µg/m^3. The building-specific VAFs for the SBW Pipe Shop building ranged from 0.000011 to 0.0018. All samples from SBW have been below the Cleanup Standards in the CAP. A summary of the indoor air sampling previously completed at the SBW property is presented in Table 2.2 and Appendix A.

2.4 VI Conceptual Site Model and Project DQOs

The basic VI CSM for the site is depicted in Figures 2.1 and 2.2. Existing indoor air sampling data has demonstrated the VI can occur at the Site, the same data also demonstrate that after implementing the remedial actions in the CAP, all measured values meet the CULs in the CAP. The source is soil vapors derived from cross-media transfer from either the VOC plume or potentially from VOCs present in soil near prior source areas.

The migration pathway is from the soil vapor to the indoor air and multiple sampling events have been implemented to quantify the magnitude of the concentrations in the indoor air.

The buildings are commercial/industrial (non-residential). The Cleanup Standards for indoor air established in the CAP are based on exposure frequency and duration in a workplace setting.

The Data Quality Objectives and anticipated project decisions and related data requirements are presented in Exhibit 2.1

Exhibit 2.1 Data Quality Objectives (DQO) Process, Existing Data Summary, and VI Evaluation

DQO process step	Application to Fox Ave Building VOC VI Evaluation	Existing Data	Additional Data Required to Support/Optimize Remedial Actions
Problem to be resolved at the site	The Fox Ave Building plume contains VOCs and may represent a risk due to vapor intrusion. Remedial actions have been selected in the CAP, designed, constructed and operated. The remedial actions need to address contamination in manner that ensures against any unacceptable risks via a VI pathway.	VI CSM & exposure pathways Existing VI and sub-slab data	No other data required to determine if problem exists: ARARs are established and site characterization data (soil vapor & groundwater data) exceeds screening criteria that indicates potential for risk
Boundaries of the study	VOC plume derived from Fox Ave Building Site and locations where existing structures are present.	Water quality data throughout plume, and pre-existing VI sampling	No other data required
The inputs to the decision	The VOC plume VOC concentrations in indoor air within existing structures Cleanup Standards in the CAP	Existing water quality data to define plume Sampling for VOCs in indoor air Existing building-specific VAFs based on prior site sampling	Monitoring at point(s) of potential exposure
The decision rules	If ../ then… format with quantitative limits: If VOCs in indoor air exceed site Cleanup Standards from CAP, excess risk exists and VI pathway must be further addressed; evaluate options for control and implement actions. The detection limit of the analytical method (TO-15) needs to be below the compliance criteria in the Cleanup Standard (Method C and Method B levels for indoor air).		

3.0 SAMPLING METHODOLOGY

This indoor air sampling and analysis plan has been prepared in general accordance with Ecology's Guidance for Evaluating Vapor Intrusion (Ecology 2022b). Prior sampling has demonstrated the Site has elevated concentrations of CVOCs in the soil vapor and groundwater and therefore follows Tier 2 evaluation.

The following sections discuss the sample locations, sample collection duration, and analytical methods. The sampling schedule will be determined after the sampling plan is approved, property access agreements are established, and availability of Summa canisters (for sample collection) are determined; the objective is to sample the buildings in a cold season condition. Typical sampling naming, and number of samples to be collected including QA samples are presented in the SOPs in Appendix B.

3.1 Pre-Sampling Building Survey and Chemical Inventory

Several tasks need to be completed prior to the sampling;
1) Notice will be provided to property owners and occupying tenants in the buildings at the Site and provide them information about upcoming activity.
2) Prepare a chemical inventory list and note potential background sources for each sampling location, these notes will be a combination of a walkthrough inspection and a list provided by the occupants if available.

The notice will be given to Cascade Columbia Distribution for sampling at their office location and warehouse breakroom. Pending an access agreement, a separate notice will be given to Seattle Boiler Works (SBW) for sampling in the Pipe-Shop and the adjacent breakroom.

Potential background sources from inside the buildings includes products containing VOCs stored or used indoors, such as paint strippers, cleaning solvents, and gasoline. Some VOCs may also be derived from other building materials such as carpets, furniture, and finished interiors. To help identify any potentially VOC emitting materials a *ppb*RAE photoionization detector (PID) will used on the walk through. Ideally, any identified VOC-emitting material identified in the building walk through or listed may be removed at least one week prior to sampling, if possible. However as both CCD and SBW are operating industrial facilities, removing potential VOC emitting materials may be infeasible.

3.2 Indoor Air Sample Locations

The indoor air sampling locations in the buildings are selected to address and account for the following:

- To gather samples that are comparable to the previously sampled locations and in the most highly occupied areas.
- To gather information near potential preferential pathways in less ventilated areas (e.g., near floor drains and utility lines), where applicable.
- To collect the required data noted above while minimizing disruptions to the operating businesses.

Within the CCD office, indoor air samples will be collected from within the office space, in the men's restroom, and in the break room. These indoor air sampling locations are shown on Figure 1. In addition to direct sampling of indoor air, measurements of other parameters will be collected including sub-slab vacuum Within the SBW area, indoor air samples will be collected from sampling locations are shown on Figure 2.

3.3 Indoor Air Sample Collection

Summa canisters will be used at each indoor air sampling location. Summa canisters will be field-checked for vacuum with a laboratory-supplied pressure gauge prior to use. All canisters used will have initial vacuums greater than -25 inches of mercury or will not be used. Each Summa canister will be fitted with a flow restrictor calibrated for sample collection at a rate of approximately 10 milliliters per minute to achieve a 7-hour sample collection time.

To collect indoor air samples, the Summa canisters will be staged 3 to 6 feet above floor level to collect indoor air samples that represents the breathing zone. Indoor air samples will be collected by opening the Summa canister valve for approximately 7 hours. Following sample collection, the Summa canister valve will be closed and sealed with a laboratory-supplied brass Swagelok cap. Beginning and ending times, and canister pressures, will be recorded on Chain-of-Custody Forms and sample labels.

3.4 Background Air Sample Locations and Procedures

Ambient air samples will be collected from the area near CCD and SBW. Locations for measuring ambient VOC concentrations will be selected considering the following:

1. Representative wind rose data for the area.
2. Upwind of buildings air intake.
3. Close to the building without being impacted by Site contaminants.
4. 6-8 feet above ground surface.
5. Away from any point sources.
6. Located in a secure area where the sampler (Summa canisters) are unlikely to be stolen.

The representative wind rose data available are from Boeing Field (station BFI) which indicates the predominant wind direction in winter (Jan/Febr/Mar) to be from the north-northwest or northwest.

Based on the above requirements, the parking area to the west of CCD office is the only viable location. The sample collection procedures for the ambient air background samples will follow the general procedures noted above for indoor air sample collection except the flow restrictor calibrated for sample collection at a rate of approximately 9 milliliters per minute to achieve a 9-hour sample collection time. Outdoor sample collection will begin at least 1 hour before indoor air sample collection begins to account for the equilibration time of outdoor air to indoor spaces. Outdoor sample collection will continue through the conclusion of the period for indoor air sampling.

3.5 Sub-slab Soil Vapor Sampling

Sub-slab soil vapor sampling probes were previously installed in 2009 and 2012 per the Interim Action Work Plan (Floyd-Snider and CALIBRE 2008). Leak testing of the finished vapor monitoring points was conducted using a helium tracer and the soil vapor probe construction at all locations was determined to be properly sealed. Figure 3 details a typical cross-section of the existing soil vapor sampling probes. Soil vapor samples are to be collected from the vapor probes that are screened from 7 to 11 inches beneath the floor surface.

For sub-slab sample collection, Teflon tubing will be connected 1-liter Summa™ canisters to the probe point with leak-proof compression fittings, and rubber ferrules. Samples will collected over a 10-minute period using flow controllers to limit the sample collection rate. Leak testing will conducted per the Work Plan to ensure the sampling train and all connections are is air-tight. Soil vapor points will be purged using an SKC® hand pump for a minimum of 5 minutes (equivalent to a purge volume of approximately 5 liters) prior to sample collection. Vapor samples will then be collected into 1 L Summa canisters.

Following sample collection, the Summa canister will be closed and sealed, with canister pressures and sample collection start and end times recorded.

3.6 Sample Naming Convention

Samples will be labeled as follows:

- AA indicates an outdoor ambient air sample
- IA indicates an indoor air sample
- SV indicates a sub-slab vapor sample
- CCD indicates a sample from the Cascade Columbia Distribution building
- SBW indicates a sample from the SBW building
- DUP indicates a duplicate for a given sample

For example, CCD-IA-2 identifies the indoor air sample from location two in the Cascade Columbia office space and SBW-SV-1 identifies the sub-slab vapor sample from location number one in the SBW property.

3.7 Sampling Event

The sampling event will ideally be scheduled in the winter months when the outdoor air is much cooler than the indoor air and the potential for building depressurization is higher. Both indoor and outdoor air samples will be collected in individually certified evacuated, 6-L Summa canisters over an approximate 7-hour period. The sampling period for the ambient outdoor air sampling will start prior to the indoor sampling and will continue past the end of the indoor air sampling collection. The IA samples will be collected before the sub-slab samples (earlier on the same day, or on the preceding day).

3.8 Sample Analysis

The COCs for the Site are listed in the CAP as benzene, 1,1-dichloroethene (1,1-DCE), pentachlorophenol, tetrachloroethene (PCE), trichloroethene (TCE), total petroleum hydrocarbons (TPH, mineral spirits to heavy oil range),and vinyl chloride (VC). The volatile COCs, i.e., those relevant to indoor air exposure include PCE, TCE, VC, and DCE and their CULs from the CAP are listed in Table 3.1. The air samples will be analyzed for VOCs by USEPA Method TO-15.

3.9 Collection of Weather Data

Weather data will be collected on the day of indoor/outdoor air sample collection to assess meteorological conditions that could affect sample collection and analytical results. The weather data to be collected include: wind speed, wind direction, temperature, relative humidity, barometric pressure, and precipitation. These data will be collected from sources around the Site that collect and post this information for the general public. Data regarding recent precipitation events will be obtained from Seattle-Tacoma International Airport, Boeing Field, or other appropriate weather gauging locations.

4.0 FIELD DOCUMENTATION AND SAMPLE MANAGEMENT

Sample documentation and control are required to ensure that the data are defensible and to verify that appropriate field and data review procedures are followed during all phases of the project. The field procedures for documentation, control, and transport of environmental samples are described in this Section.

4.1 Field Documentation

Field notes will recorded bound field logbooks or field sampling sheets. Entries will be made with indelible ink. Field logbook entries will include factual information (free of conjecture and subjective language) and include sufficient detail such that another person (not the field sampling team) reading the logbook entries is able to understand the sampling situation based on the recorded information. Logbook pages will not be removed from the logbook. Incorrect entries will be noted by striking the incorrect entry with a single line, adding the correct entry, dating, and initialing the change. Sampling information to be entered into the field logbook includes the following:

- Date and time of sampling.
- Weather conditions.
- Names or initials of sampling personnel.
- Sample location (including sketch and photograph)
    - General condition of floor and room– cracks, windows
- Room temperature
- Canister identification number
    - Initial canister vacuum
    - Final canister vacuum

4.2 Meteorological Data

Local meteorological data from a public weather station will be obtained for the sampling period to record temperature, barometric pressure, wind direction and wind speed to assess diurnal or seasonal fluctuations in atmospheric conditions that may influence physical processes causing vapor intrusion and/or sampling results.

4.3 Sample Chain-of-Custody and Transport

Sample possession will be traceable from the time of sample collection until receipt of samples at the analytical laboratory. Sample chain-of-custody will be documented following the guidelines outlined below.

4.3.1 Field Custody

Samples collected will be in the custody of the field sampler(s) from the time of sample collection until the samples are transferred or shipped to the laboratory. The Project Manager will evaluate whether proper custody procedures were followed during the fieldwork by reviewing the documentation and discussing procedures with sampling personnel. It will be the responsibility of the Project Manager to decide if additional samples are necessary.

4.3.2 Sample Transfer of Custody and Transport

A chain-of-custody record will accompany samples. When transferring custody of the samples, the individual relinquishing and receiving the samples will sign, date, and note the time of transfer on the chain-of-custody record.

Samples that are hand-delivered to the laboratory may use one chain-of-custody record for all the coolers delivered. Hand-delivered sample coolers do not need to be sealed with fiber tape or custody seals. It is anticipated that most samples will be delivered to Eurofins.

5.0 DATA MANAGEMENT AND REPORTING

Effective data management is required to provide consistent, accurate, and defensible environmental data to support subsequent project decisions/determinations based on the data. This project will collect field and laboratory data to be used for performance evaluation of remedial actions. The project plans for data management and reporting are discussed in the following sections.

5.1 Field Data

Daily field records (a combination of field logbooks and task-specific data sheets) will comprise the main documentation for field activities. As soon after collection as possible, field notes, data sheets, boring logs, and chain-of-custody forms will be scanned to create an electronic record for use in creating field summary reports. Appropriate field data will be hand-entered into the database. One hundred percent of the transferred data will be verified based on hard copy records. QA checks to identify anomalous values will also be conducted following data entry.

5.2 Laboratory Data

The contract laboratory will submit data in both electronic and hard-copy format as described in the QAPP. Written documentation will also be used to clarify how field and laboratory duplicates and QA/QC samples were recorded in the data tables and to provide explanations of other issues that may arise. The data management task will include keeping accurate records of field and laboratory QA/QC samples so that project managers and technical staff who use the data will have appropriate documentation. The laboratory will assign a unique code to each batch of samples called a sample delivery group or SDG. Each analytical data set (including any extra lab documentation) will be filed based on that code.

5.3 Data Validation and Management

In order to ensure that data is of a known and acceptable quality, a data quality review will be performed independent of the laboratory and will include a review of laboratory performance criteria and sample-specific criteria. The reviewer will determine whether the project objectives have been met and whether the data are suitable for the intended purpose. The QAPP and this SAP for the project establish various QC measures such as matrix spikes, field duplicates, project specific control limits. The data review/validation procedure include a review of these project QC measures. The primary data quality review will consist of the following elements:

- Verification that sample numbers and analyses match the chain-of-custody request.
- Verification that sample preservation and holding times are met.
- Verification that field and laboratory blanks were performed at the proper frequency and that no analytes were present in the blanks.
- Verification that field and laboratory duplicates, matrix spikes, and laboratory control samples were run at the proper frequency and that control limits were met.
- Verification that surrogate compound analyses have been performed and that results met the criteria.

- Verification that established reporting limits have been achieved.

The data quality review will also include a review of the precision, bias, and completeness of analytical data. Precision will be assessed based on the relative percent difference (RPD) of MS/MSD and/or duplicate pairs. Calculated RPDs will be compared to the control limits and if the RPD is within these limits, the precision of the analysis will be assumed to meet the DQOs of the project. Bias will be reviewed by comparing the percent recoveries of surrogates, MS, and LCS to the appropriate control limits.

Data will be reviewed in accordance with the analytical methods, laboratory's standard operating procedures, the project SOPs and QAPP and following industry guidance documents for data validation. The project SOP for vapor sampling is included in Appendix B.

All characterization data will be entered into and managed in the Site data management system for use in conjunction with mapping tools [AutoCAD or geographic information system (GIS)] to manage, summarize, and report the sampling data generated.

5.4 Data Review and Reporting

Data validation reports will be completed following receipt of the complete laboratory data package for each sampling event. A summary data report will be prepared by CALIBRE and submitted to Ecology.

The field report will include a description of the field sampling effort (e.g., procedures, sample and locations, field sample observations), descriptions and rationale for any deviations from the SAP and QAPP; a discussion of any data quality issues; and tabulated field and laboratory data. Electronic data will be provided to Ecology once all analyses and data validation have been completed.

6.0 REFERENCES

Floyd-Snider and CALIBRE, 2008. Fox Avenue Site Vapor Intrusion and Soil Vapor Extraction (SVE) Evaluation Work Plan. Prepared for Fox Avenue Building LLC. 1 December.

Floyd-Snider, 2012. Fox Avenue Site, Engineering Design Report. Prepared for Fox Avenue Building LLC. October 9, 2012.

Floyd-Snider, 2013. Fox Avenue Site, Construction Completion Report, Prepared for Fox Avenue Building LLC. September 2013.

CALIBRE, 2021. 2021 Annual Report, Fox Avenue Site, Seattle, WA. October 2021.

Ecology, 2012a. Final Cleanup Action Plan, Fox Avenue Site, Seattle, WA.

Ecology, 2012b. Agreed Order with Fox Avenue Building, LLC. Dated June 4, 2012.

Ecology, 2013. First Amendment to Agreed Order with Fox Avenue Building, LLC. Dated May 8, 2013.

Ecology 2022a. Guidance for Evaluating Vapor Intrusion in Washington State. Investigation and Remedial Action. Toxics Cleanup Program, Washington State Department of Ecology. March 2022.

Ecology 2022b. Vapor Intrusion Screening Levels for Workers, Supporting material for Cleanup Levels and Risk Calculation (CLARC), Washington State Department of Ecology. July 2022.

Ecology 2022c. Periodic Review for Fox Ave Building Facility Site ID#: 2282 Cleanup Site ID#: 5082, Northwest Regional Office, April 2022.

Tables

Table 2.1 Measured Indoor Air Concentrations at CCD coupled with Sub-slab Data and Calculated Building –Specific VAFs

Indoor Air				**Sub Slab**				**Building Specific VAFs (unit less)**	
Sample Date	Sample ID	PCE (µg/m^3)	TCE (µg/m^3)	Sample Date	Sample ID	PCE (µg/m^3)	TCE (µg/m^3)	PCE	TCE
3/26/2009	IA-1	75	1.1	3/26/2009	SV-1	47,000	1,600	0.0016	0.0007
3/26/2009	IA-2	53	1	3/26/2009	SV-2	43,000	940	0.0012	0.0011
3/26/2009	IA-3	6	0.52	3/26/2009	SV-3	43,000	2,000	0.0001	0.0003
4/15/2013	IA-1	27	0.99						
4/15/2013	IA-2	32	1.2						
4/15/2013	IA-3	0.69	0.18						
9/5/2013	IA-1	12.8	0.25	9/5/2013	SV-1	2,440	153	0.0052	0.0016
9/5/2013	IA-2	12.8	0.26	9/5/2013	SV-2	5,500	198	0.0023	0.0013
9/5/2013	IA-3	1.7	0.13	9/5/2013	SV-3	8,380	756	0.0002	0.0002

The full set of indoor air sampling data from this building are in prior reports (the 2011 RI/FS Report, 2012 CAP, 2013 Construction Completion Report, and summarized in the 2022 Periodic Review [Ecology 2022c]). All relevant data are copied from those reports and included in Appendix A to this workplan. The objective of this data summary (based on a subset of the complete indoor air data), is to present building-specific VAFs (Ecology 2022a).

The indoor air sampling results noted above on 3/26/2009 have not been adjusted based on the ambient air results. The other results on 4/15/2013 and 9/5/2013 have been adjusted based on the ambient air results.

MTCA Method C CULs
PCE 40 µg/m^3
TCE 2.0 µg/m^3
VC 2.8 µg/m^3

CCD = Cascade Columbia Distribution
µg/L = micrograms per liter
µg/m^3 = micrograms per cubic meter

Table 2.2 Measured Indoor Air Concentrations at SBW coupled with Sub-slab Data and Calculated Building –Specific VAFs

Indoor Air				**Sub Slab**				**Building Specific VAFs (unit less)**	
Sample Date	Sample ID	PCE (µg/m^3)	TCE (µg/m^3)	Sample Date	Sample ID	PCE (µg/m^3)	TCE (µg/m^3)	PCE	TCE
12/12/2010	SBW-IA-Center	2.5	0.21	10/28/2010	SVA-C	1,800	120	0.0014	0.0018
12/14/2012	SBW-IA-Center	1.0	0.43	12/14/2012	SV-2 (SBW)	16,000	1,710	0.0001	0.0003
4/15/2013	SBW-IA-Center	0.2	0.1	4/15/2013	SV-2 (SBW)	17,800	889	0.000011	0.0001
7/10/2013	SBW-IA-Center	0.9	0.1	7/10/2013	SV-2 (SBW)	27,800	1,120	0.000032	0.0001

The full set of indoor air sampling data from this building are presented in prior reports (the 2011 RI/FS Report, 2012 CAP, 2013 Construction Completion Report, and summarized in the 2022 Periodic Review [Ecology 2022c]). All relevant data are copied from those reports and included in Appendix A to this workplan. The objective of this data summary (based on a subset of the complete indoor air data), is to present building-specific VAFs (Ecology 2022a).

The indoor air sampling results noted above on 12/12/2010 have not been adjusted based on the ambient air results. The other results on 12/14/2012, 4/15/2013 and 7/10/2013 have been adjusted based on the ambient air results. The SBW sub-slab sampling results for PCE show an apparent increase in PCE vapors from 12/14/2012 through 7/10/2013; this time-frame corresponds with the thermal heating of the source areas on the nearby Fox Ave Building LLC property. The 12/14/2012 sampling detected vinyl chloride at 2.0 µg/m^3 in one sample (between the MTCA C and B criteria), all other samples have been below the MTCA B criteria and/or nondetect.

Indoor Air MTCA Method B CULs

PCE	9.6 µg/m^3
TCE	0.37 µg/m^3
VC	0.28 µg/m^3

Indoor Air *"Trigger levels"* from CAP

PCE 3.7 µg/m^3 (note this PCE *trigger level*, as printed in the CAP, does not reflect EPA /Ecology updates to PCE toxicity factors in 2013).

TCE 0.88 µg/m^3

The CAP did not define a trigger level for VC; using the MTCA formula from the CAP, the trigger level for VC would be 2.5 µg/m^3

In 2022, Ecology established indoor air *screening levels* for workers in a commercial setting (Ecology 2022b, i.e., adjustments to exposure/frequency assumptions used in MTCA Equation 750-2). The current CLARC additions for *Vapor Intrusion Screening Levels for Commercial Workers* include:

PCE	44.9 µg/m^3
TCE	2.85 µg/m^3
VC	1.33 µg/m^3

The 2022 Ecology screening levels noted above are derived in a manner similar to the "trigger levels" in the 2012 CAP (adjustments to exposure/frequency basis for commercial settings used in MTCA Equation 750-2).

SBW = Seattle Boiler Works property
µg/L = micrograms per liter
µg/m^3 = micrograms per cubic meter

Table 3.1 Revised Cleanup Levels (from CAP) for Fox Avenue Building Site, copied from CAP and 2013 amendment

Chemical of Concern	Soil Cleanup Level	Groundwater Cleanup Level	Indoor Air Cleanup Level	
	Protection of Groundwater and Indoor Air [1]	Protection of Surface Water (µg/L)	SBW MTCA Method B [2] (µg/m^3)	CCD MTCA Method C [3] (µg/m^3)
PCE	Empirical	3.3	9.6	40
TCE	Empirical	30	0.37	2.0
VC	Empirical	2.4	0.28	2.8

1,1-DCE is also listed as a Site COC but is not routinely detected in groundwater and has not been detected in indoor air. This analyte (1,1-DCE) will be covered in the TO-15 analysis and compared with MTCA B and C criteria from CLARC as required.

Notes:

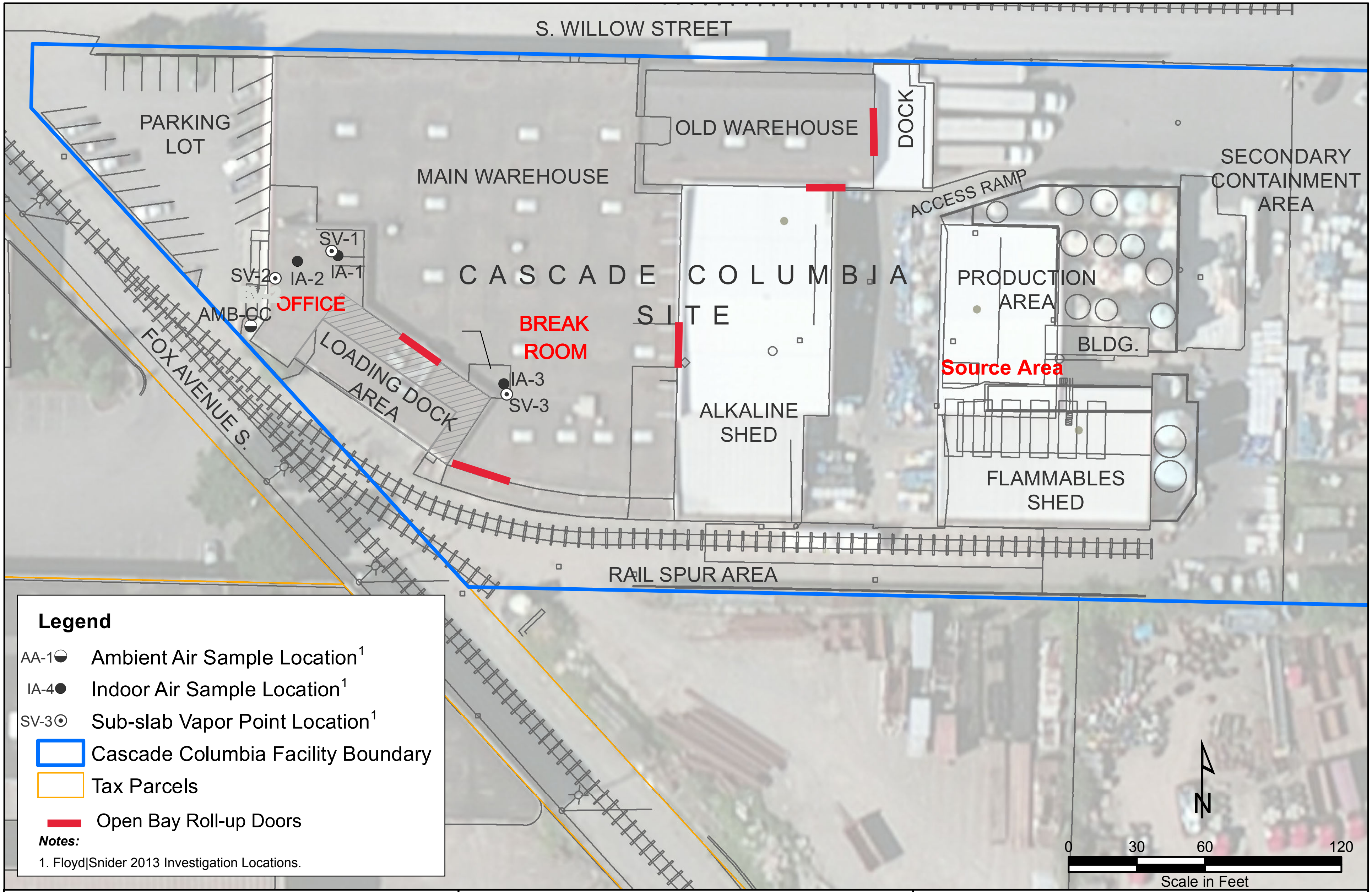
1 Soil CULs have no numeric value. Instead, soil will be empirically demonstrated to be in compliance when indoor air and groundwater (at the CPOC) meet their respective CULs within the estimated restoration time frame.

2 MTCA Method B Air CULs are applied to the Seattle Boiler Works property

3 MTCA Method C Air CULs are applied to the Cascade Columbia building.

SBW = Seattle Boiler Works property
CCD = Cascade Columbia Distribution
µg/L = micrograms per liter
µg/m^3 = micrograms per cubic meter

Figures



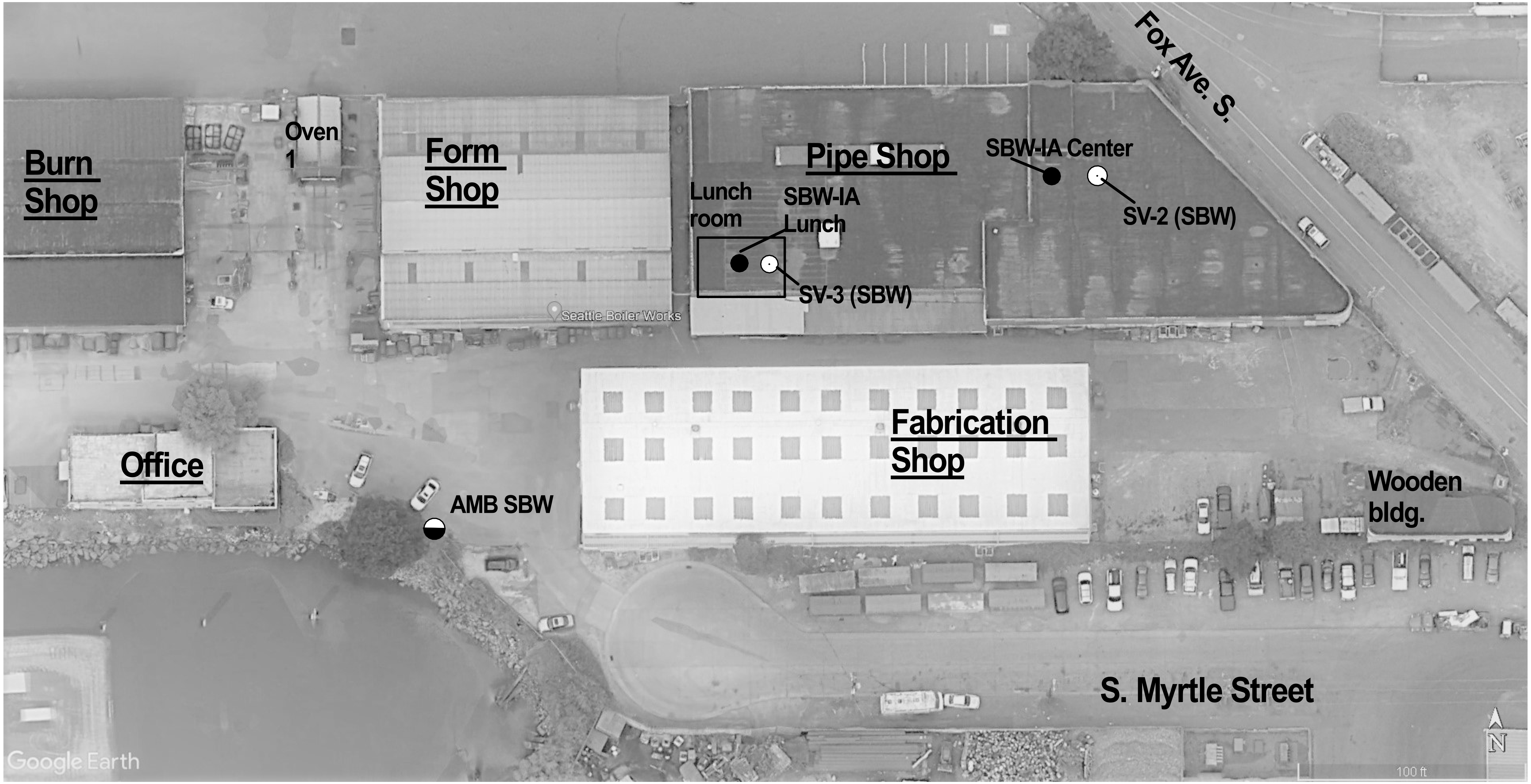
CALIBRE

Our Success Follows Yours®

Vapor Intrusion Monitoring at
Cascade Columbia
Fox Avenue Site
Seattle, Washington

Figure 1
Soil Vapor and Indoor Air Monitoring
Locations in Cascade Columbia Distribution

Copied from FloydSnider, 2013



0 50 100 ft

○ Sub-slab vapor sample location

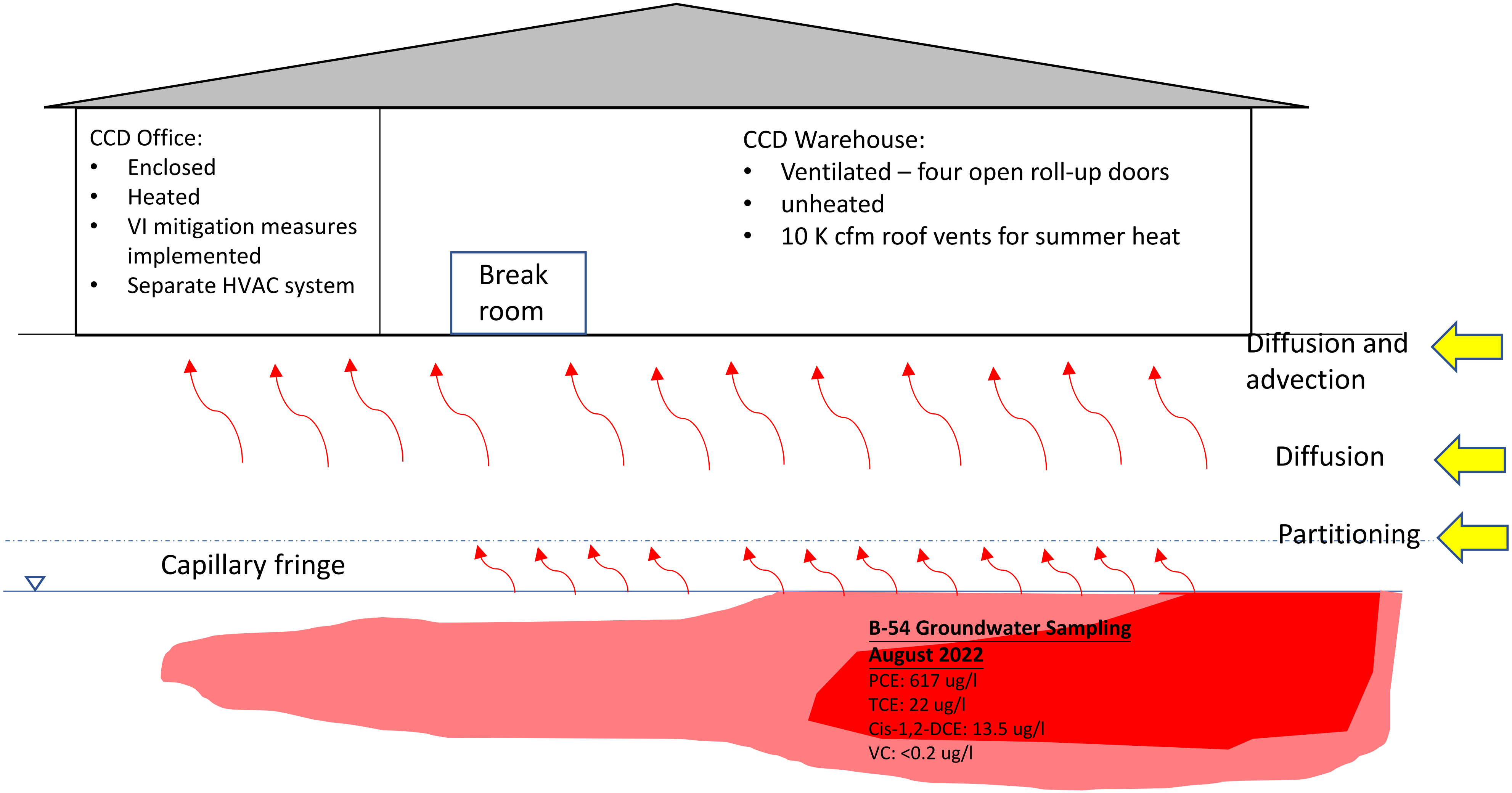
● Indoor air sample location

◒ Ambient air sample location

Vapor Instrusion Monitoring at SBW
Fox Ave Site

(all locations are tentative
pending suitable access agreement)

Figure 2
Soil Vapor and Indoor Air
Monitoring Locations in SBW
Fox Ave Site



CCD Office:
- Enclosed
- Heated
- VI mitigation measures implemented
- Separate HVAC system

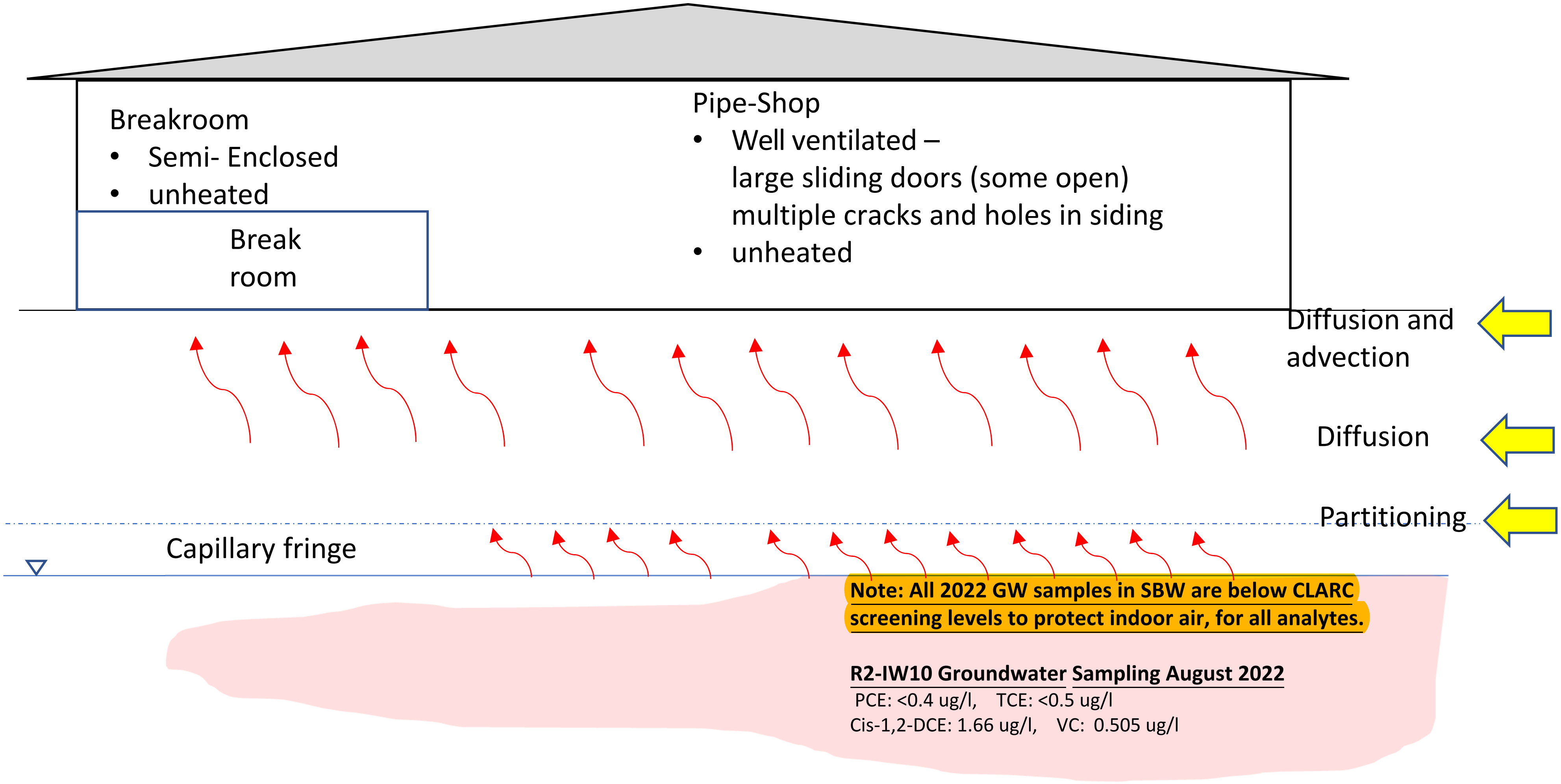
CCD Warehouse:
- Ventilated – four open roll-up doors
- unheated
- 10 K cfm roof vents for summer heat

B-54 Groundwater Sampling August 2022
PCE: 617 ug/l
TCE: 22 ug/l
Cis-1,2-DCE: 13.5 ug/l
VC: <0.2 ug/l

CALIBRE
Our Success Follows Yours®

CSM for Vapor Intrusion at Cascade Columbia Distribution Office
Fox Avenue Site
Seattle, Washington

Figure 3
Vapor transport from groundwater to indoor air, Cascade Columbia Distrib.



Breakroom
- Semi- Enclosed
- unheated

Break room

Pipe-Shop
- Well ventilated –
  large sliding doors (some open)
  multiple cracks and holes in siding
- unheated

Diffusion and advection

Diffusion

Partitioning

Capillary fringe

Note: All 2022 GW samples in SBW are below CLARC screening levels to protect indoor air, for all analytes.

R2-IW10 Groundwater Sampling August 2022

PCE: <0.4 ug/l, TCE: <0.5 ug/l

Cis-1,2-DCE: 1.66 ug/l, VC: 0.505 ug/l

CALIBRE
Our Success Follows Yours®

CSM for Vapor Intrusion at
Seattle Boiler Works
Fox Avenue Site
Seattle, Washington

Figure 4
Vapor transport from groundwater to indoor air, Pipe-Shop Building

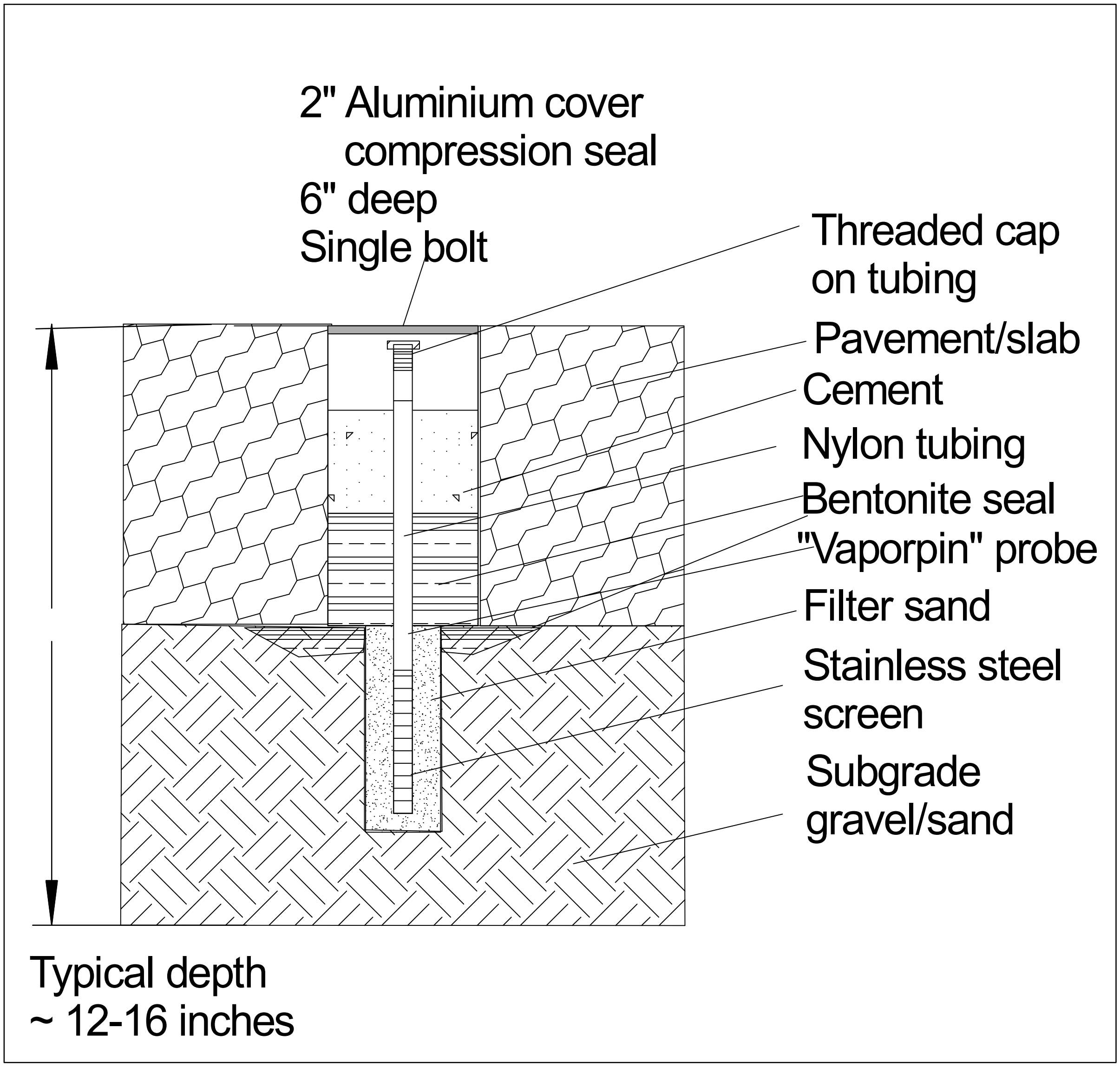


Figure 5 Soil-vapor Probe
Typical Construction Detail

Appendix A Prior Indoor Air Sampling Data from Existing Reports

As Copied from CAP

Table 2.1

Soil Gas and Indoor Air Sample Results Seattle Boiler Works and Cascade Columbia

Sample ID	Sample Date	Tetrachloroethene (μg/m^3)	Trichloroethene (μg/m^3)	Sample Location
Indoor Air —Cascade Columbia				
IA-1	3/26/2009	**75**	**1.1**	Inside office, near sink
IA-2	3/26/2009	**53**	**1**	Inside office, men's restroom
IA-3	3/26/2009	**6**	0.52	Inside warehouse breakroom
IA-4	3/26/2009	2.7[1]	0.2	Upstairs, at top of stairwell
Ambient Air—Cascade Columbia				
AA-1	3/26/2009	0.46	<0.18	Ambient outdoor, SW of facility
AA-2	3/26/2009	0.58	<0.17	Ambient outdoor, NE of facility
AA-3	3/26/2009	0.37	<0.18	Ambient outdoor, NW of facility
AA-4	3/26/2009	2	0.37	Ambient indoor, center of warehouse
Soil Vapor—Cascade Columbia				
SV-1	3/26/2009	**47,000**	**1600**	In office, near sink area, sub-slab
SV-2	3/26/2009	**43,000**	**940**	In office, men's restroom, sub-slab
SV-3	3/26/2009	**43,000**	**2000**	In warehouse breakroom, sub-slab
Indoor Air—Seattle Boiler Works [2]				
SBW-IA-SSVB	12/12/2010	**2.9**[3]	**0.24**[2]	SE corner inside Pipe Bldg
SBW-IA-Lunch	12/12/2010	**3.0**[3]	**0.14**[2]	Employee lunch room, inside Pipe Bldg
SBW-IA-Center	12/12/2010	**2.5**[3]	**0.21**[2]	Central area within Pipe Bldg
Ambient Air —Seattle Boiler Works [2]				
SBW-IA-AMB	12/12/2010	**1.5**	**0.20**	Outside, E of Pipe Bldg
Soil Vapor—Seattle Boiler Works [2]				
SVA-A	10/28/2010	**1,600**	**<6.4**	SE corner of Fabrication Shop, sub-slab
SVA-B	10/28/2010	**5,100**	**220**	SE corner of Pipe Bldg, sub-slab
SVA-C	10/28/2010	**1,800**	**120**	NE corner of Pipe Bldg, sub-slab
SVA-D	10/28/2010	**2,800**	**96**	SW corner of Pipe Bldg, sub-slab

Notes:

Bold indicates an exceedance of appropriate MTCA standard (refer to Note 1).

1 The average ambient (outside) PCE air concentration was 0.47 µg/m3. The sample results were adjusted to account for background in accordance with Section 3.2.3 of Ecology's Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action,

2 Seattle Boiler Works soil gas and indoor air sampling was performed by URS. Data was presented in a Vapor Intrusion Assessment letterprepared by URS and dated February 2, 2011.

3 Ambient air samples collected at the Seattle Boiler Works facility in October 2010 indicated that ambient (background) PCE and TCE concentrations were above MTCA Method B CULs. Therefore, in accordance with Section 3.2.3 of Ecology's Guidance for Evaluating Soil VaporIntrusion in Washington State: Investigation and Remedial Action, Draft October 2009, concentrations were adjusted to account for background. Sample results will be adjusted to account for background during each sampling event.

4 MTCA Method B CULs are applied to the Seattle Boiler Works property assuming unrestricted future land use and MTCA Method C CULs are applied to industrial use.

Abbreviations:

μg/m^3	Micrograms per cubic meter
CUL	Cleanup level
E	East
ID	Identifier
MTCA	Model Toxics Control Act
NE	Northeast

VI sampling reports prior to the 2012 CAP

Fox Avenue Site

Vapor Intrusion and Soil Vapor Extraction (SVE) Evaluation Work Plan

Prepared for

Fox Avenue Building LLC
6900 Fox Avenue
Seattle, Washington

Prepared by

FLOYD | SNIDER
601 Union Street, Suite 600
Seattle, Washington 98101

CALIBRE
Our Success Follows Yours

16935 S.E. 39th Street
Bellevue, WA 98008

December 1, 2008

Fox Avenue Site

Vapor Intrusion and Soil Vapor Extraction (SVE) Evaluation Work Plan

Tables

Table 1.1
Summary of Previous Air Sampling Results

Sample ID	Sample Date	Location	Contaminant Concentrations (ppbv)				Contaminant Concentrations (µg/m^3)			
			PCE	TCE	Methylene Chloride	Benzene	PCE	TCE	Methylene Chloride	Benzene
Air 1	April-00	Loading Dock	< 50	< 50	< 50	< 50	--	--	--	--
Air 2	April-00	Frontenac Street	40	< 50	< 50	< 50	--	--	--	--
Air 3	April-00	Frontenac Street	90	< 50	< 50	< 50	--	--	--	--
Air 4	April-00	Frontenac Street	< 50	< 50	< 50	< 50	--	--	--	--
Air 5	April-00	Fox Avenue	970	100	< 50	< 50	--	--	--	--
Air 6	April-00	Frontenac Street	1100	100	< 50	< 50	--	--	--	--
1	June-00	Fox Avenue, Upwind	--	--	--	--	1.3	NA	8.5	3
2	June-00	Fox Avenue, Upwind	--	--	--	--	0.8	NA	2.6	3.1
3	June-00	At Well B-58	--	--	--	--	2.7	NA	8.4	4
4	June-00	Duplicate at Well B-58	--	--	--	--	2.6	NA	8.8	4
5	June-00	Inside Office	--	--	--	--	82	13	20	6.2
6	June-00	Changing Room	--	--	--	--	100	22	43	9.8
7	June-00	Downwind, Emerson Property	--	--	--	--	2.9	NA	7.9	2
8	June-00	Inside Office, 6–12" height	--	--	--	--	55	12	14	4.7
9	June-00	Inside Office, 5' height	--	--	--	--	60	11	14	4.7
10	June-00	Changing Room, 5' height	--	--	--	--	130	32	53	14

Sample ID	Sample Date	Location	Contaminant Concentrations (ppbv)				Contaminant Concentrations (µg/m^3)			
			PCE	TCE	Methylene Chloride	Benzene	PCE	TCE	Methylene Chloride	Benzene
11	June-00	Changing Room, 6–12" height	--	--	--	--	140	33	59	14
MTCA Method C Industrial Cleanup Level			*0.62*	*0.19*[1]	*15.3*	*1*	*4.2*	*1.0*[1]	*53*	*3.2*
OSHA PEL			*100,000*	*100,000*	*25,000*	*100*	*678,323*	*537,423*	*86,851*	*320*

Notes:

1	Value reflects recent (November 2008) Ecology update to the toxicity factor used in the TCE cleanup level calculation
NA	Not applicable
PCE	Tetrachloroethene
ppvb	Parts per billion by volume
TCE	Trichloroethene

FLOYD | SNIDER
strategy ▪ science ▪ engineering
Two Union Square • 601 Union Street • Suite 600
Seattle, Washington 98101 • tel: 206.292.2078 • fax: 206.682.7867

Technical Memorandum

To: Sunny Lin Becker, Washington State Department of Ecology
Copies: Bob Code, Cascade Columbia Distribution
From: Megan King
Date: June 30, 2009
Project No: FoxAve-RA.T2
Re: **Fox Avenue Site Vapor Intrusion Investigation Results**

INTRODUCTION

This technical memorandum was prepared to document the results of the soil vapor intrusion investigation at the Fox Avenue Site (Site) in Seattle, Washington. The work was performed as part of the Scope of Work in the current Agreed Order between the Washington State Department of Ecology (Ecology) and Fox Avenue Building LLC and was done in accordance with the Ecology-approved Vapor Intrusion and Soil Vapor Extraction (SVE) Evaluation Work Plan (the Work Plan) dated December 1, 2008 (Floyd|Snider and CALIBRE 2008).

The Scope of Work for the Agreed Order calls for an evaluation of the soil and groundwater to indoor air pathway (Phase 1). Per the Work Plan, if the results of the Phase 1 investigation indicate that there is a completed soil vapor to indoor air pathway, Phase 2 would be implemented. Phase 2 consists of repairing and restarting the existing SVE System to evaluate the system's ability to assist in mitigation of subsurface vapor intrusion, and measure current removal rates of volatile organic compounds (VOCs) from the subsurface to evaluate if the system should be restarted prior to initiation of full-scale remedial actions. The existing SVE system at the Site successfully removed large quantities of chlorinated compounds from the subsurface beginning in 2004, but has been inactive since January 2007, when the removal rate did not justify continued system operation.

The overall objective of the vapor intrusion investigation was to assess if a current soil vapor to indoor air pathway exists within the office space of the Cascade Columbia warehouse. The first-floor office space and break room of the Cascade Columbia warehouse were the focus of the investigation, due to the use of these spaces by industrial workers and results of past sampling efforts. This technical memorandum details the results of sub-slab soil vapor, indoor air, and ambient air samples analyzed for the four contaminants of concern (COCs) identified in the Work Plan. The COCs identified in the Work Plan include tetrachloroethene (PCE), trichloroethene (TCE), benzene, and methylene chloride. Sampling results were also evaluated against applicable standards to determine if an indoor air quality risk currently exists, and whether that risk is caused solely from the migration of soil gas vapor to indoor air or due to ambient air contaminants. Additionally, this technical memo provides the results of the Phase 2 SVE system evaluation that was implemented due to Phase 1 analytical results.

PHASE 1—SUB-SLAB SOIL VAPOR AND OUTDOOR AIR MONITORING

Work Performed

On March 26, 2009 the first phase of the soil vapor intrusion investigation was conducted at the Site. Samples were collected from 11 locations, including 4 ambient air samples, 4 indoor air samples, and 3 sub-slab vapor samples collected below the concrete slab of the office and break room (Figure 1) as follows:

- **Sub-slab Samples.** Samples of sub-slab soil gas (SV series) were collected in the enclosed office area and break room. Sample SV-1 was collected from inside the northeast corner of the office, near the coffee machine and employee work stations. Sample SV-2 was collected inside the main office men's restroom. Sample SV-3 was collected in the southeast corner of the employee break room, located in the main warehouse, adjacent to the loading dock.
- **Indoor Air Samples.** Three indoor air samples (IA series) were collocated with sub-slab samples, and were named according to the associated sub-slab sample. Sample IA-1 was set up 2 feet east of SV-1, against an interior office wall. Sample IA-2 was set up in the men's restroom, 3 feet west of SV-2, above a floor drain. Sample IA-3 was collected within 1 foot of SV-3 in the break room, and Sample IA-4 was collected from the second floor office, at the top of the stairway.
- **Ambient Air Samples.** Two ambient air samples (AA series) were collected upwind of the warehouse (AA-1, AA-2). One sample was collected downwind of the warehouse (AA-3), and another was collected near the warehouse break room (AA-4). These samples provided information that was useful to determine if normal chemical handling site activities could be a potential contributor to any contaminant concentrations identified in indoor air.

Methodology and Procedures

Sub-slab Sample Collection

Sub-slab soil vapor sampling probes were installed on March 23, 2009 by a licensed driller from Environmental Services Northwest, and constructed to meet the requirements specified in the Work Plan (Floyd|Snider and CALIBRE 2008). Figure 2 details a typical cross-section of the soil vapor sampling probes.

Soil vapor samples were collected from the vapor probes that were screened from 7 to 11 inches beneath the floor surface. The slab thickness at each vapor probe location ranged from 5.5- to 6-inches thick. For sample collection, Teflon tubing was used to connect 6-liter Summa™ canisters to the probe point with leak-proof compression fittings, and rubber ferrules. Samples were collected over a 30- to 70-minute period using flow controllers to limit the sample collection rate. Following sample collection, the Summa™ canister was closed and sealed, with canister pressures and sample collection start and end times recorded as follows:

Soil Vapor Probe Sampling Information

Sample ID	**Start Time**	**End Time**	**Collection Period (minutes)**	**Initial Vacuum (inches Hg)**	**Ending Vacuum (inches Hg)**
SV-1	10:50	11:20	30	30	9.0
SV-2	11:13	11:58	45	28	10.0
SV-3	11:40	12:50	70	28.5	4.0

Abbreviation:

Hg	Mercury pressure unit

Sample collection periods were variable due to the initial vacuum of the Summa canisters, and the exact rate of the flow controllers used. The longer the collection time period, the lower the final canister vacuum, and the higher the laboratory detection limits due to dilution, and the laboratory process for sample extraction and analysis. Although sample collection times for SV-2 and SV-3 were longer than the time frames specified in the Work Plan, the final canister vacuum readings were within the acceptable range. Dilution was required for these samples due to the elevated concentrations of PCE and TCE in the samples as discussed in the following sections.

Leak testing was conducted per the Work Plan at each soil vapor probe location to ensure air-tight connections in both the sampling train, and the soil vapor probe construction. Leak testing of the vapor probe construction was conducted by placing a shroud over the soil vapor probe, and connecting the probe to a sampling fitting and peristaltic pump and Tedlar bag. Helium gas was then released into the shroud continuously, while samples were extracted through the vapor probe and into the Tedlar bags. Detectable concentrations of Helium in the Tedlar bag would indicate leaks in the construction of the probe between the slab and the subsurface, causing helium to be pulled into the vapor probe from above the slab. Leak testing was conducted three times at each soil vapor probe. Helium readings ranged from 0 percent to 1.5 percent. A standard allowable percentage according to guidance documents is typically 5 percent. Soil vapor probe construction at all locations was determined to be acceptable and properly sealed. Leaks in the sampling train were tested using laboratory provided leak testing equipment. No leaks were detected in any of the three sub-slab soil vapor sampling equipment set-ups.

Indoor Air and Ambient Air Sample Collection

The three indoor air samples collected on the first floor of the warehouse were collected above the locations of the soil vapor probe sampling points. All indoor air samples were collected via Summa™ canisters placed 3 to 6 feet above ground surface.

Four ambient air samples were collected during the sampling event from outdoor locations surrounding the Site and from within the main warehouse, to provide a comprehensive evaluation of ambient air conditions. Samples were placed surrounding the Site both upwind and downwind of the facility to evaluate ambient conditions surrounding the Site. In addition, a sample was collected from within the Main Warehouse to identify ambient conditions inside the active facility. This information was useful to determine if site activities could be a potential contributor to contaminant concentrations identified in indoor air.

Ambient air samples were collected via Summa™ canisters located on a step ladder or permanent flat surface (i.e., loading dock) 4 to 6 feet above ground surface. Sampling locations are shown on Figure 1.

For each sample, prior to sample collection the Summa™ canister was equipped with a flow controller and tested for leaks in the sampling train. Once all connections were sealed, the canister was opened and the samples were collected over a period of approximately 8 hours. Following sample collection, the canisters were closed and sealed with canister pressures and sample collection start and end times recorded as follows:

Sample ID	**Sampling Height** (inches)[1]	**Start Time**	**End Time**	**Collection Period**[2] (hrs/min)	**Initial Vacuum** (inches Hg)	**Ending Vacuum** (inches Hg)
IA-1	50	08:51	16:42	7h51m	30+	7.0
IA-2	48	08:57	16:50	7h53m	30+	9.0
IA-3	55	08:46	16:40	7h54m	30+	10.0
IA-4	53	09:00	16:55	7h55m	30+	8.0
AA-1	67	08:21	16:10	7h49m	29	6.75
AA-2	45	08:38	16:20	7h42m	30	8.0
AA-3	55	08:27	16:13	7h46	30	7.0
AA-4	48	08:07	16:03	7h56m	29	5.25

Notes:

1 Above ground surface.

2 The Work Plan stated that indoor air samples would be collected over a 9-hour period; however the flow controllers provided by the analytical laboratory were set for an 8-hour collection period. This difference was determined to be negligible.

Abbreviation:

Hg Mercury pressure unit

All ending canister vacuums were within the allowable range of 4 to 10 inches Hg.

Environmental Factors

As stated in the Work Plan, the collection of meteorological conditions at the time of sampling is important, as current weather conditions can impact sampling results. The table below summarizes the general weather conditions near the Site on March 26, 2009.

Weather Conditions during Sample Collection

Wind Speed (mph)	1
Wind Direction	SE to SSE
Temperature (°F)	42
Relative Humidity (°F)	71
Barometric Pressure (hg)	30.4
Precipitation (inches)	0.00

Note: Data were obtained from Weather Underground, and was measured at the King County International Airport—Boeing Field, located approximately 0.5 miles east of the Site.

Sample Analysis, Data Validation, and Target Screening Levels

Summa™ canisters were shipped to Air Toxics, Ltd. (ATL) in Sacramento, California for analysis by USEPA Method TO-15-SIM (Selective Ion Monitoring) using gas chromatography/ mass spectrometry (GC/MS). A Level IV data validation was performed on all analytical results by the laboratory. The data were determined to be of acceptable quality for use, as qualified by the laboratory. Laboratory reports are included in Attachment 1. Table 1 contains a summary of the sample results.

The target screening levels for the sampling event were explained in the Work Plan (Floyd|Snider 2008). Washington State Model Toxics Control Act (MTCA) Method C Industrial levels and Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) values are shown in Table 1. The laboratory method detection limits for all indoor air samples were below the target screening levels, as required by the Work Plan.

Sub-slab Sampling Results

Laboratory data indicate that PCE and TCE are present at elevated concentrations in soil vapor below the concrete slab in both the office space and break room areas. PCE concentrations in sub-slab samples ranged from 6,300 to 7,000 parts per billion as vapor (ppbv), and TCE concentrations ranged from 180 to 380 ppbv. The concentration ratio between PCE and TCE in the collected air samples reflects the ratio found in soil samples collected at the Site, with PCE being the dominant VOC. Benzene and methylene chloride, the other two COCs, were not detected; however detection limits in these samples were elevated due to the high concentrations of PCE and TCE present, which required laboratory dilution prior to analysis (refer to Table 1).

Indoor Air Sampling Results

The three indoor air samples (IA-1, IA-2, IA-3) collected from the main floor of the Fox Avenue building contained PCE ranging in concentration from 0.89 to 11 ppbv. In addition, two indoor air samples (IA-1 and IA-2) contained TCE at concentrations of 0.21 and 0.19 ppbv, respectively.

The sampling location upstairs in the Cascade Columbia office (IA-4) did not exceed MTCA Method C cleanup levels for any of the measured constituents.

Ambient Air Sample Results

PCE and benzene were detected in all ambient air samples, at low concentrations typical of urban air. Concentrations were highest in the sample collected within the warehouse, which may be attributed to more stagnant air effects. TCE and methylene chloride were not detected, except for a low detection of methylene chloride in the ambient air sample collected within the warehouse.

Discussion

Table 1 indicates that three of the four indoor samples contained PCE at concentrations exceeding the MTCA Method C Industrial cleanup level with the highest exceedances found in the two samples collected inside the office. TCE concentrations were slightly greater than or equal to the Method C concentration in the two office samples. Benzene and methylene chloride were not detected at concentrations of concern in any sample and generally reflected concentrations found in ambient air.

Results of the sub-slab vapor samples indicate that the probable source of the PCE and TCE in the office space is intrusion of contaminated soil vapor from beneath the slab. The sub-slab samples were found to contain PCE and TCE at concentrations approximately three orders of magnitude higher than the indoor air samples collected from the office and break room. This indicates the existing slab is providing significant attenuation, but not sufficient enough to meet the MTCA Method C Industrial levels in indoor air. A thorough examination of the slab was not undertaken but it is presumed that slab penetrations in the restroom (i.e., floor drains) and cracks and joints in the slab provide the most likely pathways for vapor intrusion.

Due to the levels of PCE and TCE levels identified in soil vapor and indoor air samples, the second phase of the vapor intrusion evaluation was implemented and is described below.

PHASE 2—SOIL VAPOR EXTRACTION SYSTEM EVALUATION

The SVE system evaluation was implemented and conducted per the Work Plan. These activities included restarting the existing SVE system, and monitoring the effect of the system on subsurface vacuum beneath the office and break room, based on vacuum measurements from the soil vapor probes. According to the Work Plan, if the existing system was found to provide benefit by creating a negative pressure beneath the Fox Avenue Building (which would result in reduced subsurface air intrusion into the building) the system would be operated until future remedial actions are planned to address the vapor intrusion pathway.

Work Performed

Maintenance and testing of the existing SVE system was performed by H2Oil Recovery Inc. on February 17, 2009, prior to completion of the first phase of the vapor intrusion evaluation. Once the results of the sampling event were received from the laboratory, the system was restarted and monitored for influence on the soil vapor probe points installed for collection of sub-slab vapor samples and monitoring.

Starting on May 18, 2009, the SVE system piping to the West Shed was reconnected at the system header where it had previously been disconnected by Cascade Columbia to allow for site operations. The system was restarted and operated almost continuously for 1 week, allowing for steady-state conditions to be reached[1]. Maintenance and monitoring of the system were conducted multiple times throughout the week. The measurements collected during the monitoring included:

- Flow rate and vacuum for the entire system and the individual SVE horizontal wells in the West Shed branch area (the three other older and ineffective SVE branches remained closed during this evaluation).
- Vacuum readings at the soil vapor sampling points (SV-1, SV-2, and SV-3).
- Temperature, flow rate of the extracted air stream.
- VOC concentration readings at the soil vapor sampling probe locations, the extracted air stream prior to treatment, and the effluent air stream following treatment.

System monitoring results are summarized in Table 2.

Results of Phase 2—Soil Vapor Extraction System Evaluation

Baseline Conditions

Before the system was restarted, baseline vacuum (using a magnehelic gauge) and VOC concentration (using a photoionization detector) readings were collected from the soil vapor probes installed in the Cascade Columbia office space. Soil vapor probe locations are shown on Figure 1, and results of the baseline monitoring are detailed in the table below. All vacuum readings taken throughout the week were zero, or within the sensitivity of the measuring equipment, indicating there was no measurable vacuum influence on the soil vapor probes in the Cascade Columbia office space from operation of the SVE system.

Restart of SVE System

Following restart of the SVE system, measurements were collected regularly throughout the week to monitor for any effects to the warehouse subsurface resulting from SVE system operation. Vacuum and PID readings were collected three times throughout the week, and are summarized in the table below:

---

[1] The system shut down once due to motor failure, and was restarted the following day.

SVE System Evaluation—Vapor Probe Monitoring Results

	Baseline Monitoring		SVE Operation Monitoring (week of 5/18/2009)				
	5/18/2009		**5/18/2009**	**5/21/2009**		**5/22/2009**	
SVE Hours	**0**		**1**	**49**		**81**	
Soil Vapor Probe	**Vacuum (inches in $H_{2}0$)**	**Vapor (ppm)**	**Vacuum (inches in $H_{2}0$)**	**Vacuum (inches in $H_{2}0$)**	**Vapor (ppm)**	**Vacuum (inches in $H_{2}0$)**	**Vapor (ppm)**
SV-1	0.05	7.3	0.0	0.0	20.8	0.0	19.0
SV-2	0.005	5.4	0.0	0.0	19.0	0.0	18.5
SV-3	0.0	9.5	0.005	0.0	1.1	0.0	6.5

Note:
ppm Parts per million

In addition to measurement of vacuum and VOC concentrations at the soil vapor probe locations inside the warehouse, SVE system monitoring was conducted to evaluate the system's effectiveness for removal of contaminant mass from the subsurface. Table 2 shows the SVE system operational measurements that were collected throughout the week. The overall flow rate for the system, which included input from all four horizontal SVE wells located in the West Shed, ranged from 529 to 560 standard cubic feet per minute (scfm). Individual vacuum readings for each SVE well in the West Shed were also collected, and typically ranged from 25 to 28 inches $H_{2}0$. Vapor concentrations for the extracted air stream were measured both before treatment and following treatment by activated carbon filtration. Measurements of the untreated air stream ranged from 380 ppm to 135.7 ppm, and decreased throughout the week, with the lowest concentration measured immediately before system shutdown. Concentrations in the air stream following carbon treatment ranged from 0.2 to 1.1 ppm, indicating effective adsorption of the PCE in the air stream to the carbon prior to atmospheric discharge.

Mass Removal

Assuming that the system continued to extract a vapor concentration of approximately 150 ppm of PCE at a flow rate of 550 scfm, the system would be removing an approximate mass of 50 pounds per day of PCE. Review of the previous SVE system monitoring and sampling conducted by ERM from 2005 to 2007 indicates that at the time of shutdown, VOC removal had reached a baseline removal rate of approximately 10 pounds per day. Removal rates greater than the 2007 baseline removal rate are expected, as volatilization of PCE in the subsurface has reached equilibrium over the past few years. However, it is assumed that if the system were restarted, the system would quickly remove the volatilized contaminants, and after several months, return to the baseline removal rate of approximately 10 pounds per day, as measured by ERM.

RECOMMENDATIONS

Results of the Phase 1 air sampling indicated that vapor concentrations in indoor air in the Cascade Columbia office and break room exceed the MTCA Method C Industrial cleanup levels for indoor air for PCE and TCE. Sub-slab vapor samples indicated that the exceedances are likely due to vapor intrusion from the subsurface, and does not appear to be related to ambient air concentrations or site activities. The concentrations are not at levels that exceed OSHA thresholds such that immediate action is necessary. However, the evaluation of remedial alternatives for the Site should address attainment of MTCA Method C cleanup levels for indoor air.

Results of the Phase 2 SVE system evaluation indicate that continued operation of the SVE system will not provide assistance in mitigation of the vapor intrusion pathway because the warehouse and office are located outside the radius of influence of the current system. Monitoring also indicated that the concentrations of chlorinated VOCs in extracted air are at a level low enough that operation of the system for mass removal would be negligible, and would not provide a measurable level of benefit, for the cost associated with operation and maintenance of the system. As a result, it is not recommended to restart the existing SVE system for mass removal, or for mitigation of the vapor intrusion pathway. Indoor air quality will be fully evaluated in the site Feasibility Study, and will be addressed by the selected remedial actions for the Site.

REFERENCES

Floyd|Snider and CALIBRE. 2008. *Fox Avenue Site Vapor Intrusion and Soil Vapor Extraction (SVE) Evaluation Work Plan*. Prepared for Fox Avenue Building LLC. 1 December.

ENCLOSURES

Table 1	Results of March 26, 2009 Vapor Sampling
Table 2	Operational Data for the SVE System, May 2009
Figure 1	March 26, 2009 Vapor Intrusion Evaluation Sample Locations
Figure 2	Typical Vapor Probe Construction Details
Attachment 1	Laboratory Data Report

Tables

Table 1
Results of March 26, 2009 Vapor Sampling

Sample ID	PCE (ppbv)	TCE (ppbv)	Benzene (ppbv)	Methylene Chloride (ppbv)	Sample Location
IA-1	**11**	**0.21**	0.74	0.45	Air inside office, near coffee machines
IA-2	**7.8**	**0.19**	0.73	0.46	Air inside office, in men's restroom
IA-3	**0.89**	0.096	0.84	0.69	Air inside warehouse break room
IA-4	0.48	0.037	0.53	< 0.32	Air inside office 2nd floor, top of stairwell
SV-1	**7,000**	**290**	< 18	< 73	Sub-slab vapor from inside office, near coffee machines
SV-2	**6,300**	**180**	< 16	< 62	Sub-slab vapor from men's restroom
SV-3	**6,300**	**380**	< 18	< 72	Sub-slab vapor from inside warehouse break room
AA-1	0.068	< 0.033	0.40	< 0.33	Outside, SW of building, upwind
AA-2	0.086	< 0.032	0.40	< 0.32	Outside, NE of building, upwind
AA-3	0.055	< 0.033	0.42	< 0.33	Outside, NW of building, downwind
AA-4	0.29	< 0.069	0.81	0.46	Indoor, center of main warehouse
MTCA C	*0.62*	*0.19*	*1.0*	*15.3*	*MTCA C Industrial CUL*
OSHA PEL	*100,000*	*100,000*	*100*	*25,000*	*OSHA Permissible Exposure Limit*

Note:

380	Bold indicates sample result exceeds MTCA C cleanup level.

Abbreviations:

CUL	Cleanup level
MTCA	Model Toxics Control Act
OSHA	Occupational Safety and Health Administration
PCE	Tetrachloroethene
PEL	Permissible Exposure Limit
TCE	Trichloroethene

Table 2
Operational Data for the SVE System, May 2009

Date	System Operational Hours	Effluent Temperature (°F)	Knockout Influent Vacuum (inches H_20)	Knockout Effluent Pressure (inches H_20)	Manifold Vapor Flow Rate (scfm)	Blower Effluent VOC Concentration (ppm)[1]	Carbon Discharge Effluent VOC Concentration (ppm)[1]	Carbon Filter Effluent (inches H_20)
5/18/2009	1	130	32	25	559.3	250	0.2	36
5/20/2009	31	NA	38	NA	534	NA	NA	NA
5/21/2009	51	132	39	23	535	256	0.7	42
5/22/2009	76	138	39	23	533.6	NA	NA	NA
5/22/2009	83	142	38	23	529	135.7	1.1	NA

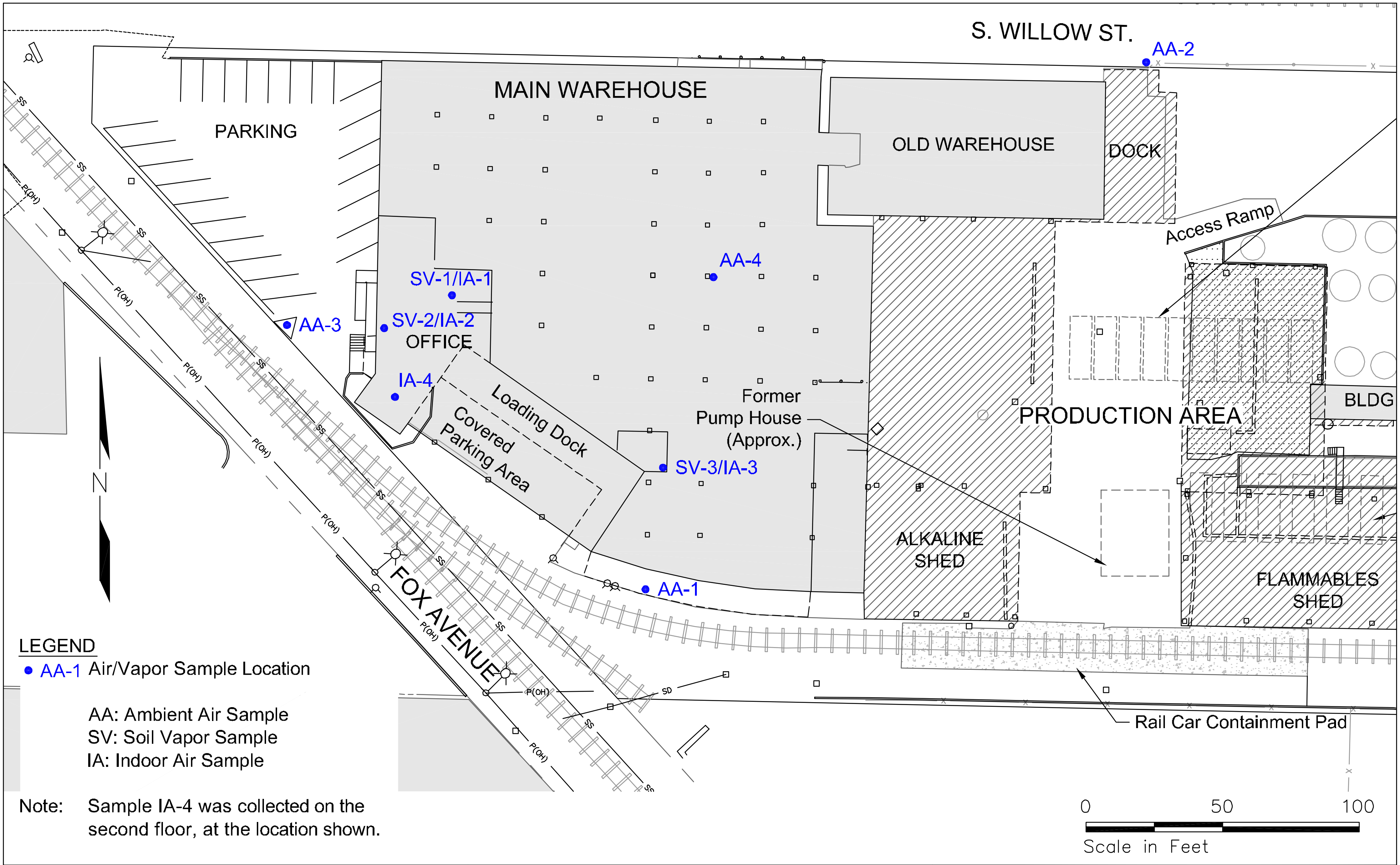
Note:

1 VOC concentrations were measured using a photoionization detector.

Abbreviations:

NA	Not available
ppm	Parts per million
scfm	Standard cubic feet per minute
SVE	Soil vapor extraction
VOC	Volatile organic compound

Figures



LEGEND

- ● AA-1 Air/Vapor Sample Location

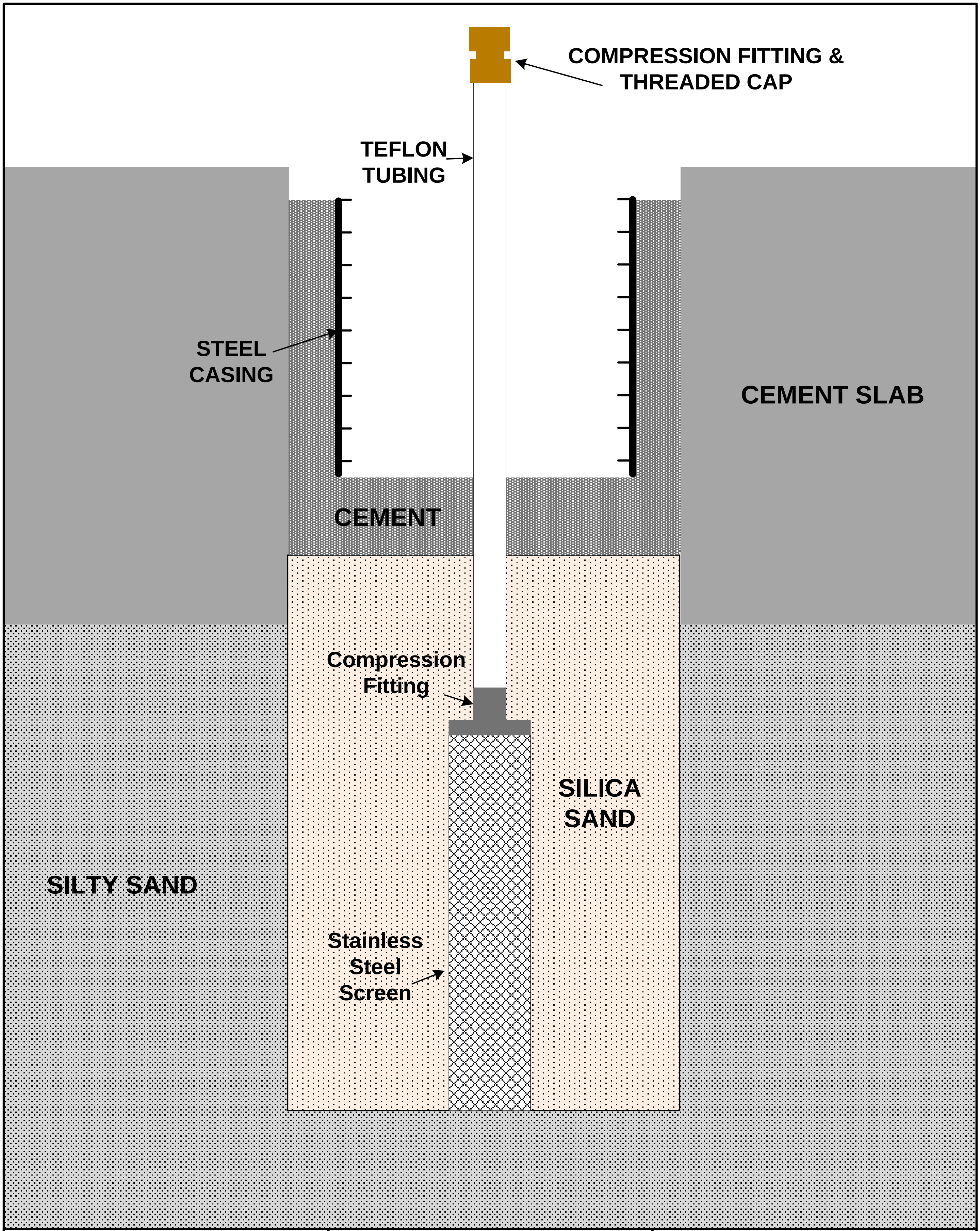
AA: Ambient Air Sample
SV: Soil Vapor Sample
IA: Indoor Air Sample

Note: Sample IA-4 was collected on the second floor, at the location shown.

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Vapor Intrusion Evaluation
Technical Memorandum
Fox Avenue Site
Seattle, Washington

Figure 1
March 26, 2009 Vapor Intrusion Evaluation
Sample Locations



FLOYD | SNIDER
strategy ▪ science ▪ engineering

Vapor Intrusion Evaluation
Technical Memorandum
Fox Avenue Site
Seattle, WA

Figure 2
Typical Vapor Probe
Construction Details

F:\projects\FoxAve-RA\Vapor Intrusion Evaluation\Vapor Intrusion Memo\Figures\Figure 2.vsd

6/30/2009

Attachment 1
Laboratory Data Report

Air Toxics LTD.

AN ENVIRONMENTAL ANALYTICAL LABORATORY

4/10/2009

Ms. Megan King
Floyd Snider
601 Union Street, Suite 600

Seattle WA 98101

Project Name: Vapor eval.
Project #: FOX AVE - RA
Workorder #: 0903761

Dear Ms. Megan King

The following report includes the data for the above referenced project for sample(s) received on 3/30/2009 at Air Toxics Ltd.

The data and associated QC analyzed by Modified TO-15 SIM are compliant with the project requirements or laboratory criteria with the exception of the deviations noted in the attached case narrative.

Thank you for choosing Air Toxics Ltd. for you air analysis needs. Air Toxics Ltd. is committed to providing accurate data of the highest quality. Please feel free to contact the Project Manager: Kelly Buettner at 916-985-1000 if you have any questions regarding the data in this report.

Regards,

Kelly Buettner
Project Manager

Air Toxics LTD.
AN ENVIRONMENTAL ANALYTICAL LABORATORY

WORK ORDER #: 0903761

Work Order Summary

CLIENT:
Ms. Megan King
Floyd Snider
601 Union Street, Suite 600
Seattle, WA 98101

BILL TO:
Ms. Megan King
Floyd Snider
601 Union Street, Suite 600
Seattle, WA 98101

PHONE: 206-292-2078
FAX: 206-682-7867
DATE RECEIVED: 03/30/2009
DATE COMPLETED: 04/10/2009

P.O. # Fox Ave RA-T4
PROJECT # FOX AVE - RA Vapor eval.
CONTACT: Kelly Buettner

FRACTION #	NAME	TEST	RECEIPT VAC./PRES.	FINAL PRESSURE
01A	SV-3	Modified TO-15 SIM	2.0 "Hg	5 psi
02A	AA-4	Modified TO-15 SIM	4.5 "Hg	5 psi
02AA	AA-4 Lab Duplicate	Modified TO-15 SIM	4.5 "Hg	5 psi
03A	AA-1	Modified TO-15 SIM	5.5 "Hg	5 psi
04A	AA-3	Modified TO-15 SIM	5.5 "Hg	5 psi
05A	AA-2	Modified TO-15 SIM	5.0 "Hg	5 psi
06A	IA-3	Modified TO-15 SIM	6.0 "Hg	5 psi
07A	IA-1	Modified TO-15 SIM	4.5 "Hg	5 psi
08A	IA-2	Modified TO-15 SIM	5.5 "Hg	5 psi
09A	IA-4	Modified TO-15 SIM	5.0 "Hg	5 psi
10A	SV-1	Modified TO-15 SIM	8.0 "Hg	5 psi
11A	SV-2	Modified TO-15 SIM	8.5 "Hg	5 psi
12A	Lab Blank	Modified TO-15 SIM	NA	NA
13A	CCV	Modified TO-15 SIM	NA	NA
14A	LCS	Modified TO-15 SIM	NA	NA

CERTIFIED BY: Linda L. Freeman
Laboratory Director

DATE: 04/10/09

Certfication numbers: CA NELAP - 02110CA, LA NELAP/LELAP- AI 30763, NJ NELAP - CA004
NY NELAP - 11291, UT NELAP - 9166389892, AZ Licensure AZ0719
Name of Accrediting Agency: NELAP/Florida Department of Health, Scope of Application: Clean Air Act,
Accreditation number: E87680, Effective date: 07/01/08, Expiration date: 06/30/09
Air Toxics Ltd. certifies that the test results contained in this report meet all requirements of the NELAC standards

Air Toxics LTD.

AN ENVIRONMENTAL ANALYTICAL LABORATORY

LABORATORY NARRATIVE
Modified TO-15 SIM
Floyd Snider
Workorder# 0903761

Eleven 6 Liter Summa Canister (SIM Certified) samples were received on March 30, 2009. The laboratory performed analysis via modified EPA Method TO-15 using GC/MS in the SIM acquisition mode. The method involves concentrating up to 0.5 liters of air. The concentrated aliquot is then flash vaporized and swept through a water management system to remove water vapor. Following dehumidification, the sample passes directly into the GC/MS for analysis.

This workorder was independently validated prior to submittal using 'USEPA National Functional Guidelines' as generally applied to the analysis of volatile organic compounds in air. A rules-based, logic driven, independent validation engine was employed to assess completeness, evaluate pass/fail of relevant project quality control requirements and verification of all quantified amounts.

Method modifications taken to run these samples are summarized in the table below. Specific project requirements may over-ride the ATL modifications.

Requirement	***TO-15***	***ATL Modifications***
ICAL %RSD acceptance criteria	</=30% RSD with 2 compounds allowed out to < 40% RSD	Project specific; default criteria is </=30% RSD with 10% of compounds allowed out to < 40% RSD
Daily Calibration	+- 30% Difference	Project specific; default criteria is </= 30% Difference with 10% of compounds allowed out up to </=40%.; flag and narrate outliers
Blank and standards	Zero air	Nitrogen
Method Detection Limit	Follow 40CFR Pt.136 App. B	The MDL met all relevant requirements in Method TO-15 (statistical MDL less than the LOQ). The concentration of the spiked replicate may have exceeded 10X the calculated MDL in some cases

Receiving Notes

There were no receiving discrepancies.

Analytical Notes

There were no analytical discrepancies.

Definition of Data Qualifying Flags

Eight qualifiers may have been used on the data analysis sheets and indicates as follows:

B - Compound present in laboratory blank greater than reporting limit (background subtraction not performed).

J - Estimated value.

E - Exceeds instrument calibration range.

S - Saturated peak.

Q - Exceeds quality control limits.
U - Compound analyzed for but not detected above the reporting limit.
UJ- Non-detected compound associated with low bias in the CCV
N - The identification is based on presumptive evidence.

File extensions may have been used on the data analysis sheets and indicates as follows:
a-File was requantified
b-File was quantified by a second column and detector
r1-File was requantified for the purpose of reissue

Summary of Detected Compounds
MODIFIED EPA METHOD TO-15 GC/MS SIM

Client Sample ID: SV-3

Lab ID#: 0903761-01A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Trichloroethene	7.2	380	39	2000
Tetrachloroethene	7.2	6300	49	43000

Client Sample ID: AA-4

Lab ID#: 0903761-02A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.079	0.73	0.25	2.3
Trichloroethene	0.032	0.069	0.17	0.37
Tetrachloroethene	0.032	0.29	0.21	2.0
Methylene Chloride	0.32	0.46	1.1	1.6

Client Sample ID: AA-4 Lab Duplicate

Lab ID#: 0903761-02AA

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.79	0.81	2.5	2.6
Tetrachloroethene	0.32	0.31 J	2.1	2.1 J

Client Sample ID: AA-1

Lab ID#: 0903761-03A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.082	0.40	0.26	1.3
Tetrachloroethene	0.033	0.068	0.22	0.46

Client Sample ID: AA-3

Lab ID#: 0903761-04A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.082	0.42	0.26	1.4
Tetrachloroethene	0.033	0.055	0.22	0.37

Summary of Detected Compounds
MODIFIED EPA METHOD TO-15 GC/MS SIM

Client Sample ID: AA-2

Lab ID#: 0903761-05A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.080	0.40	0.26	1.3
Tetrachloroethene	0.032	0.086	0.22	0.58

Client Sample ID: IA-3

Lab ID#: 0903761-06A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.086	0.84	0.27	2.7
Trichloroethene	0.034	0.096	0.18	0.52
Tetrachloroethene	0.034	0.89	0.23	6.0
Methylene Chloride	0.34	0.69	1.2	2.4

Client Sample ID: IA-1

Lab ID#: 0903761-07A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.079	0.74	0.25	2.4
Trichloroethene	0.032	0.21	0.17	1.1
Tetrachloroethene	0.032	11	0.21	75
Methylene Chloride	0.32	0.45	1.1	1.6

Client Sample ID: IA-2

Lab ID#: 0903761-08A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.082	0.73	0.26	2.3
Trichloroethene	0.033	0.19	0.18	1.0
Tetrachloroethene	0.033	7.8	0.22	53
Methylene Chloride	0.33	0.46	1.1	1.6

Client Sample ID: IA-4

Lab ID#: 0903761-09A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)

Summary of Detected Compounds
MODIFIED EPA METHOD TO-15 GC/MS SIM

Client Sample ID: IA-4

Lab ID#: 0903761-09A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.080	0.53	0.26	1.7
Trichloroethene	0.032	0.037	0.17	0.20
Tetrachloroethene	0.032	0.48	0.22	3.2

Client Sample ID: SV-1

Lab ID#: 0903761-10A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Trichloroethene	7.3	290	39	1600
Tetrachloroethene	7.3	7000	50	47000

Client Sample ID: SV-2

Lab ID#: 0903761-11A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Trichloroethene	6.2	180	34	940
Tetrachloroethene	6.2	6300	42	43000

Client Sample ID: SV-3

Lab ID#: 0903761-01A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**a040518**	**Date of Collection:**	**3/26/09 11:40:00 AM**
Dil. Factor:	**360**	**Date of Analysis:**	**4/5/09 10:19 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	18	Not Detected	58	Not Detected
Trichloroethene	7.2	380	39	2000
Tetrachloroethene	7.2	6300	49	43000
Methylene Chloride	72	Not Detected	250	Not Detected

Container Type: 6 Liter Summa Canister (SIM Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	109	70-130
Toluene-d8	102	70-130
4-Bromofluorobenzene	95	70-130

Client Sample ID: AA-4

Lab ID#: 0903761-02A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**a040508**	**Date of Collection: 3/26/09 8:07:00 AM**
Dil. Factor:	**1.58**	**Date of Analysis: 4/5/09 02:35 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.079	0.73	0.25	2.3
Trichloroethene	0.032	0.069	0.17	0.37
Tetrachloroethene	0.032	0.29	0.21	2.0
Methylene Chloride	0.32	0.46	1.1	1.6

Container Type: 6 Liter Summa Canister (SIM Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	108	70-130
Toluene-d8	103	70-130
4-Bromofluorobenzene	98	70-130

Client Sample ID: AA-4 Lab Duplicate

Lab ID#: 0903761-02AA

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**a040507**	**Date of Collection:**	**3/26/09 8:07:00 AM**
Dil. Factor:	**15.8**	**Date of Analysis:**	**4/5/09 01:41 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.79	0.81	2.5	2.6
Trichloroethene	0.32	Not Detected	1.7	Not Detected
Tetrachloroethene	0.32	0.31 J	2.1	2.1 J
Methylene Chloride	3.2	Not Detected	11	Not Detected

J = Estimated value.

Container Type: 6 Liter Summa Canister (SIM Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	107	70-130
Toluene-d8	102	70-130
4-Bromofluorobenzene	94	70-130

Client Sample ID: AA-1

Lab ID#: 0903761-03A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**a040509**	**Date of Collection: 3/26/09 8:21:00 AM**
Dil. Factor:	**1.64**	**Date of Analysis: 4/5/09 03:33 PM**

Compound	**Rpt. Limit (ppbv)**	**Amount (ppbv)**	**Rpt. Limit (ug/m3)**	**Amount (ug/m3)**
Benzene	0.082	0.40	0.26	1.3
Trichloroethene	0.033	Not Detected	0.18	Not Detected
Tetrachloroethene	0.033	0.068	0.22	0.46
Methylene Chloride	0.33	Not Detected	1.1	Not Detected

Container Type: 6 Liter Summa Canister (SIM Certified)

Surrogates	**%Recovery**	**Method Limits**
1,2-Dichloroethane-d4	108	70-130
Toluene-d8	102	70-130
4-Bromofluorobenzene	99	70-130

Client Sample ID: AA-3

Lab ID#: 0903761-04A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**a040510**	**Date of Collection:**	**3/26/09 8:27:00 AM**
Dil. Factor:	**1.64**	**Date of Analysis:**	**4/5/09 04:12 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.082	0.42	0.26	1.4
Trichloroethene	0.033	Not Detected	0.18	Not Detected
Tetrachloroethene	0.033	0.055	0.22	0.37
Methylene Chloride	0.33	Not Detected	1.1	Not Detected

Container Type: 6 Liter Summa Canister (SIM Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	108	70-130
Toluene-d8	103	70-130
4-Bromofluorobenzene	99	70-130

Client Sample ID: AA-2

Lab ID#: 0903761-05A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**a040511**	**Date of Collection: 3/26/09 8:38:00 AM**
Dil. Factor:	**1.61**	**Date of Analysis: 4/5/09 04:51 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.080	0.40	0.26	1.3
Trichloroethene	0.032	Not Detected	0.17	Not Detected
Tetrachloroethene	0.032	0.086	0.22	0.58
Methylene Chloride	0.32	Not Detected	1.1	Not Detected

Container Type: 6 Liter Summa Canister (SIM Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	108	70-130
Toluene-d8	101	70-130
4-Bromofluorobenzene	93	70-130

Client Sample ID: IA-3

Lab ID#: 0903761-06A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**a040512**	**Date of Collection: 3/26/09 8:46:00 AM**
Dil. Factor:	**1.71**	**Date of Analysis: 4/5/09 05:30 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.086	0.84	0.27	2.7
Trichloroethene	0.034	0.096	0.18	0.52
Tetrachloroethene	0.034	0.89	0.23	6.0
Methylene Chloride	0.34	0.69	1.2	2.4

Container Type: 6 Liter Summa Canister (SIM Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	109	70-130
Toluene-d8	102	70-130
4-Bromofluorobenzene	95	70-130

Client Sample ID: IA-1

Lab ID#: 0903761-07A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**a040513**	**Date of Collection: 3/26/09 8:51:00 AM**
Dil. Factor:	**1.58**	**Date of Analysis: 4/5/09 06:09 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.079	0.74	0.25	2.4
Trichloroethene	0.032	0.21	0.17	1.1
Tetrachloroethene	0.032	11	0.21	75
Methylene Chloride	0.32	0.45	1.1	1.6

Container Type: 6 Liter Summa Canister (SIM Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	108	70-130
Toluene-d8	104	70-130
4-Bromofluorobenzene	102	70-130

Client Sample ID: IA-2

Lab ID#: 0903761-08A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**a040514**	**Date of Collection:**	**3/26/09 8:57:00 AM**
Dil. Factor:	**1.64**	**Date of Analysis:**	**4/5/09 06:51 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.082	0.73	0.26	2.3
Trichloroethene	0.033	0.19	0.18	1.0
Tetrachloroethene	0.033	7.8	0.22	53
Methylene Chloride	0.33	0.46	1.1	1.6

Container Type: 6 Liter Summa Canister (SIM Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	108	70-130
Toluene-d8	101	70-130
4-Bromofluorobenzene	97	70-130

Client Sample ID: IA-4

Lab ID#: 0903761-09A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**a040515**	**Date of Collection:**	**3/26/09 9:00:00 AM**
Dil. Factor:	**1.61**	**Date of Analysis:**	**4/5/09 07:30 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.080	0.53	0.26	1.7
Trichloroethene	0.032	0.037	0.17	0.20
Tetrachloroethene	0.032	0.48	0.22	3.2
Methylene Chloride	0.32	Not Detected	1.1	Not Detected

Container Type: 6 Liter Summa Canister (SIM Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	108	70-130
Toluene-d8	103	70-130
4-Bromofluorobenzene	96	70-130

Client Sample ID: SV-1

Lab ID#: 0903761-10A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**a040516**	**Date of Collection:**	**3/26/09 10:50:00 AM**
Dil. Factor:	**366**	**Date of Analysis:**	**4/5/09 08:13 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	18	Not Detected	58	Not Detected
Trichloroethene	7.3	290	39	1600
Tetrachloroethene	7.3	7000	50	47000
Methylene Chloride	73	Not Detected	250	Not Detected

Container Type: 6 Liter Summa Canister (SIM Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	110	70-130
Toluene-d8	102	70-130
4-Bromofluorobenzene	96	70-130

Client Sample ID: SV-2

Lab ID#: 0903761-11A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**a040517**	**Date of Collection:**	**3/26/09 11:13:00 AM**
Dil. Factor:	**312**	**Date of Analysis:**	**4/5/09 09:29 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	16	Not Detected	50	Not Detected
Trichloroethene	6.2	180	34	940
Tetrachloroethene	6.2	6300	42	43000
Methylene Chloride	62	Not Detected	220	Not Detected

Container Type: 6 Liter Summa Canister (SIM Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	109	70-130
Toluene-d8	103	70-130
4-Bromofluorobenzene	97	70-130

Client Sample ID: Lab Blank

Lab ID#: 0903761-12A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**a040506**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 4/5/09 12:44 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Benzene	0.050	Not Detected	0.16	Not Detected
Trichloroethene	0.020	Not Detected	0.11	Not Detected
Tetrachloroethene	0.020	Not Detected	0.14	Not Detected
Methylene Chloride	0.20	Not Detected	0.69	Not Detected

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	107	70-130
Toluene-d8	103	70-130
4-Bromofluorobenzene	99	70-130

Client Sample ID: CCV

Lab ID#: 0903761-13A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**a040502**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 4/5/09 08:54 AM**

Compound	**%Recovery**
Benzene	88
Trichloroethene	85
Tetrachloroethene	88
Methylene Chloride	85

Container Type: NA - Not Applicable

Surrogates	**%Recovery**	**Method Limits**
1,2-Dichloroethane-d4	102	70-130
Toluene-d8	106	70-130
4-Bromofluorobenzene	106	70-130

Client Sample ID: LCS

Lab ID#: 0903761-14A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**a040503**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 4/5/09 09:50 AM**

Compound	%Recovery
Benzene	85
Trichloroethene	82
Tetrachloroethene	87
Methylene Chloride	90

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	105	70-130
Toluene-d8	103	70-130
4-Bromofluorobenzene	104	70-130

Fox Avenue Site
Seattle, Washington

Remedial Investigation/ Feasibility Study

Appendix E
Vapor Intrusion Assessment at Seattle Boiler Works Property Report

FINAL

February 2, 2011

Mr. Craig Hopkins
Seattle Boiler Works, Inc.
500 South Myrtle Street
Seattle, WA 98108

Vapor Intrusion Assessment
Seattle Boiler Works Property
500 South Myrtle Street, Seattle, WA
URS Job No. 33756383

Dear Mr. Hopkins:

INTRODUCTION

URS Corporation (URS) is pleased to present this letter report to Seattle Boiler Works, Inc. (SBW) describing the results of a Vapor Intrusion Assessment (VIA) at the SBW property (subject property) located at 500 South Myrtle Street in Seattle, Washington. The VIA was performed by URS in two phases consistent with Washington State Department of Ecology's *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action (Review Draft, October 2009).*

The first phase was conducted in October 2010 and consisted of collecting three sub-slab soil gas samples beneath the Pipe Shop Building, and one sub-slab soil gas sample beneath the Fabrication Shop Building. As shown on Figure 1, these buildings are located downgradient of a groundwater plume (primarily chlorinated volatile organic compounds or CVOCs) originating from the Fox Avenue LLC Site.

Based on elevated concentrations of CVOCs in sub-slab soil gas samples collected during Phase 1, additional indoor air sampling was conducted as part of Phase 2 to evaluate whether or not the vapor intrusion pathway was complete, and if it was complete, whether or not the indoor air levels meet applicable Model Toxics Control Act (MTCA) Method B indoor air cleanup levels. This second phase was performed in December 2010 and consisted of collecting three indoor air samples inside the Pipe Shop Building and one ambient air sample outside of this building (Figure 1). Results of this second phase investigation indicate that there is in fact a direct vapor intrusion pathway, resulting in indoor air concentrations within the Pipe Shop Building that consistently exceed applicable MTCA Method B cleanup levels (and applicable Method C cleanup levels).

BACKGROUND

The Fox Avenue LLC property located at 6900 Fox Avenue in Seattle, Washington is the former site of a chemical handling and distribution facility operated by Great Western Chemical Company (GWCC). That property is now referred to as the Fox Avenue LLC Site. GWCC operations resulted in contamination of groundwater. The primary contaminants of concern migrating from the Fox Avenue site and affecting the SBW property are perchloroethene (PCE), trichloroethene (TCE), cis-1,2 dichloroethene (cis 1,2-DCE), and vinyl chloride (VC). Per the terms of an Agreed Order between Ecology and Fox Avenue Building LLC (Fox Ave), an Interim Action has been initiated at the Fox Avenue LLC Site, while Fox Ave is completing the Remedial Investigation/Feasibility Study (RI/FS) and final cleanup action design as required by Ecology. The objectives of the Interim Action are to 1) remediate the VOC plume in groundwater downgradient of the Fox Avenue Site, and 2) mitigate the risk presented by CVOCs in groundwater until the final remedy is complete.

Currently, no cleanup levels have formerly been established for the Site. However, the expectation is that Ecology's cleanup levels will be MTCA Method A or B for all constituents of concern in all media (soil, groundwater, air) at least for the SBW property. If more restrictive cleanup levels are established elsewhere at the Site, then appropriate safeguards would be in place to protect the SBW from recontamination by upgradient sources at levels above MTCA Method A or B cleanup levels. We understand that institutional controls restricting future use of the SBW property are unacceptable to SBW.

PURPOSE AND SCOPE

The objective of the VIA was to evaluate whether vapor intrusion of PCE and its primary degradation products present in the shallow groundwater beneath the Site has affected indoor air quality within the SBW Pipe Shop building. The building was selected for investigation because it is located nearest to the highest PCE/TCE concentrations within groundwater CVOC plume. However, it should be noted that other buildings on the SBW property are located within or in close proximity to the groundwater CVOC plume. Soil vapor and/or indoor air have not been evaluated for potential vapor intrusion into indoor air for these other buildings. To achieve these objectives, URS implemented the following scope of work:

- Collected sub-slab soil vapor samples from four locations inside two SBW buildings using Summa canisters and analyzed the samples for PCE and degradation products using EPA Method TO-15;
- Collected three indoor air samples and one exterior air sample using Summa canisters and analyzed the samples for PCE and degradation products using EPA Method TO-15;
- Prepared this report summarizing the field activities, analytical results, and conclusions based on the results of these investigations

Prior to implementing the soil vapor and indoor air testing, URS notified Ecology to inform them of the work. Additionally, SBW notified Fox Avenue LLC and provided them an opportunity to collect the sub-slab vapor samples and indoor air samples. We understand that Fox Avenue LLC was unwilling to perform both the sub-slab vapor sampling and indoor air sampling, indicating that sub-slab sampling was not necessary to assess the vapor intrusion pathway. A tiered approach consisting of sub-slab soil gas sampling and, if necessary, subsequent indoor air testing is considered appropriate to evaluate if a potential vapor intrusion exists beneath the SBW property, and if so, whether or not the vapor intrusion pathway to indoor air was in fact complete. Knowledge of sub-slab soil vapor concentrations is important to inform future decisions regarding site remediation, future air monitoring requirements, and potential mitigation measures associated with a complete vapor intrusion pathway to indoor air. No questions or concerns were raised by Ecology regarding this approach during these notifications.

Information regarding the SBW buildings and a description of the sampling methods and procedures are provided in the following sections.

SITE & BUILDING DESCRIPTION

The SBW property is an approximate 4.5 acre parcel comprised of several buildings under approximately 65,000 square feet of roof. The SBW facility is an active ASME fabrication shop, which is primarily engaged in fabrication and assembly of various industrial equipment items, such as boilers, pressure vessels, tanks, heat exchangers, and other industrial equipment. Current facility operations primarily consist of assembly of various components that are manufactured elsewhere.

Figure 1 shows an aerial photograph of the SBW property that illustrates the various buildings and structures on the property. This map also shows inferred groundwater concentrations of combined PCE and TCE in the shallow 1st Water Bearing Zone beneath the Site. Groundwater concentration data was obtained from CVOC plume maps prepared by Fox Avenue LLC’s consultant Floyd|Snider, as presented in the Draft RI/FS report in 2009.

The building evaluated in this IAA is commonly referred to as the Pipe Shop Building. This building was constructed in the late 1940’s and consists of a slab on grade with exterior walls and a concrete floor. The building is actively used by SBW for parts and equipment assembly. The building is approximately two stories high and is open from the floor to the roof. A small enclosed lunch room is located on the southeast corner of the building, as shown in Figure 1.

SAMPLING METHODS AND PROCEDURES

Sub-Slab Soil Vapor Sampling

URS conducted sub-slab soil vapor sampling and testing for PCE and its common degradation products the morning of October 28, 2010. Four indoor air samples (SSV-A through SSV-D) within the Pipe Shop and Fabrication Shop buildings were collected, as illustrated on Figure 1. The sampling methods and procedures implemented were in general conformance with Ecology’s *Guidance for Evaluating Soil Vapor Intrusion in Washington State* (Ecology, 2009). The sampling was accomplished using 1-liter Summa canisters with flow controllers limiting flow to 167 milliliters per minute (mL/min). Prior to sampling, 5/8” holes were cut through the concrete slab at the four selected sampling locations, allowing access to the fill material beneath the concrete slab. Temporary sampling probes were installed by inserting ¼” outside diameter (O.D.) Teflon tubing into the holes cut through the slab. The surface was sealed using a rubber washer and modeling clay compound to prevent the sampling intake at the bottom of the hole from drawing ambient air into the sampling canister. A shroud was placed over the sampling location and a positive pressure of helium gas was maintained within the shroud during the course of sampling. Each Summa canister and flow controller setup was leak tested to verify flow controllers were functioning properly and there were no leaks in the sampling train. Using a hand pump, each sampling line was purged of at least 1L of soil vapor prior to sampling. The purged vapor was captured in a Tedlar bag and screened using a photoionization detector (PID). Each canister and flow controller assembly was connected to the corresponding sampling line and samples were collected. With a flow rate of 167 mL/min regulated by flow controllers, each sample was collected over about a 5 minute time period. Photographs taken during sample collection are provided in Appendix A.

URS collected the samples during a light rain event, with barometric pressure readings ranging from approximately 29.88 to 29.96 inches of mercury and a temperature of approximately 45° F (Appendix B).

The Summa canisters were provided and the air testing was performed by Air Toxics Ltd. of Folsom, CA. The canisters were pre-evacuated by the laboratory and checked by URS upon receipt to ensure a proper vacuum remained in the canister. The canisters were provided with calibrated and certified flow regulator designed to allow a flow of 167 mL/min into the evacuated canister. The initial and final vacuum readings for each canister were recorded on the chain of custody. The samples were analyzed by EPA Method TO–15 and the laboratory analytical report is provided in Appendix C.

Following sample collection, the holes in the floor were patched by SBW by filling them with concrete to the original surface elevation of the floor.

Air Sampling

URS conducted indoor air sampling and testing for chlorinated VOCs, specifically PCE and its common degradation products over a a 8-hour period (8AM to 4PM) on December 12, 2010. Three indoor air samples (SBW-IA-SSVB, SBW-IA-Center and SBW-IA-Lunch) were collected within the Pipe Shop Building and one outdoor ambient (SBW-IA-AMB) air sample was collected outside of the building (Figure 1). The sampling methods and procedures implemented were in general conformance with Ecology's *Guidance for Evaluating Soil Vapor Intrusion in Washington State* (Ecology, 2009). The sampling was accomplished using 6-liter Summa canisters with 8-hour flow controllers. The canisters were set up at the interior locations at approximately 3 feet above the floor to represent a typical worker/patient seating height and breathing zone. The samples were collected during weekend hours and building windows and exterior doors remained closed during the sampling event to minimize air exchange in the building. Photographs taken during sample collection are provided in Appendix A.

URS collected the samples during a rain event with approximately 0.69 inches of rain falling during the sampling period and with barometric pressure readings ranging from approximately 29.85 to 29.94 inches of mercury and temperatures ranging from 56 to 57 °F (Appendix B).

The Summa canisters were provided and the air testing was performed by Air Toxics Ltd. of Folsom, CA. The canisters were pre-evacuated by the laboratory and checked by URS upon receipt to ensure a proper vacuum remained in the canister. The canisters were provided with calibrated and certified flow regulator designed to allow a flow 0.11 ml/min into the evacuated canister over an 8-hour period. The initial and final vacuum readings for each canister were recorded on the chain of custody. The samples were analyzed by EPA Method TO–15 and the laboratory analytical report is provided in Appendix C.

ANALYTICAL RESULTS

Sub-Slab Soil Vapor

Sub-slab soil vapor sampling results are summarized in Table 1 and the sampling locations are shown on Figure 1. PCE and its common degradation produces trichloroethylene (TCE), vinyl chloride (VC), and cis-1,2-dichloroethene (cis12DCE) were detected in samples collected from beneath the building. PCE was detected in all four samples at concentrations ranging from 1,600 micrograms per cubic meter ($\mu g/m^{3)}$ to 5,100 $\mu g/m^3$ and TCE was detected in three samples at concentrations ranging from 96 $\mu g/m^3$ to 220 $\mu g/m^3$. The sample collected at location SSV-B, near the southeast corner of the Pipe Shop Building reported the highest concentrations of both PCE and TCE in sub-slab soil vapor. Concentrations of cis-1,2-dichloroethene and vinyl chloride were reported above detection limits at the sample collected from location SSV-C, nearest the Fox Avenue LLC property and adjacent to the railway.

Consistent with Ecology's guidance for evaluating soil vapor intrusion (Ecology, 2009), URS compared soil vapor analytical results to MTCA Method B vapor screening levels for unrestricted land use. All of the soil vapor PCE concentrations exceed the applicable unrestricted land use screening level (Table 1), as do three TCE concentrations (SSV-B, SSV-C, and SSV-D) and one vinyl chloride concentration (SSV-C).

Indoor Air

The indoor air sampling results are summarized in Table 1 and the sampling locations are shown on Figure 1. An indoor air sample was collected nearly coincident with soil vapor sample SSV-B because of the high concentrations of PCE and TCE reported in the sub-slab vapor sample. PCE and its common degradation products TCE, VC and cis1, 2 DCE were detected in all three air samples within the building, as well as the ambient air sample, at concentrations above laboratory reporting limits. PCE concentrations in indoor air ranged from 4.0 $\mu g/m^3$ to 4.5 $\mu g/m^3$. The highest concentration of PCE (4.5 $\mu g/m^3$) was detected at location SBW-IA-Lunch, in the employee lunchroom inside the Pipe Shop Building. TCE concentrations in indoor ranged from 0.34 $\mu g/m^3$ to 0.44 $\mu g/m^3$. The highest concentration of TCE (0.44 $\mu g/m^3$) was detected at location SBW-IA-SSVB. VC concentrations ranged from 0.13 $\mu g/m^3$ to 0.22 $\mu g/m^3$, and cis- 1,2 DCE concentrations ranged from 0.27 $\mu g/m^3$ to 0.42 $\mu g/m^3$. CVOCs were detected in the ambient air sample (SBW-IA-AMB) collected outside of the building (Figure 1) at concentrations less than those reported in indoor air, with the exception of vinyl chloride, which was reported at a concentration of 0.16 $\mu g/m^3$.

Consistent with Ecology's guidance for evaluating soil vapor intrusion (Ecology, 2009), URS compared indoor air results to MTCA Method B indoor air cleanup levels for unrestricted land use. All of the indoor air PCE and TCE concentrations exceed the applicable unrestricted land use cleanup levels (Table 1).

CONCLUSIONS & RECOMMENDATIONS

The following conclusions are based on the findings of the VIA described above.

- The sub-slab soil vapor sampling performed in October 2010 beneath the Pipe Shop Building identified PCE in all sub-slab soil vapor samples at concentrations exceeding the applicable MTCA Method B soil gas screening levels. Concentrations of TCE exceeding the MTCA B soil gas screening levels were identified in three samples collected beneath the Pipe Shop Building. The soil vapor sample collected at location SSV-C, nearest the Fox Avenue property also reported detectable concentrations of cis-1,2-dichloroethene, and vinyl chloride. The vinyl chloride concentration in soil gas at location SSV-C also exceeds MTCA Method B shallow soil gas screening criteria.

- The indoor air sampling performed in December 2010 beneath the Pipe Shop Building identified PCE and TCE in the indoor air at concentrations exceeding applicable MTCA B cleanup levels. The ambient air sample collected on the east side of the building also detected these compounds, but generally at lower levels compared to indoor air samples. Vinyl chloride and cis-1,2-DCE were also reported at concentrations exceeding laboratory detection limits, however these concentrations do not exceed the applicable cleanup levels.

- The detection of elevated levels of CVOCs in shallow soil gas samples demonstrate that a potential vapor intrusion risk is present at the SBW property from CVOC contaminated groundwater beneath the SBW property originating from the Fox Avenue LLC Site. Additional assessment of sub-slab soil gas concentrations and/or indoor air at all buildings and covered/enclosed work spaces on the SBW property would be appropriate given the relatively high concentrations of CVOCs detected beneath the Pipe Shop Building compared to established soil gas screening levels.

- The available data demonstrate a complete groundwater to vapor and vapor to indoor air pathway beneath the SBW property. Indoor air levels in the Pipe Shop Building are unacceptable based on Ecology guidance. Based on these data, further vapor intrusion and indoor air assessments should be undertaken in a timely manner to fully characterize indoor air impacts to the SBW property. This assessment should be expanded to all buildings and covered/enclosed work spaces at the SBW property.

- We understand that the currently proposed Site cleanup levels by Fox Avenue LLC do not consider protection of human health from a vapor intrusion pathway. The data reported herein clearly demonstrate a complete vapor to indoor air pathway at the SBW property. As such, we recommend that Ecology establish, in consultation with SBW, groundwater cleanup levels beneath the SBW property that are protective of indoor air quality. Cleanup levels on the SBW property should be appropriate for unrestricted land use. We understand institutional controls that would restrict the future use and development of the SBW property are unacceptable to SBW as a means to allow concentrations of contaminants to remain on the SBW Property above concentrations applicable to unrestricted land use – especially in light of the vapor intrusion data presented herein.

- Active mitigation measures are appropriate to address the identified indoor air impacts. Implementation of a soil vapor extraction system on the SBW property should be considered as an

> interim measure until more permanent and aggressive measures can be undertaken as part of the final cleanup action which should require reduction of groundwater contamination to concentrations which are protective of human health and the environment especially in relation to the soil gas to indoor air vapor pathway.

We trust this letter report meets your requirements. If you have any questions or require additional information, please call us at (206) 438-2700.

Sincerely,

URS CORPORATION

Jessica Wellmeyer

Jessica Wellmeyer
Geologist

Paul T. McCullough

Paul McCullough, PE
Senior Project Engineer

Attachments

Table 1 – Soil Vapor and Indoor Air Analytical Results
Figure 1 – Site and Sampling Locations
Appendix A – Site Photographs
Appendix B – Meterological Data
Appendix C – Analytical Reports

Copy: John Houlihan, Houlihan Law
Roy Elliott, URS Corporation

TABLES

TABLE 1
SUMMARY OF SOIL VAPOR AND INDOOR AIR ANALYTICAL RESULTS
SEATTLE BOILER WORKS PROPERTY - SEATTLE, WASHINGTON

Sub-Slab Soil Vapor Results

Sample Id	Date	Depth	Units	PCE	TCE	cis 1,2-DCE	trans-1,2 DCE	VC
SVA-A	10/28/10	Subslab	µg/m^3	**1,600**	ND(<6.4)	ND(<4.7)	ND (<4.7)	ND(<3.0)
SVA-B	10/28/10	Subslab	µg/m^3	**5,100**	**220**	ND(<12)	ND(<12)	ND(<7.6)
SVA-C	10/28/10	Subslab	µg/m^3	**1,800**	**120**	26	ND(<11)	**18**
SVA-D	10/28/10	Subslab	µg/m^3	**2,800**	**96**	ND (<4.6)	ND(<4.6)	ND(<3.0)
Applicable Regulatory Levels								
MTCA Method B Soil Gas Screening Level	--	shallow	µg/m^3	4.2	1	160	320	2.8

Indoor Air Results

Sample Id	Date	Depth	Units	PCE	TCE	cis 1,2-DCE	trans-1,2 DCE	VC
SBW-IA-AMB	12/12/10	Ambient Air	µg/m^3	1.5	0.20	0.22	ND(<0.13)	0.16
SBW-IA-SSVB	12/12/10	Indoor Air	µg/m^3	**4.4**	**0.44**	0.42	ND(<0.13)	0.22
SBW-IA-Lunch	12/12/10	Indoor Air	µg/m^3	**4.5**	**0.34**	0.27	ND(<0.13)	0.13
SBW-IA-Center	12/12/10	Indoor Air	µg/m^3	**4.0**	**0.41**	0.41	ND(<0.12)	0.21
Applicable Regulatory Levels								
MTCA Method B Indoor Air CUL	--	--	µg/m^3	0.42	0.1	16	32	0.28

Notes:

µg/m^3 = micrograms per cubic meter

Bold values exceed applicable MTCA Method B soil gas screening levels or Method B indoor air cleanup levels

CUL = Indoor Air Cleanup Level

ND = Not Detected (above indicated reporting limit)

PCE = tetrachloroethene

cis-1,1-DCE = cis-1,2-dichloroethene

TCE = trichloroethene

trans-1,1-DCE = trans-1,2-dichloroethene

VC = vinyl chloride

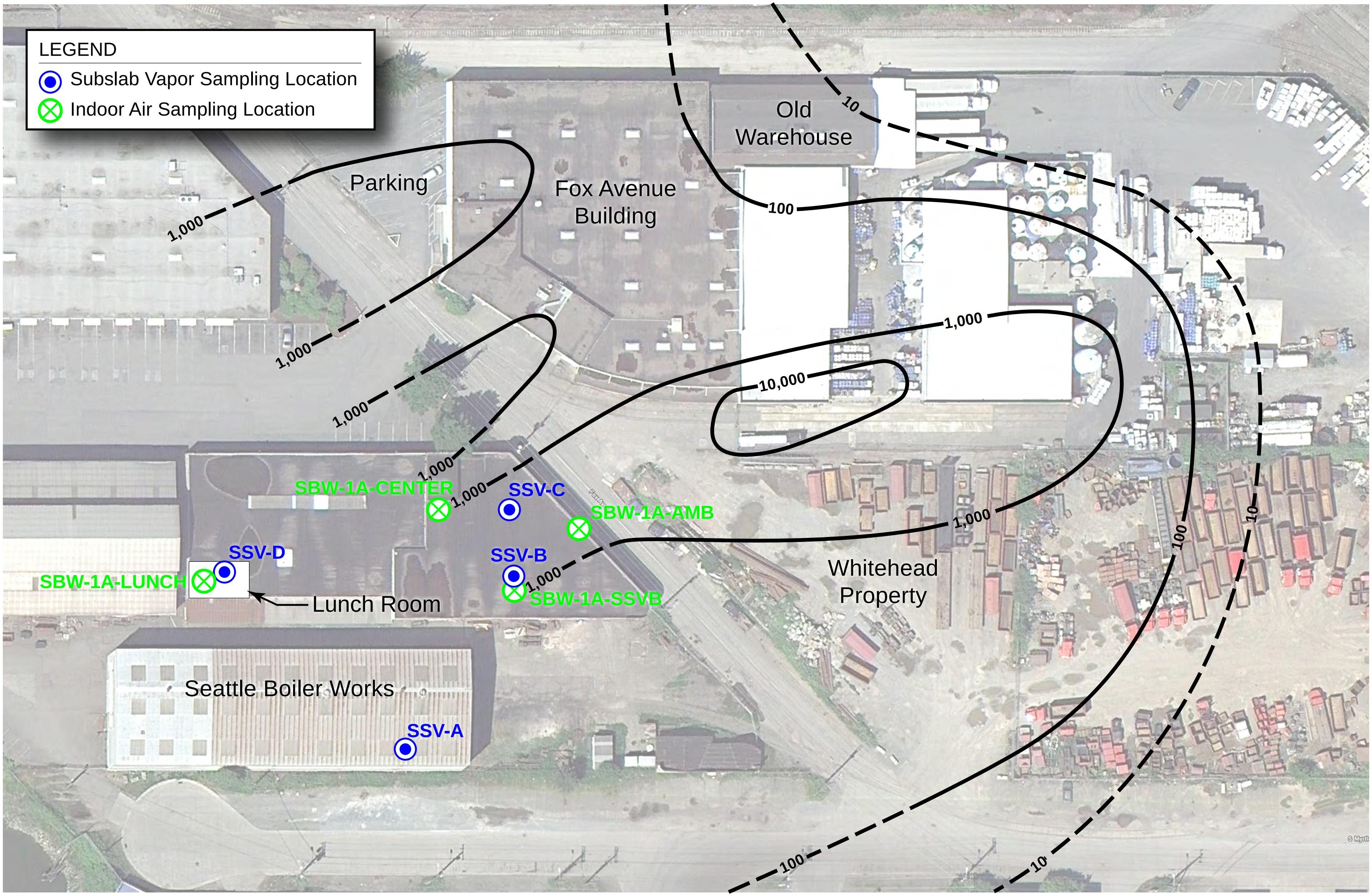
MTCA Method B is described in WAC 173-340 for calculating cleanup levels for unrestricted land use

Soil Gas Screening Levels are based on Ecology's Draft Guidance for Soil Vapor Intrusion (October 2009)

Soil Gas Screening Levels for PCE, TCE, and VC are based on carcinogenity

Soil Gas Screening Levels for cis-1,2 DCE and trans-1,2 DCE are based on non-carcinogenity

FIGURES



Source: (1) Floyd | Snider, Draft Feasibility Study, Figure 2.6A Maximum PCE and TCE Concentrations in Groundwater in 1st Water Bearing Zone; (2) Google Earth Pro, 2010

Job No. 33756383

0 100 200

Approximate Scale in Feet

Figure 1

Soil Vapor and Indoor Air Sampling

URS

Seattle Boiler Works Property
500 S. Myrtle Street
Seattle, Washington

APPENDIX A
SITE PHOTOGRAPHS

Photograph No: 1 Sub-slab soil vapor sampling location SSV-B, near former borehole 3-9 inside SBW tube shop building

Photograph No: 2 Sub-slab soil vapor sampling train set up at SSV-B

Photograph No: 3 Indoor air sampling location SBW-IA-LUNCH in lunchroom located in southwest corner of tube shop building

Photograph No: 4 Indoor air sampling location SBW-IA-SSVB in the main portion of the tube shop

APPENDIX B
METEROLOGICAL DATA

Past Weather Conditions for KBFI

Observations prior to selected time: October 29, 2010 - 00:00 PDT

Weather Conditions at October 29, 2010 - 0:00 PDT

	0:00	24 Hour Max	24 Hour Min
Temperature	51.8° F	60.1 at 1:53	51.8 at 0:00
Dew Point	46.4° F	48.0 at 14:53	35.1 at 1:53
Relative Humidity	82%	83 at 20:53	39 at 1:53
Wind Speed	0 mph	9 at 1:53	0 at 4:53
Wind Gust	-	20 at 1:53	20 at 1:53
Pressure	30.01 in	30.01 at 23:53	29.87 at 2:53
Sea level pressure	-	30.02 at 23:53	29.89 at 2:53
Altimeter	30.03 in	30.03 at 23:53	29.89 at 2:53
Weather conditions	lt rain	-	-
Visibility	7.00 miles	10.00 at 0:53	6.00 at 23:53
Ceiling	2200 feet	10000 at 0:53	2200 at 0:00

Precipitation variable accumulated	Since Midnight	In 24 Hours
Precipitation 1hr	0.00"	0.10"
Precipitation 6hr	0.00"	0.04"

Tabular Listing: October 27, 2010 - 23:00 through October 29, 2010 - 00:00 PDT

Time (PDT)	Temperature ° F	Dew Point ° F	Relative Humidity %	Wind Speed mph	Wind Gust mph	Wind Direction	Quality check	Pressure in	Sea level pressure in	Altimeter in	Weather conditions	Visibility miles	Precipitation 1hr in	Precipitation 3hr in	Precipitation 6hr in	Ceili fee
0:00	51.8	46.4	82	0			OK	30.01		30.03	lt rain	7.00	0.00			220
23:53	52.0	46.9	83	0			OK	30.01	30.02	30.03	lt rain	6.00	0.01			360
22:53	53.1	46.9	80	0			OK	29.99	30.01	30.01	overcast	10.00				450
21:53	53.1	46.0	77	0			OK	29.98	30.00	30.00	overcast	10.00				480
20:53	53.1	48.0	83	0			OK	29.99	30.01	30.01	overcast	10.00				500
19:53	54.0	46.9	77	0			OK	29.98	30.00	30.00	overcast	10.00				470
18:53	54.0	46.9	77	0			OK	29.97	29.98	29.99	overcast	10.00				600
17:53	54.0	46.9	77	5		SE	OK	29.96	29.98	29.98	overcast	10.00				700
16:53	54.0	48.0	80	5		SE	OK	29.95	29.97	29.97	overcast	10.00	0.00			800
15:53	54.0	48.0	80	6		SE	OK	29.96	29.97	29.98	overcast	10.00	0.02			300
14:53	54.0	48.0	80	7		SE	OK	29.96	29.98	29.98	lt rain	10.00	0.01			380
13:53	54.0	46.9	77	7		SE	OK	29.96	29.98	29.98	partly cloudy	10.00	0.00			
12:53	54.0	46.9	77	5		S	OK	29.97	29.99	29.99	overcast	10.00	0.01			460
11:53	55.0	46.0	72	5		S	OK	29.96	29.97	29.98	overcast	10.00				500
10:53	54.0	45.0	72	5		SSE	OK	29.94	29.96	29.96	overcast	10.00	0.00		0.04	500
9:53	53.1	46.0	77	3		SE	OK	29.93	29.94	29.95	lt rain	10.00	0.01			500
8:53	54.0	44.1	69	6		ESE	OK	29.92	29.94	29.94	lt rain	10.00	0.01			500
7:53	53.1	46.0	77	0			OK	29.89	29.91	29.91	lt rain	10.00	0.01	0.02		460
6:53	53.1	45.0	74	0			OK	29.88	29.90	29.90	lt rain	10.00	0.00			600
5:53	55.0	43.0	64	0			OK	29.88	29.90	29.90	lt rain	10.00	0.01			500
4:53	55.0	42.1	62	0			OK	29.87	29.89	29.89	overcast	10.00			0.00	600
3:53	57.0	39.0	51	9		ESE	OK	29.88	29.90	29.90	overcast	10.00	0.00			650
2:53	59.0	35.6	41	7		SE	OK	29.87	29.89	29.89	overcast	10.00				800
1:53	60.1	35.1	39	9	20	ESE	OK	29.88	29.89	29.90	overcast	10.00	0.00			100

0:53	57.9	37.0	46	3		ESE	OK	29.88	29.90	29.90	mostly cloudy	10.00		100
23:53	59.0	35.6	41	3		ESE	OK	29.89	29.91	29.91	overcast	10.00		90

Past Weather Conditions for KBFI

Observations prior to selected time: December 13, 2010 - 00:00 PST

Weather Conditions at December 12, 2010 - 23:53 PST

	23:53	24 Hour Max	24 Hour Min
Temperature	55.0° F	57.9 at 2:53	51.1 at 0:53
Dew Point	51.1° F	55.0 at 1:53	50.0 at 0:53
Relative Humidity	86%	96 at 0:53	84 at 16:53
Wind Speed	7 mph from SSW	17 at 4:53	5 at 23:00
Wind Gust	-	32 at 4:53	17 at 10:53
Pressure	29.94 in	29.95 at 22:53	29.82 at 4:53
Sea level pressure	29.96 in	29.96 at 22:53	29.83 at 5:53
Altimeter	29.96 in	29.97 at 22:53	29.84 at 4:53
Weather conditions	overcast	-	-
Visibility	10.00 miles	10.00 at 14:53	3.00 at 0:53
Ceiling	4300 feet	6500 at 23:00	1200 at 0:53

Precipitation variable accumulated	Since Midnight	In 24 Hours
Precipitation 1hr	0.00"	2.24"
Precipitation 6hr	0.00"	1.66"

Tabular Listing: December 11, 2010 - 23:00 through December 13, 2010 - 00:00 PST

Time (PST)	Temperature ° F	Dew Point ° F	Relative Humidity %	Wind Speed mph	Wind Gust mph	Wind Direction	Quality check	Pressure in	Sea level pressure in	Altimeter in	Weather conditions	Visibility miles	Precipitation 1hr in	Precipitation 3hr in	Precipitation 6hr in	Precip 24
23:53	55.0	51.1	86	7		SSW	OK	29.94	29.96	29.96	overcast	10.00				
23:00	55.4	51.8	88	5		SSW	OK	29.95		29.97	overcast	10.00				
22:53	55.0	51.1	86	8		SSW	OK	29.95	29.96	29.97	overcast	10.00				
18:53	55.0	51.1	86	10	24	S	OK	29.94	29.96	29.96	mostly cloudy	10.00				
17:53	55.0	52.0	89	9	18	S	OK	29.94	29.95	29.96	mostly cloudy	10.00				
16:53	55.9	51.1	84	13	20	S	OK	29.94	29.96	29.96	mostly cloudy	10.00				
15:53	55.9	52.0	87	15	22	S	OK	29.93	29.95	29.95	overcast	10.00			0.29	
14:53	55.9	53.1	90	15	25	S	OK	29.92	29.94	29.94	overcast	10.00				
13:53	55.9	53.1	90	12	23	SSW	OK	29.93	29.94	29.95	lt rain, fog	3.00	0.02			
12:53	55.9	53.1	90	13	18	S	OK	29.91	29.93	29.93	lt rain, fog	3.00	0.02	0.27		
11:53	55.9	53.1	90	13	18	S	OK	29.91	29.93	29.93	lt rain, fog	5.00	0.07			
10:53	55.9	53.1	90	10	17	S	OK	29.92	29.94	29.94	lt rain, fog	3.00	0.18			
9:53	57.0	53.1	87	12	21	S	OK	29.90	29.91	29.92	mod rain, fog	4.00	0.19			
8:53	57.0	53.1	87	12	26	S	OK	29.86	29.88	29.88	mod rain, fog	4.00	0.21			
											mod					

7:53	57.0	54.0	89	9	21	S	OK	29.85	29.87	29.87	rain, fog	4.00	0.29			
6:53	57.9	54.0	87	12	22	S	OK	29.84	29.86	29.86	mod rain, fog	3.00	0.25	0.39		
6:22	57.2	53.6	88	13		S	OK	29.83		29.85	mod rain, fog	3.00	0.11			
6:00	57.2	53.6	88	13	23	S	OK	29.82		29.84	mod rain, fog	5.00	0.01			
5:53	57.9	54.0	87	13	26	S	OK	29.82	29.83	29.84	lt rain, fog	5.00	0.09			
4:53	57.9	54.0	87	17	32	S	OK	29.82	29.84	29.84	lt rain	9.00	0.05			
3:53	57.9	54.0	87	10	24	S	OK	29.85	29.87	29.87	lt rain, fog	3.00	0.16		1.37	2.
2:53	57.9	55.0	90	13	22	SSE	OK	29.86	29.88	29.88	lt rain, fog	5.00	0.22			
1:53	57.0	55.0	93	10	22	S	OK	29.85	29.87	29.87	mod rain, fog	3.00	0.23			
0:53	51.1	50.0	96	9		SE	OK	29.85	29.87	29.87	mod rain, fog	3.00	0.26			
23:53	48.9	48.0	97	5		SSE	OK	29.86	29.88	29.88	mod rain, fog	3.00	0.24			
23:00	48.2	46.4	93	6		SSE	OK	29.86		29.88	mod rain, fog	2.50	0.03			

APPENDIX C
ANALYTICAL

Air Toxics LTD.
Laboratory Services Since 1989

11/11/2010

Mr. Paul McCullough
URS Corporation
1501 4th Avenue
Suite 1400
Seattle WA 98101-1616

Project Name: Seattle Boiler
Project #: 33756383
Workorder #: 1010611B

Dear Mr. Paul McCullough

The following report includes the data for the above referenced project for sample(s) received on 10/29/2010 at Air Toxics Ltd.

The data and associated QC analyzed by Modified ASTM D-1946 are compliant with the project requirements or laboratory criteria with the exception of the deviations noted in the attached case narrative.

Thank you for choosing Air Toxics Ltd. for your air analysis needs. Air Toxics Ltd. is committed to providing accurate data of the highest quality. Please feel free to contact the Project Manager: Karen Lopez at 916-985-1000 if you have any questions regarding the data in this report.

Regards,

Karen Lopez

Karen Lopez

Project Manager

WORK ORDER #: 1010611B

Work Order Summary

CLIENT:
Mr. Paul McCullough
URS Corporation
1501 4th Avenue
Suite 1400
Seattle, WA 98101-1616

BILL TO:
Accounts Payable Austin
URS Corporation
P.O. BOX 203970
Austin, TX 78720-1088

PHONE: 206-438-2700

FAX: 206-438-2699

DATE RECEIVED: 10/29/2010

DATE COMPLETED: 11/11/2010

P.O. # 239850-US

PROJECT # 33756383 Seattle Boiler

CONTACT: Karen Lopez

FRACTION #	NAME	TEST	RECEIPT VAC./PRES.	FINAL PRESSURE
01A	SSV-A	Modified ASTM D-1946	4.5 "Hg	15 psi
02A	SSV-B	Modified ASTM D-1946	3.0 "Hg	15 psi
03A	SSV-C	Modified ASTM D-1946	3.5 "Hg	15 psi
04A	SSV-D	Modified ASTM D-1946	4.0 "Hg	15 psi
05A	Lab Blank	Modified ASTM D-1946	NA	NA
06A	LCS	Modified ASTM D-1946	NA	NA
06AA	LCSD	Modified ASTM D-1946	NA	NA

CERTIFIED BY: Linda L. Freeman DATE: 11/11/10

Laboratory Director

Certfication numbers: CA NELAP - 02110CA, LA NELAP/LELAP- AI 30763,
NY NELAP - 11291, UT NELAP - 9166389892, AZ Licensure AZ0719
Name of Accrediting Agency: NELAP/Florida Department of Health, Scope of Application: Clean Air Act,
Accreditation number: E87680, Effective date: 07/01/09, Expiration date: 06/30/11
Air Toxics Ltd. certifies that the test results contained in this report meet all requirements of the NELAC standards

LABORATORY NARRATIVE
Modified ASTM D-1946
URS Corporation
Workorder# 1010611B

Four 1 Liter Summa Canister samples were received on October 29, 2010. The laboratory performed analysis via Modified ASTM Method D-1946 for Helium in air using GC/TCD. The method involves direct injection of 1.0 mL of sample.

Method modifications taken to run these samples are summarized in the table below. Specific project requirements may over-ride the ATL modifications.

Requirement	*ASTM D-1946*	*ATL Modifications*
Calibration	A single point calibration is performed using a reference standard closely matching the composition of the unknown.	A 3-point calibration curve is performed. Quantitation is based on a daily calibration standard which may or may not resemble the composition of the associated samples.
Reference Standard	The composition of any reference standard must be known to within 0.01 mol % for any component.	The standards used by ATL are blended to a >/= 95% accuracy.
Sample Injection Volume	Components whose concentrations are in excess of 5 % should not be analyzed by using sample volumes greater than 0.5 mL.	The sample container is connected directly to a fixed volume sample loop of 1.0 mL on the GC. Linear range is defined by the calibration curve. Bags are loaded by vacuum.
Normalization	Normalize the mole percent values by multiplying each value by 100 and dividing by the sum of the original values. The sum of the original values should not differ from 100% by more than 1.0%.	Results are not normalized. The sum of the reported values can differ from 100% by as much as 15%, either due to analytical variability or an unusual sample matrix.
Precision	Precision requirements established at each concentration level.	Duplicates should agree within 25% RPD for detections > 5 X's the RL.

Receiving Notes

There were no receiving discrepancies.

Analytical Notes

There were no analytical discrepancies.

Definition of Data Qualifying Flags

Seven qualifiers may have been used on the data analysis sheets and indicate as follows:

B - Compound present in laboratory blank greater than reporting limit.
J - Estimated value.
E - Exceeds instrument calibration range.
S - Saturated peak.
Q - Exceeds quality control limits.
U - Compound analyzed for but not detected above the detection limit.
M - Reported value may be biased due to apparent matrix interferences.

File extensions may have been used on the data analysis sheets and indicates as follows:

a-File was requantified
b-File was quantified by a second column and detector
r1-File was requantified for the purpose of reissue

Summary of Detected Compounds

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

Client Sample ID: SSV-A

Lab ID#: 1010611B-01A

Compound	Rpt. Limit (%)	Amount (%)
Helium	0.12	30

Client Sample ID: SSV-B

Lab ID#: 1010611B-02A

Compound	Rpt. Limit (%)	Amount (%)
Helium	0.11	33

Client Sample ID: SSV-C

Lab ID#: 1010611B-03A

Compound	Rpt. Limit (%)	Amount (%)
Helium	0.11	29

Client Sample ID: SSV-D

Lab ID#: 1010611B-04A

Compound	Rpt. Limit (%)	Amount (%)
Helium	0.12	0.23

Client Sample ID: SSV-A

Lab ID#: 1010611B-01A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**9102922b**	**Date of Collection:**	**10/28/10 9:51:00 AM**
Dil. Factor:	**2.38**	**Date of Analysis:**	**10/29/10 07:28 PM**

Compound	Rpt. Limit (%)	Amount (%)
Helium	0.12	30

Container Type: 1 Liter Summa Canister

Client Sample ID: SSV-B

Lab ID#: 1010611B-02A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**9102923b**	**Date of Collection: 10/28/10 8:06:00 AM**
Dil. Factor:	**2.24**	**Date of Analysis: 10/29/10 07:52 PM**

Compound	**Rpt. Limit (%)**	**Amount (%)**
Helium	0.11	33

Container Type: 1 Liter Summa Canister

Client Sample ID: SSV-C

Lab ID#: 1010611B-03A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**9102924b**	**Date of Collection: 10/28/10 8:47:00 AM**
Dil. Factor:	**2.29**	**Date of Analysis: 10/29/10 08:21 PM**

Compound	**Rpt. Limit (%)**	**Amount (%)**
Helium	0.11	29

Container Type: 1 Liter Summa Canister

Air Toxics LTD.
Laboratory Services Since 1989

Client Sample ID: SSV-D

Lab ID#: 1010611B-04A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**9102925b**	**Date of Collection: 10/28/10 9:19:00 AM**
Dil. Factor:	**2.33**	**Date of Analysis: 10/29/10 08:43 PM**

Compound	**Rpt. Limit (%)**	**Amount (%)**
Helium	0.12	0.23

Container Type: 1 Liter Summa Canister

Client Sample ID: Lab Blank

Lab ID#: 1010611B-05A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**9102904b**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 10/29/10 10:02 AM**

Compound	Rpt. Limit (%)	Amount (%)
Helium	0.050	Not Detected

Container Type: NA - Not Applicable

Client Sample ID: LCS

Lab ID#: 1010611B-06A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**9102902b**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 10/29/10 09:19 AM**

Compound	%Recovery
Helium	98

Container Type: NA - Not Applicable

Client Sample ID: LCSD

Lab ID#: 1010611B-06AA

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**9102929b**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 10/29/10 10:13 PM**

Compound	%Recovery
Helium	98

Container Type: NA - Not Applicable

Air Toxics LTD.
Laboratory Services Since 1989

12/30/2010

Mr. Paul McCullough
URS Corporation
1501 4th Avenue
Suite 1400
Seattle WA 98101-1616

Project Name: Seattle Boiler-Fox Ave
Project #: 33756383.00001
Workorder #: 1012301

Dear Mr. Paul McCullough

The following report includes the data for the above referenced project for sample(s) received on 12/14/2010 at Air Toxics Ltd.

The data and associated QC analyzed by Modified TO-15 SIM are compliant with the project requirements or laboratory criteria with the exception of the deviations noted in the attached case narrative.

Thank you for choosing Air Toxics Ltd. for your air analysis needs. Air Toxics Ltd. is committed to providing accurate data of the highest quality. Please feel free to contact the Project Manager: Karen Lopez at 916-985-1000 if you have any questions regarding the data in this report.

Regards,

Karen Lopez

Karen Lopez

Project Manager

WORK ORDER #: 1012301

Work Order Summary

CLIENT:	Mr. Paul McCullough URS Corporation 1501 4th Avenue Suite 1400 Seattle, WA 98101-1616	**BILL TO:**	Accounts Payable Austin URS Corporation P.O. BOX 203970 Austin, TX 78720-1088
PHONE:	206-438-2700	**P.O. #**	239850-US
FAX:	206-438-2699	**PROJECT #**	33756383.00001 Seattle Boiler-Fox Ave
DATE RECEIVED:	12/14/2010	**CONTACT:**	Karen Lopez
DATE COMPLETED:	12/30/2010		

FRACTION #	**NAME**	**TEST**	**RECEIPT VAC./PRES.**	**FINAL PRESSURE**
01A	SBW-IA-SSVB	Modified TO-15 SIM	5.5 "Hg	5 psi
02A	SBW-IA-LUNCH	Modified TO-15 SIM	5.5 "Hg	5 psi
03A	SBW-IA-AMB	Modified TO-15 SIM	5.0 "Hg	5 psi
04A	SBW-IA-CENTER	Modified TO-15 SIM	4.5 "Hg	5 psi
05A	Lab Blank	Modified TO-15 SIM	NA	NA
06A	CCV	Modified TO-15 SIM	NA	NA
07A	LCS	Modified TO-15 SIM	NA	NA
07AA	LCSD	Modified TO-15 SIM	NA	NA

CERTIFIED BY: Linda d. Fruman DATE: 12/30/10

Laboratory Director

Certfication numbers: CA NELAP - 02110CA, LA NELAP/LELAP- AI 30763,
NY NELAP - 11291, UT NELAP - 9166389892, AZ Licensure AZ0719
Name of Accrediting Agency: NELAP/Florida Department of Health, Scope of Application: Clean Air Act,
Accreditation number: E87680, Effective date: 07/01/09, Expiration date: 06/30/11
Air Toxics Ltd. certifies that the test results contained in this report meet all requirements of the NELAC standards

LABORATORY NARRATIVE
Modified TO-15 SIM
URS Corporation
Workorder# 1012301

Four 6 Liter Summa Canister (SIM Certified) samples were received on December 14, 2010. The laboratory performed analysis via modified EPA Method TO-15 using GC/MS in the SIM acquisition mode.

This workorder was independently validated prior to submittal using 'USEPA National Functional Guidelines' as generally applied to the analysis of volatile organic compounds in air. A rules-based, logic driven, independent validation engine was employed to assess completeness, evaluate pass/fail of relevant project quality control requirements and verification of all quantified amounts.

Method modifications taken to run these samples are summarized in the table below. Specific project requirements may over-ride the ATL modifications.

Requirement	***TO-15***	***ATL Modifications***
ICAL %RSD acceptance criteria	</=30% RSD with 2 compounds allowed out to < 40% RSD	Project specific; default criteria is </=30% RSD with 10% of compounds allowed out to < 40% RSD
Daily Calibration	+- 30% Difference	Project specific; default criteria is </= 30% Difference with 10% of compounds allowed out up to </=40%.; flag and narrate outliers
Blank and standards	Zero air	Nitrogen
Method Detection Limit	Follow 40CFR Pt.136 App. B	The MDL met all relevant requirements in Method TO-15 (statistical MDL less than the LOQ). The concentration of the spiked replicate may have exceeded 10X the calculated MDL in some cases

Receiving Notes

There were no receiving discrepancies.

Analytical Notes

There were no analytical discrepancies.

Definition of Data Qualifying Flags

Eight qualifiers may have been used on the data analysis sheets and indicates as follows:

B - Compound present in laboratory blank greater than reporting limit (background subtraction not performed).
J - Estimated value.
E - Exceeds instrument calibration range.
S - Saturated peak.
Q - Exceeds quality control limits.
U - Compound analyzed for but not detected above the reporting limit.
UJ- Non-detected compound associated with low bias in the CCV

N - The identification is based on presumptive evidence.

File extensions may have been used on the data analysis sheets and indicates as follows:

a-File was requantified
b-File was quantified by a second column and detector
r1-File was requantified for the purpose of reissue

Summary of Detected Compounds
MODIFIED EPA METHOD TO-15 GC/MS SIM

Client Sample ID: SBW-IA-SSVB

Lab ID#: 1012301-01A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.016	0.086	0.042	0.22
cis-1,2-Dichloroethene	0.033	0.11	0.13	0.42
Trichloroethene	0.0049	0.081	0.026	0.44
Tetrachloroethene	0.033	0.65	0.22	4.4

Client Sample ID: SBW-IA-LUNCH

Lab ID#: 1012301-02A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.016	0.052	0.042	0.13
cis-1,2-Dichloroethene	0.033	0.068	0.13	0.27
Trichloroethene	0.0049	0.064	0.026	0.34
Tetrachloroethene	0.033	0.67	0.22	4.5

Client Sample ID: SBW-IA-AMB

Lab ID#: 1012301-03A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.016	0.063	0.041	0.16
cis-1,2-Dichloroethene	0.032	0.057	0.13	0.22
Trichloroethene	0.0048	0.036	0.026	0.20
Tetrachloroethene	0.032	0.23	0.22	1.5

Client Sample ID: SBW-IA-CENTER

Lab ID#: 1012301-04A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.016	0.081	0.040	0.21
cis-1,2-Dichloroethene	0.032	0.10	0.12	0.41
Trichloroethene	0.0047	0.076	0.025	0.41
Tetrachloroethene	0.032	0.59	0.21	4.0

Client Sample ID: SBW-IA-SSVB

Lab ID#: 1012301-01A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**c122106**	**Date of Collection:**	**12/12/10 4:28:00 PM**
Dil. Factor:	**1.64**	**Date of Analysis:**	**12/21/10 12:47 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.016	0.086	0.042	0.22
cis-1,2-Dichloroethene	0.033	0.11	0.13	0.42
Trichloroethene	0.0049	0.081	0.026	0.44
Tetrachloroethene	0.033	0.65	0.22	4.4
trans-1,2-Dichloroethene	0.033	Not Detected	0.13	Not Detected

Container Type: 6 Liter Summa Canister (SIM Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	101	70-130
Toluene-d8	96	70-130
4-Bromofluorobenzene	99	70-130

Client Sample ID: SBW-IA-LUNCH

Lab ID#: 1012301-02A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**c122107**	**Date of Collection:**	**12/12/10 4:16:00 PM**
Dil. Factor:	**1.64**	**Date of Analysis:**	**12/21/10 01:32 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.016	0.052	0.042	0.13
cis-1,2-Dichloroethene	0.033	0.068	0.13	0.27
Trichloroethene	0.0049	0.064	0.026	0.34
Tetrachloroethene	0.033	0.67	0.22	4.5
trans-1,2-Dichloroethene	0.033	Not Detected	0.13	Not Detected

Container Type: 6 Liter Summa Canister (SIM Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	101	70-130
Toluene-d8	96	70-130
4-Bromofluorobenzene	98	70-130

Client Sample ID: SBW-IA-AMB

Lab ID#: 1012301-03A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**c122108**	**Date of Collection:**	**12/12/10 4:39:00 PM**
Dil. Factor:	**1.61**	**Date of Analysis:**	**12/21/10 02:05 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.016	0.063	0.041	0.16
cis-1,2-Dichloroethene	0.032	0.057	0.13	0.22
Trichloroethene	0.0048	0.036	0.026	0.20
Tetrachloroethene	0.032	0.23	0.22	1.5
trans-1,2-Dichloroethene	0.032	Not Detected	0.13	Not Detected

Container Type: 6 Liter Summa Canister (SIM Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	100	70-130
Toluene-d8	96	70-130
4-Bromofluorobenzene	99	70-130

Client Sample ID: SBW-IA-CENTER

Lab ID#: 1012301-04A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**c122109**	**Date of Collection:**	**12/12/10 4:37:00 PM**
Dil. Factor:	**1.58**	**Date of Analysis:**	**12/21/10 02:50 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.016	0.081	0.040	0.21
cis-1,2-Dichloroethene	0.032	0.10	0.12	0.41
Trichloroethene	0.0047	0.076	0.025	0.41
Tetrachloroethene	0.032	0.59	0.21	4.0
trans-1,2-Dichloroethene	0.032	Not Detected	0.12	Not Detected

Container Type: 6 Liter Summa Canister (SIM Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	102	70-130
Toluene-d8	96	70-130
4-Bromofluorobenzene	100	70-130

Client Sample ID: Lab Blank

Lab ID#: 1012301-05A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**c122105**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 12/21/10 11:04 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.010	Not Detected	0.026	Not Detected
cis-1,2-Dichloroethene	0.020	Not Detected	0.079	Not Detected
Trichloroethene	0.0030	Not Detected	0.016	Not Detected
Tetrachloroethene	0.020	Not Detected	0.14	Not Detected
trans-1,2-Dichloroethene	0.020	Not Detected	0.079	Not Detected

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	102	70-130
Toluene-d8	95	70-130
4-Bromofluorobenzene	90	70-130

Client Sample ID: CCV

Lab ID#: 1012301-06A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**c122102**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 12/21/10 08:53 AM**

Compound	%Recovery
Vinyl Chloride	102
cis-1,2-Dichloroethene	98
Trichloroethene	102
Tetrachloroethene	111
trans-1,2-Dichloroethene	100

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	102	70-130
Toluene-d8	100	70-130
4-Bromofluorobenzene	102	70-130

Client Sample ID: LCS

Lab ID#: 1012301-07A

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**c122103**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 12/21/10 09:38 AM**

Compound	%Recovery
Vinyl Chloride	101
cis-1,2-Dichloroethene	93
Trichloroethene	97
Tetrachloroethene	100
trans-1,2-Dichloroethene	95

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	105	70-130
Toluene-d8	100	70-130
4-Bromofluorobenzene	100	70-130

Client Sample ID: LCSD

Lab ID#: 1012301-07AA

MODIFIED EPA METHOD TO-15 GC/MS SIM

File Name:	**c122104**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 12/21/10 10:15 AM**

Compound	%Recovery
Vinyl Chloride	101
cis-1,2-Dichloroethene	86
Trichloroethene	91
Tetrachloroethene	92
trans-1,2-Dichloroethene	88

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	102	70-130
Toluene-d8	102	70-130
4-Bromofluorobenzene	106	70-130

VI sampling reports after the 2012 CAP

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Two Union Square
601 Union Street, Suite 600
Seattle, WA 98101
tel: 206.292.2078 fax: 206.682.7867

Memorandum

To: Sunny Becker, Washington State Department of Ecology
Copies: Bob Code, Cascade Columbia
From: Tom Colligan and Lynn Grochala, Floyd|Snider
Date: February 4, 2013
Project: Fox Ave-RA, Task 5
Re: **Vapor Intrusion Monitoring at Seattle Boiler Works: December 2012**

Per the requirements of the final Engineering Design Report (EDR) dated October 9, 2012, this memo is being submitted to the Washington State Department of Ecology (Ecology) to document protection monitoring activities completed at the Seattle Boiler Works (SBW) property prior to initiation of thermal heating at the Fox Avenue Site (Site) located at 6900 Fox Avenue South in Seattle, Washington.

A site visit to identify buildings and locations for soil vapor and indoor air samples, as specified in the EDR, was completed at the SBW property on December 7, 2012. Representatives of Floyd|Snider, SBW, Cascade Columbia, Ecology, and Calibre Systems were present for the site walk. The Pipe Building and Fabrication Building were identified as buildings with the highest potential for vapor intrusion. The office, which is located side-gradient of the groundwater plume, was found to be constructed above grade; therefore, the crawl space was identified for testing. Results from the crawl space sample would identify the need for follow-up testing inside the elevated office building. The remaining buildings at the facility were inspected and found to have low risk of vapor intrusion due to their distance from the plume, unoccupied nature, or permanent open-air status.

INSTALLATION OF SOIL VAPOR POINTS

On December 13, 2012, Floyd|Snider personnel installed four soil vapor points identified as SV-1(SBW) through SV-4(SBW) as shown on Figure 1. Three points were installed inside the Pipe Building and one was installed along the paved outside perimeter of the nearby Fabrication Building to avoid disturbance to interior operations. Vapor point locations in the Pipe Building were chosen to be near the sub-slab sample locations previously collected by URS Corporation (URS) in October 2010.

Prior to installation, locations were cleared by Applied Professional Services, Inc. (APS) and the concrete at each location was cored by Evergreen Concrete Cutting, Inc. to provide access to beneath the slab. Floyd|Snider personnel installed the four vapor points just beneath the slab at each location. Vapor points were each constructed using an AMS® stainless steel mesh vapor implant connected to rigid polyethylene tubing (refer to Photograph 1, Attachment 1). The hole was subsequently backfilled with coarse sand and sealed with hydraulic cement. A brass cover was installed over each point for future access and protection (refer to photograph 2, Attachment 1).

SOIL VAPOR SAMPLE COLLECTION AND RESULTS

On December 14, 2012, Floyd|Snider personnel collected four soil vapor grab samples from the newly installed vapor monitoring points. Soil vapor points were purged using an SKC® hand pump for a minimum of 5 minutes (equivalent to a purge volume of approximately 5 liters) and field screened for volatile organic compounds (VOCs) with a RAE Systems photo-ionization detector (PID) prior to sample collection. VOCs were detected at concentrations of 1.5, 7.5, 4.7, and 0.9 parts per million by volume (ppmv) at vapor points SV-1(SBW) through SB-4(SBW), respectively. Vapor samples were then collected into Tedlar® bags and submitted to Fremont Analytical for VOC analysis by U.S. Environmental Protection Agency (USEPA) method 8260. Refer to Figure 1 for the soil vapor sample locations and designations.

Laboratory analysis indicated sub-slab vapors at all four locations contain the primary site constituents of concern (COCs), tetrachloroethene (PCE) and trichloroethene (TCE). Several other VOCs including vinyl chloride; cis-dichloroethene; chloroethene; 1,1 dichloroethene; and xylenes were also detected in the two vapor points in the Pipe Building closest to Fox Avenue. The sub-slab compounds detected and their concentrations were generally consistent with the data previously collected by URS in 2010. A copy of the soil vapor laboratory report is included in Attachment 2 and a summary of the analytical data for all detected compounds is included on Table 1.

INDOOR AIR SAMPLE COLLECTION AND RESULTS

On December 14, 2012, Floyd|Snider personnel collected three indoor air samples (6-hour composites) from the Pipe Building (SBW-IA-Center), the lunch room (SBW-IA-lunch), and the Fabrication Building (SBW-IA-Fab Bldg) to evaluate indoor air quality; two ambient air samples (Amb-1 and Amb-2; 7-hour composites) were collected outdoors to evaluate background conditions; and one grab air sample was collected from the crawl space beneath the SBW office (SBW-IA-Office Crawl Space) during high tide to evaluate if vapor intrusion was occurring to the crawl space at this location. These six air samples were collected into Summa® canisters and submitted to Columbia Analytical for VOC analysis by USEPA Method TO-15, low level. Refer to Figure 1 for the indoor air sample locations and designations. Photographs of the indoor air sample locations are included in Attachment 1 (Photographs 4–6).

Table 2 contains a listing of all the VOCs detected in indoor air or ambient air with concentrations greater than laboratory method detection limits. The results indicated that in addition to site COCs numerous other VOCs were detected in both indoor air and the ambient air samples. The following compounds were not present in the sub-slab samples but were detected at concentrations greater than ambient (background): 1-propene, ethanol, methylene chloride, nonane, alpha-pinene, 1,4-dichlorobenzene, and d-limonene. The presence of these compounds is likely attributable to the industrial nature of the area and not attributable to contamination at the Site, given their absence in the sub-slab samples.

A Tier I data quality review was completed by Floyd|Snider on all analytical reports received. Data were determined to be of acceptable quality for use as intended. Some results were assigned minor data qualifiers. A data validation summary memo was prepared for each event and copies are included in Attachment 4. Laboratory reports for indoor air samples are included in Attachment 3.

DISCUSSION

Following adoption of the final Cleanup Action Plan (CAP) for the Site, Ecology raised the indoor air cleanup levels for PCE and TCE. Those new values are higher than the indoor air cleanup values in the CAP to be attained 10 to 15 years after thermal remediation (and are shown on Table 3). Fox Avenue LLC is proceeding with Ecology to amend the CAP to allow use of these new values as well as establishing a final cleanup level for vinyl chloride. Table 3 lists the three compounds detected in indoor air at concentrations greater than either the older or newer regulatory limits. These compounds are PCE, TCE, and vinyl chloride. In accordance with Section 3.2.3 of Ecology's *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action, Draft October 2009,* the specific concentrations shown for these three compounds have been corrected to account for the background levels for each compound also detected in the ambient air samples. Each compound is discussed separately below.

PCE—Results indicate that none of the detections exceeded the Modified MTCA Method B concentration specified in the CAP (June 2012) as the trigger level for contingency actions. Concentrations in all samples were greater than the older MTCA Method B concentration specified in the CAP but all were less than the current MTCA Method B concentration, which was established by Ecology following finalization of the CAP.

TCE—Results indicate that none of the detections exceeded the Modified MTCA Method B concentration specified in the CAP (June 2012) as the trigger level for contingency actions. Concentrations were greater than the older MTCA Method B concentration specified in the CAP; however, when compared to the current MTCA Method B concentration, all sample concentrations were less than the current level, except in one sample from the Pipe Building that had a slight exceedance.

Vinyl Chloride—Neither cleanup levels nor trigger levels were established for vinyl chloride as it was not detected at concentrations greater than MTCA Method B levels in prior samples collected by URS. Results are therefore compared to the current default MTCA Methods B and C. Only one out of four samples exceeded the default MTCA Method B concentration but that result (from the Pipe Building) was less than the MTCA Method C concentration.

CONCLUSIONS

Based on a review of both soil vapor and indoor air data collected at SBW in both 2010 and 2012, the only building with evidence of vapor intrusion is the Pipe Building. Conditions appear to be similar to the previous URS sample results in 2010. PCE concentrations in indoor air have decreased when compared to the 2010 data. TCE concentrations have increased slightly, but are less than the Modified MTCA Method B levels used as trigger levels for contingency actions. The office crawl space contained VOC concentrations (including site COCs and others) that were consistent with ambient background concentrations. Therefore, vapor intrusion into the office is not likely, and it is recommended that the office crawl space not be sampled again during future events. No contingency actions are necessary as all concentrations were less than the trigger levels specified in the CAP. In all but one sample, concentrations were in compliance with the current MTCA Method B cleanup levels.

PLANNED ACTIVITIES

Monthly field screening with a PID of the vapor points at SBW is being conducted as part of the compliance monitoring during thermal operations, which are now underway. According to the ERD, if a significant rise in sub-slab vapor concentrations is noted, then we will inform Ecology and collect a sub-slab vapor sample for chemical analysis to verify the increase and assess if additional indoor air monitoring should be conducted. If sub-slab vapors remain consistent during monthly monitoring, the next round of vapor intrusion monitoring (which will consist of the collection of soil vapor and indoor air samples at the SBW property) will be conducted in early April 2012, the mid-point of thermal remediation.

ATTACHMENTS

Table 1	Sub-slab Soil Vapor Seattle Boiler Works
Table 2	Summary of Volatile Organic Compounds Detected in Indoor Air Seattle Boiler Works December 2012
Table 3	Indoor Air Sample Results Seattle Boiler Works
Figure 1	Indoor Air Monitoring Locations at Seattle Boiler Works
Attachment 1	Photographs
Attachment 2	Soil Vapor Laboratory Report
Attachment 3	Indoor Air Laboratory Report
Attachment 4	Data Validation Summary

Tables

Table 1
Sub-slab Soil Vapor
Seattle Boiler Works[1,2]

Sample ID	Sample Date	Tetrachloroethene ($\mu g/m^3$)	Trichloroethene ($\mu g/m^3$)	Vinyl Chloride ($\mu g/m^3$)	cis-1,2-Dichloroethene ($\mu g/m^3$)	Chloroethane ($\mu g/m^3$)	1,1-Dichloroethene ($\mu g/m^3$)	Sample Location
SVA-A	10/28/2010	1,600	ND (6.4)	ND (3.0)	ND (4.7)	--	--	SE corner of Fabrication Building
SVA-B	10/28/2010	5,100	220	ND (7.6)	ND (12)	--	--	SE corner of Pipe Building
SVA-C	10/28/2010	1,800	120	18	26	--	--	NE corner of Pipe Building
SVA-D	10/28/2010	2,800	96	ND (3.0)	ND (4.6)	--	--	SW corner of Pipe Building
SV-1 (SBW)	12/14/2012	451	173	296	745	248	ND (100)	SE corner of Pipe Building
SV-2 (SBW)	12/14/2012	16,000	1,710	141	984	166	106	NE corner of Pipe Building
SV-3 (SBW)	12/14/2012	2,770	164	ND (20)	ND (100)	ND (100)	ND (100)	SW corner of Pipe Building (lunch room)
SV-4 (SBW)	12/14/2012	478	ND (100)	ND (20)	ND (100)	ND (100)	ND (100)	NE corner of Fabrication Building

Notes:

1 Seattle Boiler Works soil gas and indoor air sampling was performed by URS Corporation in February 2010. Data were presented in a Vapor Intrusion Assessment letter prepared by URS Corporation and dated February 2, 2011. Subsequent samples were collected by Floyd|Snider.

2 Soil vapor samples were collected using a tedlar bag and analyzed using MTCA Method 8260.

3 -- Data not included in URS Corporation's Vapor Intrusion Assessment letter.

Abbreviations:

ID	Identifier
$\mu g/m^3$	Micrograms per cubic meter
MTCA	Model Toxics Control Act
ND	Not-detected greater than laboratory detection limited denoted in parenthesis
NE	Northeast
SE	Southeast
SW	Southwest

Table 2
Summary of Volatile Organic Compounds Detected in Indoor Air
Seattle Boiler Works
December 2012

Parameter	Unit	SBW-IA-Center	SBW-IA-Lunch	SBW-IA-Fab Bldg.	SBW-Office Crawl Space	AMB-1	AMB-2
1-Propene	µg/m^3	22	3.7	6.3	0.71	7.1	1.7
CFC-12	µg/m^3	2.6	2.6	2.7	2.5	3.1	2.5
Chloromethane	µg/m^3	0.37	0.4	0.38 U	0.45	0.37	0.44
Vinyl Chloride	µg/m^3	2	0.25	0.19 U	0.12 U	0.14 U	0.18 U
1,3-Butadiene	µg/m^3	1.4	0.32 U	0.49	0.24 U	2.2	0.35 U
Chloroethane	µg/m^3	0.21	0.16 U	0.19 U	0.12 U	0.14 U	0.18 U
Ethanol	µg/m^3	8.2	170	9.5 U	5.9 U	24	8.9 U
Acetone	µg/m^3	11	14	9.5 U	17	14	9.9
CFC-11	µg/m^3	3.7	3.7	4.7	1.3	10	1.7
Methylene Chloride	µg/m^3	2.4	2.6	110	0.59 U	1.5	1
Trichlorotrifluoroethane	µg/m^3	0.59	0.59	0.59	0.63	0.59	0.58
Cis-1,2-Dichloroethene	µg/m^3	2.5	0.39	0.19 U	0.12 U	0.14 U	0.18 U
Ethyl Acetate	µg/m^3	1.6	2.9	5	1.2 U	1.4 U	3.5
Hexane(Dot)	µg/m^3	6.3	2.1	2.3	0.59 U	7.2	1.2
Chloroform	µg/m^3	0.12 U	0.58	0.19 U	0.12 U	0.14 U	0.18 U
Benzene	µg/m^3	4.9	2	2.3	0.68	11	1.3
Carbon Tetrachloride	µg/m^3	0.55	0.5	0.51	0.55	0.49	0.48
Cyclohexane	µg/m^3	3.4	1.6 U	1.9 U	1.2 U	4.9	1.8 U
Trichloroethene	µg/m^3	0.61	0.31	0.27	0.12 U	0.18	0.18
Heptane	µg/m^3	3.7	1.7	1.8	0.59 U	5.1	1.6
Toluene	µg/m^3	16	15	9.4	2.8	30	5.8
Butyl Acetate	µg/m^3	0.58 U	0.8 U	0.95 U	0.59 U	0.81	0.89 U
n-Octane	µg/m^3	1.4	0.8 U	0.95 U	0.59 U	2	0.89 U
Tetrachloroethene	µg/m^3	1.4	3	0.56	0.13	0.51	0.4
Ethylbenzene	µg/m^3	3.3	2.3	1.9	0.59 U	6	1.5
m, p-Xylene	µg/m^3	11	8.1	6.6	1.3	20	5.9
Styrene	µg/m^3	0.58 U	0.8 U	0.95 U	0.59 U	1.5	0.89 U
o-Xylene	µg/m^3	3.9	2.8	2.4	0.59 U	7.1	2
Nonane (8ci9ci)	µg/m^3	3.5	1.2	0.95 U	0.59 U	0.96	0.89 U
Alpha-Pinene	µg/m^3	1.9	3.9	0.95 U	0.59 U	0.71 U	0.89 U
n-Propylbenzene	µg/m^3	0.6	0.8 U	0.95 U	0.59 U	1.2	0.89 U
Benzene, 1-Ethyl-4-Methyl-	µg/m^3	0.9	0.8 U	0.95 U	0.59 U	2	0.89 U
1,3,5-Trimethylbenzene	µg/m^3	1	0.8 U	0.95 U	0.59 U	2.1	0.89 U
1,2,4-Trimethylbenzene	µg/m^3	3.1	2.3	1.6	0.59 U	6.7	1.1
1,4-Dichlorobenzene	µg/m^3	1.5	5.4	0.19 U	0.12 U	0.14 U	0.18 U
D-Limonene	µg/m^3	0.75	390 D	3.6	0.85	0.95	0.89 U
Naphthalene	µg/m^3	0.58 U	0.8 U	0.95 U	0.59 U	1.5	0.89 U

Abbreviation:

µg/m^3 Micrograms per cubit meter

Qualifier:

U Not detected at concentration greater than laboratory method detection limit

Table 3
Indoor Air Sample Results
Seattle Boiler Works

Sample ID	Sample Date	Tetrachloroethene (µg/m^3)	Trichloroethene (µg/m^3)	Vinyl Chloride (µg/m^3)	Sample Location
Indoor Air—Seattle Boiler Works [1,2]					
SBW-IA-SSVB	12/12/2010	2.9	0.24	0.06	SE corner inside Pipe Building
SBW-IA-Lunch	12/12/2010	3.0	0.14	0.13	Employee lunch room, inside Pipe Building
	12/14/2012	2.6	0.13	0.25	
SBW-IA-Center	12/12/2010	2.5	0.21	0.21	Central area within Pipe Building
	12/14/2012	1.0	0.43	2.0	
SBW-IA-Fab Bldg	12/14/2012	0.16	0.09	ND	NE portion of Fabrication Building
SBW-IA-Office crawl space	12/14/2012	0.13	ND	ND	Grab, in office crawl space
Ambient Air —Seattle Boiler Works [1,2]					
SBW-IA-AMB	12/12/2010	1.5	0.20	0.16	Outside, E of Pipe Building
AMB-1	12/14/2012	0.51	0.18	ND	Outside, E of Office at entry gate
AMB-2	12/14/2012	0.4	0.18	ND	Outside, E property line along Fox Avenue
Applicable Regulatory Indoor Air CULs used in Cleanup Action Plan [3]					
Default MTCA Method B		0.42	0.1	NA	Unrestricted Use Indoor Air CUL
Modified MTCA Method B		3.7	0.88	NA	Modified for Industrial Exposure
Default MTCA Method C		4.2	1	NA	Industrial Indoor Air CUL
Current Regulatory Indoor Air CULs based on New Risk Values					
Default MTCA Method B		9.6	0.37	0.28	Unrestricted Use Indoor Air CUL
Default MTCA Method C		40	2	2.8	Industrial Indoor Air CUL

Notes:

1 The sample results were adjusted to account for background in accordance with Section 3.2.3 of Ecology's *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action, Draft October 2009.*

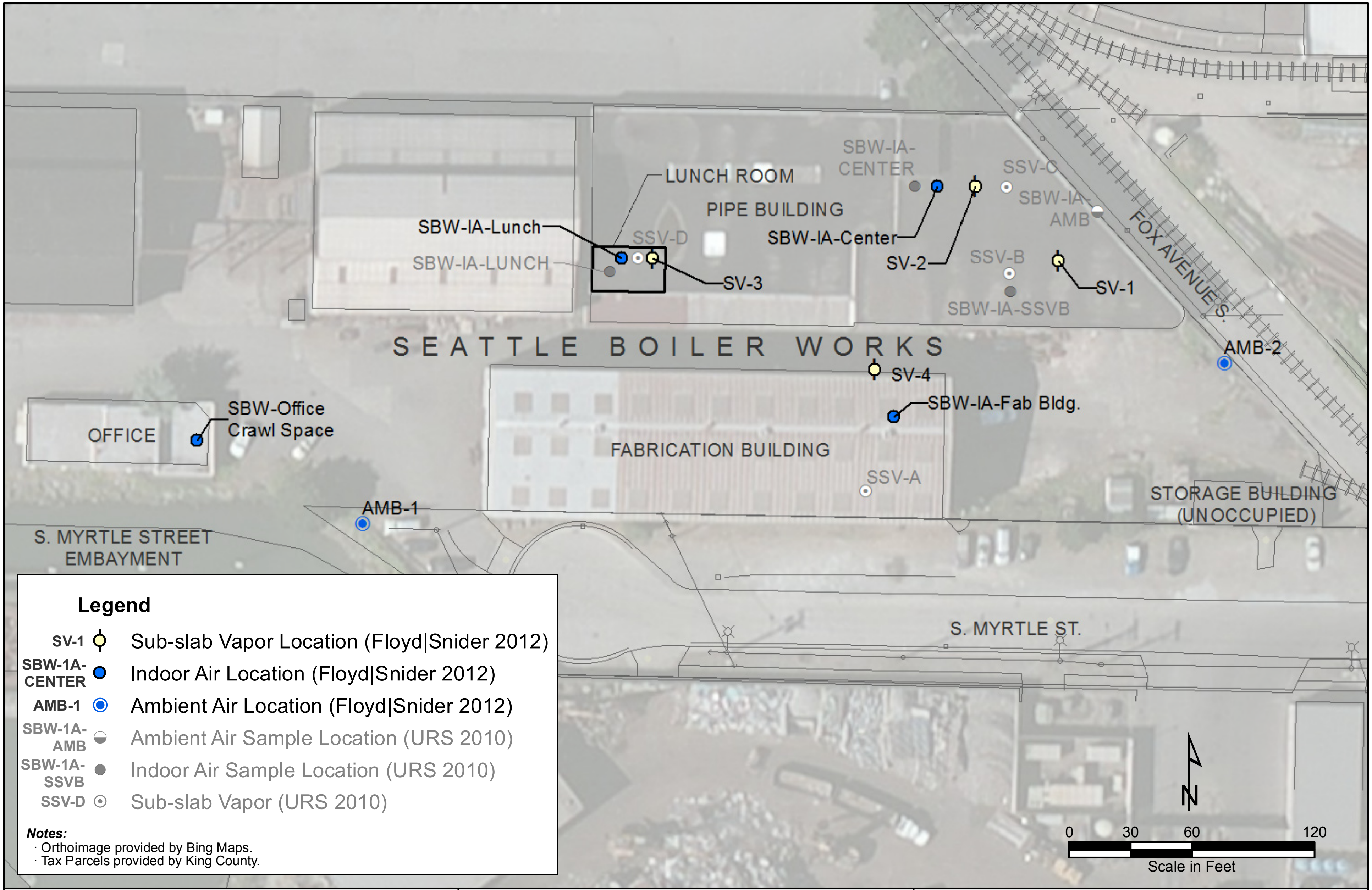
2 Seattle Boiler Works soil gas and indoor air sampling was performed by URS Corporation in February 2010. Data were presented in a Vapor Intrusion Assessment letter prepared by URS Corporation and dated February 2, 2011. Subsequent samples were collected by Floyd|Snider.

3 MTCA Method B CULs are applied to the Seattle Boiler Works property assuming unrestricted future land use and MTCA Method C CULs are applied to Cascade Columbia assuming future industrial use. Modified Method B is being used as the contingency action trigger for the Seattle Boiler Works Property.

Abbreviations:

CAP	Cleanup Action Plan
CLARC	Cleanup Levels and Risk Calculation
CUL	Cleanup level
Ecology	Washington State Department of Ecology
ID	Identifier
µg/m^3	Micrograms per cubic meter
MTCA	Model Toxics Control Act
NA	Not applicable; vinyle chloride was not defined as a constituent of concern in the CAP
ND	Not-detected greater than laboratory detection limited denoted in parenthesis
NE	Northeast
PCE	Tetrachloroethene
SE	Southeast
TCE	Trichloroethene

Figure



Notes:
- Orthoimage provided by Bing Maps.
- Tax Parcels provided by King County.

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Monthly Summary Report
Fox Avenue Site
Seattle, Washington

Figure 1
Soil Vapor And Indoor
Air Monitoring Locations
at Seattle Boiler Works

F:\projects\FoxAve-RA\GIS\MXD\Remediation Monitoring Reports\Figure 1 (Soil Vapor And Indoor Air Monitoring at Seattle Boiler Works).mxd
1/9/2013

Attachment 1
Photographs

Photograph 1. Soil Vapor Implant.

Photograph 2. Completed Vapor Point with Protective Brass Cover.

Photograph 3. Alternative View of Completed Soil Vapor Point.

Photograph 4. SBW-IA-Center.

FLOYD | SNIDER
strategy ▪ science ▪ engineering

December 2012 Vapor Intrusion Monitoring Memo
Fox Avenue Site
Seattle, Washington

Attachment 1
Photographs 3 and 4

Photograph 5. SBW-IA-Lunch and SV-3.

Photograph 6. SBW-IA-Fabrication Building.

FLOYD | SNIDER strategy ▪ science ▪ engineering	**December 2012 Vapor Intrusion Monitoring Memo** **Fox Avenue Site** **Seattle, Washington**	Attachment 1 Photographs 5 and 6

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Two Union Square
601 Union Street, Suite 600
Seattle, WA 98101
tel: 206.292.2078 fax: 206.682.7867

Memorandum

To: Sunny Becker, Washington State Department of Ecology
Copies: Bob Code, Cascade Columbia
From: Tom Colligan and Jenny Graves, Floyd|Snider
Date: June 14, 2013
Project: Fox Ave-RA, Task 5
Re: **Vapor Intrusion Monitoring at Cascade Columbia: April 2013**

Per the requirements of the final Engineering Design Report (EDR) dated October 9, 2012, this memo is being submitted to the Washington State Department of Ecology (Ecology) to document protection monitoring activities completed at the Cascade Columbia Distribution (Cascade Columbia) building during operation of the soil vapor extraction (SVE) and thermal heating systems at the Fox Avenue Site (Site) located at 6900 Fox Avenue South in Seattle, Washington.

SOIL VAPOR SAMPLE COLLECTION AND RESULTS

On April 15, 2013, Floyd|Snider personnel collected soil vapor grab samples from the vapor monitoring points at Cascade Columbia. Three sets of soil vapor samples have been collected to date at Cascade Columbia. The first set of samples was taken in March 2009 before the start of the SVE system. The second set was taken in November 2012, approximately 2 months after the SVE system had started operating. Prior to sample collection, the soil vapor points were purged using an SKC® hand pump for a minimum of 5 minutes (equivalent to a purge volume of approximately 5 liters) and field screened for volatile organic compounds (VOCs) with a RAE Systems photoionization detector (PID) prior to sample collection. PID readings were 50.3, 9.4, and 0.7 parts per million by volume (ppmv) at vapor points SV-1 through SV-3, respectively. Vapor samples were then collected into Tedlar® bags and submitted to Fremont Analytical, Inc. (Fremont) for VOC analysis by U.S. Environmental Protection Agency (USEPA) Method 8260. Refer to Figure 1 for the soil vapor sample locations and designations.

Laboratory analysis indicated only one of the three samples with a single detection of tetrachloroethylene (PCE) in SV-2. A copy of the soil vapor laboratory report is included as Attachment 1 and a summary of the analytical data from all events is included in Table 1. These samples were taken in the seventh month of SVE operation and concentrations of VOCs in sub-slab vapors have decreased significantly since the second set of samples taken in November 2012, a few months after start-up of the SVE system.

INDOOR AIR SAMPLE COLLECTION AND RESULTS

On April 15, 2012, Floyd|Snider personnel collected three indoor air samples (8-hour composites) from inside the office near the kitchen area (IA-1), inside the office near the men's restroom (IA-2), and inside the warehouse break room (IA-3) to evaluate indoor air quality during thermal operations. One ambient air sample (AMB-CC, 8-hour composite) was collected upwind to evaluate background conditions. These four air samples were collected into Summa® canisters and submitted to ALS Environmental for VOC (PCE, trichloroethylene [TCE], and vinyl chloride) analysis by USEPA Method TO-15, low level. Refer to Figure 1 for the indoor air sample locations and designations. A copy of the indoor air laboratory report is included as Attachment 2 and the results from the indoor air sampling are contained in Table 2.

DISCUSSION

Per the cleanup levels specified in the amendment to the Cleanup Action Plan (CAP; dated May 2013), current Model Toxics Control Act (MTCA) Method C cleanup levels for indoor air are applied to Cascade Columbia. In accordance with Section 3.2.3 of Ecology's *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action, Draft October 2009,* the specific concentrations shown for the compounds have been corrected to account for the background levels for each compound also detected in the ambient air samples. Each compound is discussed separately below.

PCE—Results indicate that none of the detections exceeded the MTCA Method C cleanup level. Concentrations in all samples have decreased significantly from previous concentrations measured in March 2009.

TCE—Results indicate that none of the detections exceeded the MTCA Method C cleanup level. Concentrations in all samples are generally consistent with previous concentrations measured in March 2009.

CONCLUSIONS

Based on a review of both soil vapor and indoor air data collected during SVE and thermal operations, there is no evidence of vapor intrusion at levels greater than applicable cleanup levels at Cascade Columbia. PCE and TCE concentrations in indoor air have decreased or stayed consistent when compared to the 2009 data. All concentrations were in compliance with the MTCA Method C cleanup levels.

PLANNED ACTIVITIES

Monthly field screening with a PID of the vapor points at the Cascade Columbia Facility will continue to be conducted until the shutdown of the SVE system. The next round of vapor intrusion monitoring (which will consist of the collection of soil vapor and indoor air samples) will be conducted 1 month after the SVE system has ceased operations, which is expected to occur by August or September 2013.

ATTACHMENTS

Table 1	Sub-slab Soil Vapor Cascade Columbia
Table 2	Indoor Air Sample Results Cascade Columbia
Figure 1	Indoor Air Monitoring Locations at Cascade Columbia
Attachment 1	Soil Vapor Laboratory Report
Attachment 2	Indoor Air Laboratory Report
Attachment 3	Sub-Slab Data Validation Summary
Attachment 4	Indoor Air Data Validation Summary

Tables

Table 1
Sub-slab Soil Vapor Cascade Columbia

Sample ID	Sample Date	Tetrachloroethene ($\mu g/m^3$)	Trichloroethene ($\mu g/m^3$)	Sample Location
Soil Vapor—Cascade Columbia				
SV-1	3/26/2009	**47,000**	**1,600**	In Office, near sink area, sub-slab
	11/8/2012[1]	142	ND (100)	
	4/15/2013[1]	ND (100)	ND (100)	
SV-2	3/26/2009	**43,000**	**940**	In Office, men's restroom, sub-slab
	11/8/2012[1]	280	ND (100)	
	4/15/2013[1]	137	ND (100)	
SV-3	3/26/2009	**43,000**	**2,000**	In warehouse breakroom, sub-slab
	4/15/2013[1]	ND (100)	ND (100)	
Applicable Regulatory Soil Gas Screening and Indoor Air CULs [2]				
MTCA Method C		**400**	**20**	Soil vapor screening level
		40	**2**	Industrial indoor air CUL

Notes:

Bold Indicates an exceedance of appropriate MTCA standard.

1 Soil vapor samples were collected using a tedlar bag and analyzed using MTCA Method 8260.

2 MTCA Method C CULs are applied to Cascade Columbia assuming future industrial use.

Abbreviations:

$\mu g/m^3$	Micrograms per cubic meter
CUL	Cleanup level
ID	Identifier
MTCA	Model Toxics Control Act
ND	Not-detected greater than laboratory detection limited denoted in parenthesis

Table 2
Indoor Air Sample Results Cascade Columbia

Sample ID	Sample Date	Tetrachloroethene (μg/m^3)	Trichloroethene (μg/m^3)	Sample Location
Indoor Air—Cascade Columbia [1]				
IA-1	3/26/2009	**75**	1.1	Inside Office, near sink; collected before SVE and thermal operations
	4/15/2013	27.5	0.99	Inside Office, near kitchen area; collected during SVE and thermal operations
IA-2	3/26/2009	**53**	1	Inside Office, men's restroom; collected before SVE and thermal operations
	4/15/2013	32.5	1.2	Inside Office, top of shelf near men's restroom; collected during SVE and thermal operations
IA-3	3/26/2009	6	0.52	Inside warehouse breakroom; collected before SVE and thermal operations
	4/15/2013[2]	0.69	0.18	Inside warehouse breakroom; collected during SVE and thermal operations
IA-4	3/26/2009	2.7	0.2	Upstairs, at top of stairwell; collected before SVE and thermal operations
Ambient Air—Cascade Columbia				
AA-1	3/26/2009	0.46	<0.18	Ambient outdoor, SW of facility
AA-2	3/26/2009	0.58	<0.17	Ambient outdoor, NE of facility
AA-3	3/26/2009	0.37	<0.18	Ambient outdoor, NW of facility
AA-4	3/26/2009	2	0.37	Ambient indoor, center of warehouse
AMB-CC	4/15/2013	1.5	ND (0.12)	Ambient outdoor, SW of facility
Applicable Regulatory Soil Gas Screening and Indoor Air CULs [3]				
MTCA Method C		**40**	**2**	Industrial Indoor Air CUL

Notes:

Bold Indicates an exceedance of appropriate MTCA standard.

1 The sample results were adjusted to account for background in accordance with Section 3.2.3 of Ecology's *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action, Draft October 2009*.

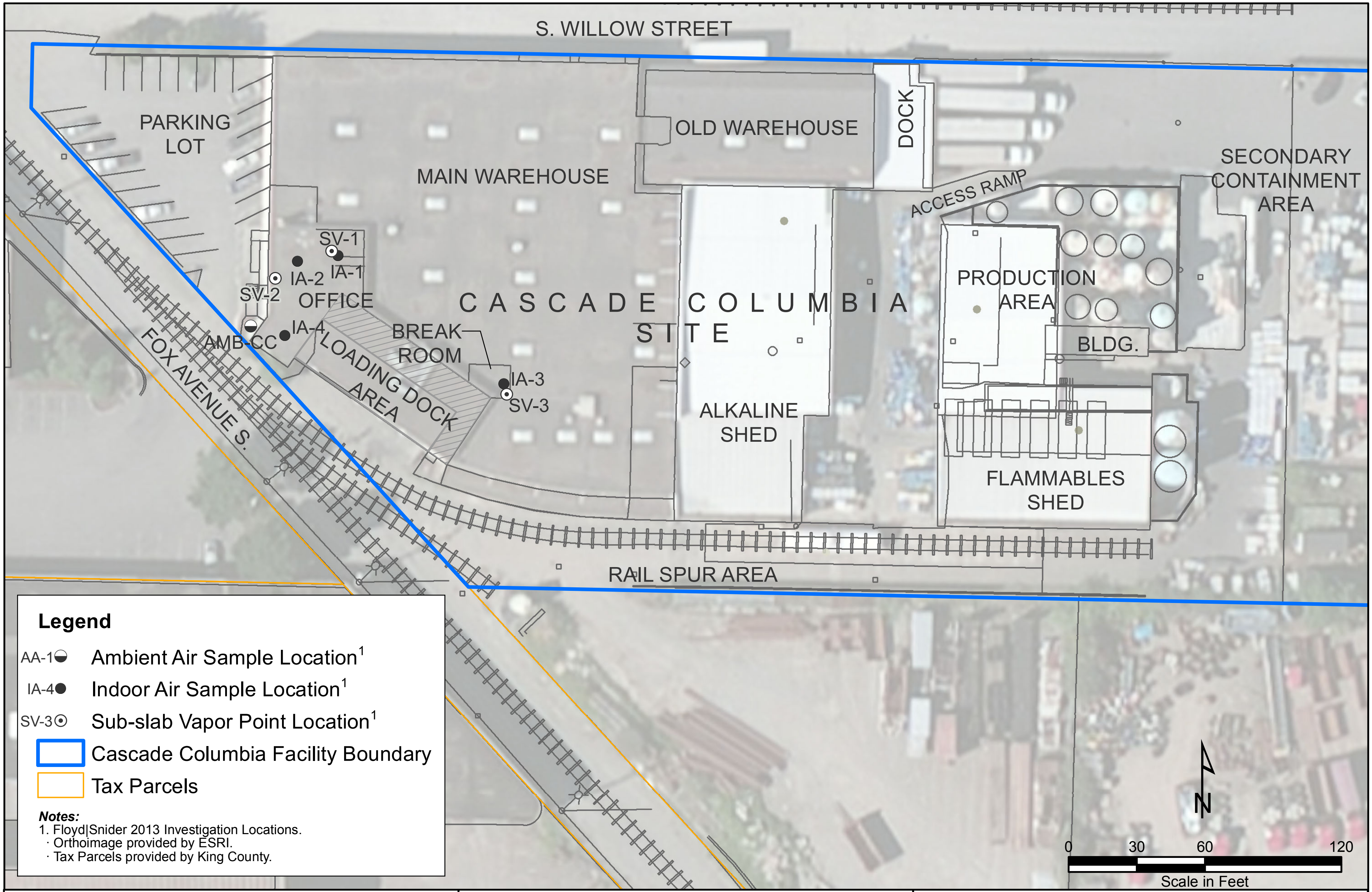
2 Concentrations were below both ambient/background concentrations; therefore, results were considered to be consistent with background and were not adjusted for background.

3 MTCA Method C CULs based on current CLARC values are applied to Cascade Columbia assuming future industrial use.

Abbreviations:

CLARC	Cleanup Levels and Risk Calculation
CUL	Cleanup level
Ecology	Washington State Department of Ecology
ID	Identifier
μg/m^3	Micrograms per cubic meter
MTCA	Model Toxics Control Act
ND	Not-detected greater than laboratory detection limited denoted in parenthesis
NE	Northeast
NW	Northwest
SVE	Soil vapor extraction
SW	Southwest

Figure



Legend

AA-1◒ Ambient Air Sample Location[1]

IA-4● Indoor Air Sample Location[1]

SV-3⦿ Sub-slab Vapor Point Location[1]

🟦 Cascade Columbia Facility Boundary

🟧 Tax Parcels

Notes:

1. Floyd|Snider 2013 Investigation Locations.
- Orthoimage provided by ESRI.
- Tax Parcels provided by King County.

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Vapor Intrusion Monitoring at
Cascade Columbia
Fox Avenue Site
Seattle, Washington

Figure 1
Indoor Air Monitoring Locations
at Cascade Columbia Site

I:\GIS\Projects\FOXAVE-RA\MXD\Vapor Intrusion Memorandum\Figure 1 (VIM - Proposed Indoor Air Monitoring at Cascade Columbia Site).mxd
6/11/2013

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Two Union Square
601 Union Street, Suite 600
Seattle, WA 98101
tel: 206.292.2078 fax: 206.682.7867

Memorandum

To: Sunny Becker, Washington State Department of Ecology
Copies: Bob Code, Cascade Columbia
From: Tom Colligan and Jenny Graves, Floyd|Snider
Date: June 14, 2013
Project: Fox Ave-RA, Task 5
Re: **Vapor Intrusion Monitoring at Seattle Boiler Works: April 2013**

Per the requirements of the final Engineering Design Report (EDR) dated October 9, 2012, this memorandum is being submitted to the Washington State Department of Ecology (Ecology) to document protection monitoring activities completed at the Seattle Boiler Works (SBW) during operation of the thermal heating system at the Fox Avenue Site (Site) located at 6900 Fox Avenue South in Seattle, Washington.

SOIL VAPOR SAMPLE COLLECTION AND RESULTS

On April 15, 2013, Floyd|Snider personnel collected four soil vapor grab samples from the vapor monitoring points installed in December 2012. Soil vapor points were purged using an SKC® hand pump for a minimum of 5 minutes (equivalent to a purge volume of approximately 5 liters), and were then field screened for volatile organic compounds (VOCs) with a RAE Systems photoionization detector (PID) prior to sample collection. PID readings were 0.0, 29.6, 6.9, and 0.1 parts per million by volume (ppmv) at vapor points SV-1(SBW) through SV-4(SBW), respectively. Vapor samples were then collected into Tedlar® bags and submitted to Fremont Analytical, Inc. for VOC analysis by U.S. Environmental Protection Agency (USEPA) Method 8260. Refer to Figure 1 for the soil vapor sample locations and designations.

Laboratory analysis indicated sub-slab vapors at all four locations contain tetrachloroethene (PCE) and one location (SV-2 [SBW]) contained trichloroethene (TCE). In the two vapor points in the Pipe Building, which is located closest to Fox Avenue South, cis-1,2-dichloroethene was also detected. The sub-slab compounds detected and their concentrations have generally decreased or are consistent with the data previously collected in December 2012. A copy of the soil vapor laboratory report is included as Attachment 1 and a summary of the analytical soil vapor data for all detected compounds is included in Table 1.

INDOOR AIR SAMPLE COLLECTION AND RESULTS

On April 15, 2012, Floyd|Snider personnel collected three indoor air samples (7-hour composites) from the Pipe Building (SBW-IA-Center), the lunch room (SBW-IA-lunch), and the Fabrication Building (SBW-IA-Fab Bldg) to evaluate indoor air quality. One ambient air sample (AMB-SBW, 7-hour composite) was collected outdoors to evaluate background conditions.

These four air samples were collected into Summa® canisters and submitted to ALS Environmental for analysis by USEPA Method TO-15, low level. Refer to Figure 1 for the indoor air sample locations and designations. A copy of the indoor air laboratory report is included as Attachment 2 and the results from the indoor air sampling are contained in Table 2.

DISCUSSION

Table 2 lists the concentrations of PCE, TCE, and vinyl chloride detected, including results from the 2010 sampling by URS Corporation and the December 2012 sampling conducted just prior to the initiation of thermal remediation. In accordance with Section 3.2.3 of Ecology's *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action, Draft October 2009,* the specific concentrations shown for these three compounds have been corrected to account for the background levels for each compound also detected in the ambient air samples. Each compound is discussed separately below.

PCE—Results indicate the detected concentrations were all well under the MTCA Method B concentration specified in the amendment to the Cleanup Action Plan (CAP) adopted in May 2013. Please note that the detected concentrations in all samples were less than previous concentrations obtained in December 2012.

TCE—Results indicate no detections for TCE in any of the samples collected.

Vinyl Chloride—Results indicate no detections for vinyl chloride in any of the samples collected.

CONCLUSIONS

Based on a review of indoor air data collected during thermal operations, there is not evidence of vapor intrusion at levels greater than cleanup levels at SBW. PCE, TCE, and vinyl chloride concentrations in indoor air have decreased when compared to the 2010 and 2012 data. Contingency actions are not necessary, as all concentrations were either non-detect or less than the trigger levels under the CAP and the final cleanup levels specified in the amendment to the CAP, which are the current MTCA Method B cleanup levels.

PLANNED ACTIVITIES

Monthly field screening with a PID of the vapor points at SBW will no longer be conducted as thermal operations have come to an end. The next round of vapor intrusion monitoring (which will consist of the collection of soil vapor and indoor air samples) will be conducted in June or July of 2013

ATTACHMENTS

Table 1	Sub-slab Soil Vapor Seattle Boiler Works
Table 2	Indoor Air Sample Results Seattle Boiler Works
Figure 1	Soil Vapor and Indoor Air Monitoring Locations at Seattle Boiler Works
Attachment 1	Soil Vapor Laboratory Report (SBW Only)

Attachment 2	Indoor Air Laboratory Report (SBW Only)
Attachment 3	Sub-Slab Data Validation Summary
Attachment 4	Indoor Air Data Validation Summary

Tables

Table 1
Sub-slab Soil Vapor
Seattle Boiler Works[1,2]

Sample ID	Sample Date	Tetrachloroethene (μg/m^3)	Trichloroethene (μg/m^3)	Vinyl Chloride (μg/m^3)	cis-1,2-Dichloroethene (μg/m^3)	Chloroethane (μg/m^3)	1,1-Dichloroethene (μg/m^3)	Sample Location
SVA-A	10/28/2010	1,600	ND (6.4)	ND (3.0)	ND (4.7)	--	--	SE corner of Fabrication Building
SV-4 (SBW)	12/14/2012	478	ND (100)	ND (20)	ND (100)	ND (100)	ND (100)	NE corner of Fabrication Building
SV-4 (SBW)	4/15/2013	206	ND (100)	ND (20)	ND (100)	ND (100)	ND (100)	NE corner of Fabrication Building
SVA-B	10/28/2010	5,100	220	ND (7.6)	ND (12)	--	--	SE corner of Pipe Building
SV-1 (SBW)	12/14/2012	451	173	296	745	248	ND (100)	SE corner of Pipe Building
SV-1 (SBW)	4/15/2013	220	ND (100)	ND (20)	268	ND (100)	ND (100)	SE corner of Pipe Building
SVA-C	10/28/2010	1,800	120	18	26	--	--	NE corner of Pipe Building
SV-2 (SBW)	12/14/2012	16,000	1,710	141	984	166	106	NE corner of Pipe Building
SV-2 (SBW)	4/15/2013	17,800	889	ND (20)	128	ND (100)	ND (100)	NE corner of Pipe Building
SVA-D	10/28/2010	2,800	96	ND (3.0)	ND (4.6)	--	--	SW corner of Pipe Building
SV-3 (SBW)	12/14/2012	2,770	164	ND (20)	ND (100)	ND (100)	ND (100)	SW corner of Pipe Building (lunch room)
SV-3 (SBW)	4/15/2013	2,140	ND (100)	ND (20)	ND (100)	ND (100)	ND (100)	SW corner of Pipe Building (lunch room)

Notes:

1 Seattle Boiler Works soil gas and indoor air sampling was performed by URS Corporation in February 2010. Data were presented in a Vapor Intrusion Assessment letter prepared by URS Corporation and dated February 2, 2011. Subsequent samples were collected by Floyd|Snider.

2 Soil vapor samples were collected using a tedlar bag and analyzed using MTCA Method 8260.

-- Data not included in URS Corporation's Vapor Intrusion Assessment letter.

Abbreviations:

ID	Identifier
μg/m^3	Micrograms per cubic meter
MTCA	Model Toxics Control Act
ND	Not-detected greater than laboratory detection limited denoted in parenthesis
NE	Northeast
SE	Southeast
SW	Southwest

Table 2
Indoor Air Sample Results
Seattle Boiler Works

Sample ID	Sample Date	Tetrachloroethene (µg/m^3)	Trichloroethene (µg/m^3)	Vinyl Chloride (µg/m^3)	Sample Location
Indoor Air—Seattle Boiler Works [1,2]					
SBW-IA-SSVB	12/12/2010	2.9	0.24	0.06	SE corner inside Pipe Building
SBW-IA-Lunch	12/12/2010	3.0	0.14	0.13	Employee lunch room, inside Pipe Building
	12/14/2012	2.6	0.13	0.25	
	4/15/2013	2.1	ND	ND	
SBW-IA-Center	12/12/2010	2.5	0.21	0.21	Central area within Pipe Building
	12/14/2012	1.0	0.43	2.0	
	4/15/2013	0.2	ND	ND	
SBW-IA-Fab Bldg	12/14/2012	0.16	0.09	ND	NE portion of Fabrication Building
	4/15/2013	0.08	ND	ND	
SBW-IA-Office crawl space	12/14/2012	0.13	ND	ND	Grab, in office crawl space
Ambient Air —Seattle Boiler Works [1,2]					
SBW-IA-AMB	12/12/2010	1.5	0.20	0.16	Outside, E of Pipe Building
AMB-1	12/14/2012	0.51	0.18	ND	Outside, E of Office at entry gate
AMB-2	12/14/2012	0.4	0.18	ND	Outside, E property line along Fox Avenue
AMB-SBW	4/15/2013	0.24	ND	ND	Outside, E of Office at entry gate
Current Indoor Air CULs [3]					
Default MTCA Method B		9.6	0.37	0.28	

Notes:

1 The sample results were adjusted to account for background in accordance with Section 3.2.3 of Ecology's *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action, Draft October 2009.*

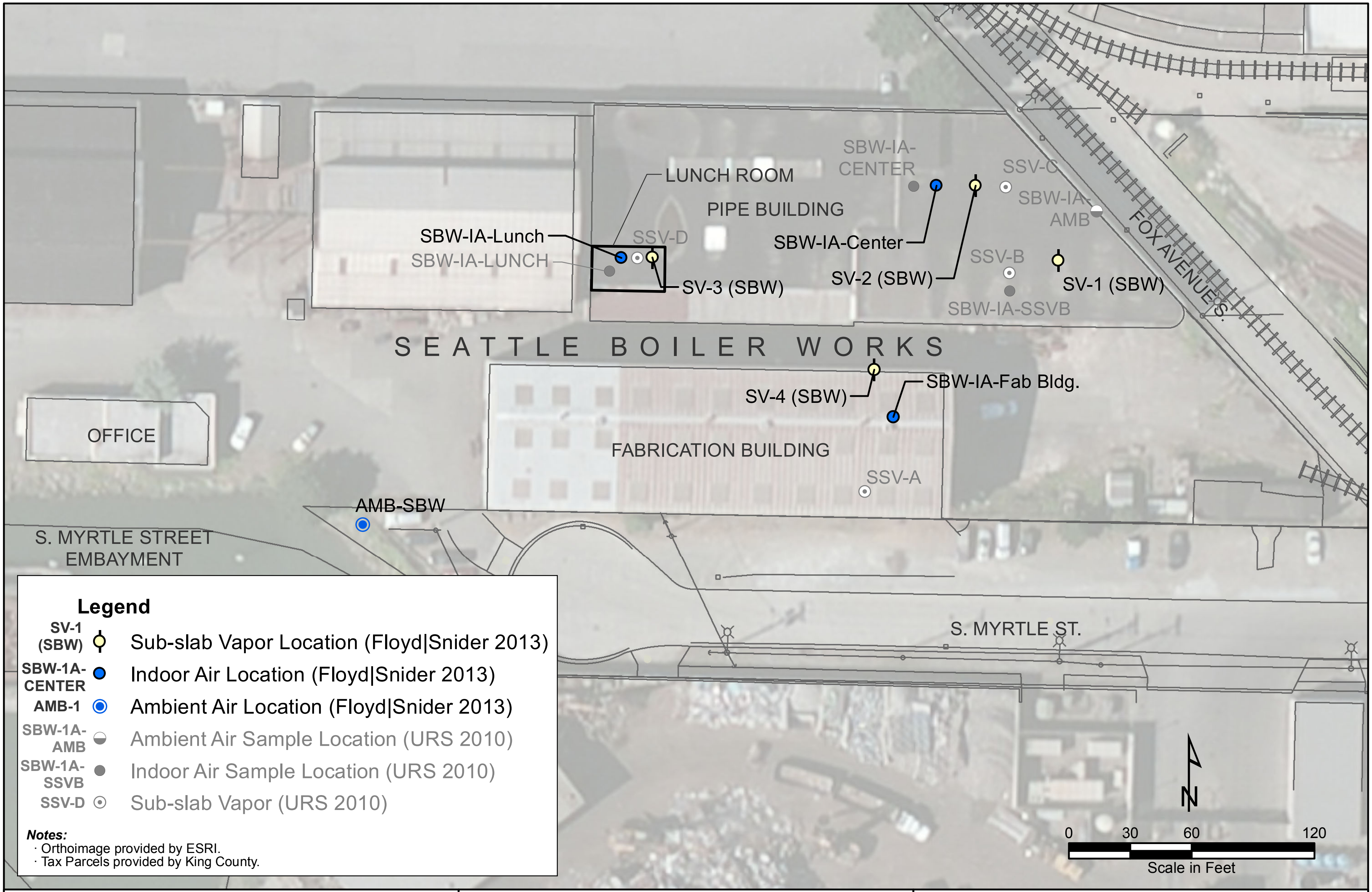
2 Seattle Boiler Works soil gas and indoor air sampling was performed by URS Corporation in February 2010. Data were presented in a Vapor Intrusion Assessment letter prepared by URS Corporation and dated February 2, 2011. Subsequent samples were collected by Floyd|Snider.

3 Indoor air cleanup levels specified in the Cleanup Action Plan were adjusted to reflect current CLARC values based on an amendment to the Agreed Order, dated May 2013.

Abbreviations:

CLARC	Cleanup Levels and Risk Calculation
CUL	Cleanup level
E	East
Ecology	Washington State Department of Ecology
ID	Identifier
µg/m^3	Micrograms per cubic meter
MTCA	Model Toxics Control Act
ND	Not-detected greater than laboratory detection limit
NE	Northeast
SE	Southeast

Figure



Notes:
- Orthoimage provided by ESRI.
- Tax Parcels provided by King County.

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Vapor Intrusion Monitoring at
Seattle Boiler Works
Fox Avenue Site
Seattle, Washington

Figure 1
Soil Vapor And Indoor
Air Monitoring Locations
at Seattle Boiler Works

I:\GIS\Projects\FOXAVE-RA\MXD\Vapor Intrusion Memorandum\Figure 1 (VIM - Soil Vapor And Indoor Air Monitoring at Seattle Boiler Works).mxd
6/5/2013

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Two Union Square
601 Union Street, Suite 600
Seattle, WA 98101
tel: 206.292.2078 fax: 206.682.7867

Memorandum

To: Sunny Becker, Washington State Department of Ecology
Copies: Bob Code, Cascade Columbia
From: Tom Colligan and Jenny Graves, Floyd|Snider
Date: August 12, 2013
Project: Fox Ave-RA, Task 5
Re: **Post-thermal Vapor Intrusion Monitoring at Seattle Boiler Works: July 2013**

Per the requirements of the final Engineering Design Report (EDR) dated October 9, 2012, this memorandum is being submitted to the Washington State Department of Ecology (Ecology) to document sub-slab vapor and indoor air monitoring activities completed at Seattle Boiler Works (SBW) following shutdown of the thermal heating system at the Fox Avenue Site (Site) located at 6900 Fox Avenue South in Seattle, Washington.

SUB-SLAB SOIL VAPOR SAMPLE COLLECTION AND RESULTS

On July 10, 2013, Floyd|Snider personnel collected four soil vapor grab samples from the sub-slab vapor monitoring points installed in December 2012. Soil vapor points were purged using an SKC® hand pump for a minimum of 5 minutes (equivalent to a purge volume of approximately 5 liters), and were then field screened for volatile organic compounds (VOCs) with a RAE Systems photoionization detector (PID) prior to sample collection. PID readings were 0.6, 4.7, 1.2, and 0.4 parts per million by volume (ppmv) at vapor points SV-1(SBW) through SV-4(SBW), respectively. Vapor samples were then collected into Tedlar® bags and submitted to Fremont Analytical, Inc. for VOC analysis by U.S. Environmental Protection Agency (USEPA) Method 8260. Refer to Figure 1 for the soil vapor sample locations and designations.

Laboratory analysis indicated sub-slab vapors at all four locations contain tetrachloroethene (PCE) and one location (SV-2 [SBW]) contained trichloroethene (TCE), vinyl chloride, and cis-1,2-dichloroethene. With the exception of the cis-1,2-dichloroethene found in SV-2(SBW), the sub-slab compounds detected and their concentrations have increased in concentration from the data previously collected in April 2013. A copy of the soil vapor laboratory report is included in Attachment 1 and a summary of the analytical soil vapor data for all detected compounds is included in Table 1.

INDOOR AIR SAMPLE COLLECTION AND RESULTS

On July 10, 2013, Floyd|Snider personnel collected three indoor air samples (7-hour composites) from the Pipe Building (SBW-IA-Center), the lunch room (SBW-IA-Lunch), and the Fabrication Building (SBW-IA-Fab Bldg) to evaluate indoor air quality. One ambient air sample

(AMB-SBW, 8-hour composite) was collected outdoors to evaluate background conditions. These four air samples were collected into Summa® canisters and submitted to ALS Environmental for analysis by USEPA Method TO-15, low level. Refer to Figure 1 for the indoor air sample locations and designations. A copy of the indoor air laboratory report is included in Attachment 1 and the results from the indoor air sampling are presented in Table 2.

DISCUSSION

Table 2 lists the current and past detected concentrations of PCE, TCE, and vinyl chloride, the three contaminants of concern in indoor air. In accordance with Section 3.2.3 of Ecology's *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action, Draft October 2009,* the specific concentrations shown for these three compounds have been corrected to account for the background levels for each compound also detected in the ambient air samples. Each compound is discussed separately below.

PCE—Results indicate the detected concentrations in all three indoor air samples were all well under the Model Toxics Control Act (MTCA) Method B concentration specified in the amendment to the Cleanup Action Plan (CAP) adopted in May 2013.

TCE—Results indicate no detections for TCE in any of the indoor air samples collected.

Vinyl Chloride—Results indicate no detections for vinyl chloride in any of the indoor air samples collected.

CONCLUSIONS

Based on a review of indoor air data collected during thermal operations, there is no evidence of vapor intrusion impacting indoor air at levels greater than cleanup levels at SBW. Continued sampling of indoor air is not necessary, as all concentrations were either non-detect or much less than the current MTCA Method B cleanup levels.

PLANNED ACTIVITIES

No further indoor air or sub-slab sampling activities are planned for the SBW property, as all thermal operations have come to an end and post-thermal indoor air results remain less than final cleanup levels. However, groundwater will continue to be treated and monitored.

ATTACHMENTS

Table 1	Sub-slab Soil Vapor at Seattle Boiler Works
Table 2	Indoor Air Sample Results at Seattle Boiler Works
Figure 1	Soil Vapor and Indoor Air Monitoring Locations at Seattle Boiler Works
Attachment 1	Soil Vapor and Indoor Air Laboratory Reports
Attachment 2	Sub-slab Data Validation Summary
Attachment 3	Indoor Air Data Validation Summary

Tables

Table 1
Sub-slab Soil Vapor at Seattle Boiler Works[1,2]

Sample ID	Sample Date	Tetrachloroethene ($\mu g/m^3$)	Trichloroethene ($\mu g/m^3$)	Vinyl Chloride ($\mu g/m^3$)	cis-1,2-Dichloroethene ($\mu g/m^3$)	Chloroethane ($\mu g/m^3$)	1,1-Dichloroethene ($\mu g/m^3$)	Sample Location
SVA-A	10/28/2010	1,600	ND (6.4)	ND (3.0)	ND (4.7)	--	--	SE corner of Fabrication Building
SV-4 (SBW)	12/14/2012	478	ND (100)	ND (20)	ND (100)	ND (100)	ND (100)	NE corner of Fabrication Building
SV-4 (SBW)	4/15/2013	206	ND (100)	ND (20)	ND (100)	ND (100)	ND (100)	NE corner of Fabrication Building
SV-4 (SBW)	7/10/2013	427	ND (100)	ND (20)	ND (100)	ND (100)	ND (100)	NE corner of Fabrication Building
SVA-B	10/28/2010	5,100	220	ND (7.6)	ND (12)	--	--	SE corner of Pipe Building
SV-1 (SBW)	12/14/2012	451	173	296	745	248	ND (100)	SE corner of Pipe Building
SV-1 (SBW)	4/15/2013	220	ND (100)	ND (20)	268	ND (100)	ND (100)	SE corner of Pipe Building
SV-1 (SBW)	7/10/2013	515	ND (100)	ND (20)	ND (100)	ND (100)	ND (100)	SE corner of Pipe Building
SVA-C	10/28/2010	1,800	120	18	26	--	--	NE corner of Pipe Building
SV-2 (SBW)	12/14/2012	16,000	1,710	141	984	166	106	NE corner of Pipe Building
SV-2 (SBW)	4/15/2013	17,800	889	ND (20)	128	ND (100)	ND (100)	NE corner of Pipe Building
SV-2 (SBW)	7/10/2013	27,800	1,120	84	100	ND (100)	ND (100)	NE corner of Pipe Building
SVA-D	10/28/2010	2,800	96	ND (3.0)	ND (4.6)	--	--	SW corner of Pipe Building
SV-3 (SBW)	12/14/2012	2,770	164	ND (20)	ND (100)	ND (100)	ND (100)	SW corner of Pipe Building (lunch room)
SV-3 (SBW)	4/15/2013	2,140	ND (100)	ND (20)	ND (100)	ND (100)	ND (100)	SW corner of Pipe Building (lunch room)
SV-3 (SBW)	7/10/2013	2,510	ND (100)	ND (20)	ND (100)	ND (100)	ND (100)	SW corner of Pipe Building (lunch room)

Notes:

1 Seattle Boiler Works soil gas and indoor air sampling was performed by URS Corporation in February 2010. Data were presented in a Vapor Intrusion Assessment letter prepared by URS Corporation and dated February 2, 2011. Subsequent samples were collected by Floyd|Snider.

2 Soil vapor samples were collected using a tedlar bag and analyzed using MTCA Method 8260.

-- Data not included in URS Corporation's Vapor Intrusion Assessment letter.

Abbreviations:

ID	Identifier
$\mu g/m^3$	Micrograms per cubic meter
MTCA	Model Toxics Control Act
ND	Not-detected greater than laboratory detection limited denoted in parenthesis
NE	Northeast
SE	Southeast
SW	Southwest

Table 2
Indoor Air Sample Results at Seattle Boiler Works

Sample ID	Sample Date	Tetrachloroethene (µg/m^3)	Trichloroethene (µg/m^3)	Vinyl Chloride (µg/m^3)	Sample Location
Indoor Air—Seattle Boiler Works [1,2]					
SBW-IA-SSVB	12/12/2010	2.9	0.24	0.06	SE corner inside Pipe Building
SBW-IA-Lunch	12/12/2010	3.0	0.14	0.13	Employee lunch room, inside Pipe Building
	12/14/2012	2.6	0.13	0.25	
	4/15/2013	2.1	ND	ND	
	7/10/2013	1.5	ND	ND	
SBW-IA-Center	12/12/2010	2.5	0.21	0.21	Central area within Pipe Building
	12/14/2012	1.0	0.43	2.0	
	4/15/2013	0.2	ND	ND	
	7/10/2013	0.9	ND	ND	
SBW-IA-Fab Bldg	12/14/2012	0.16	0.09	ND	NE portion of Fabrication Building
	4/15/2013	0.08	ND	ND	
	7/10/2013	1.85	ND	ND	
SBW-IA-Office crawl space	12/14/2012	0.13	ND	ND	Grab, in office crawl space
Ambient Air —Seattle Boiler Works [1,2]					
SBW-IA-AMB	12/12/2010	1.5	0.20	0.16	Outside, E of Pipe Building
AMB-1	12/14/2012	0.51	0.18	ND	Outside, E of Office at entry gate
AMB-2	12/14/2012	0.4	0.18	ND	Outside, E property line along Fox Avenue
AMB-SBW	4/15/2013	0.24	ND	ND	Outside, E of Office at entry gate
AMB-SBW	7/10/2013	0.35	ND	ND	Outside, E of Office at entry gate
Current Indoor Air CULs [3]					
Default MTCA Method B		9.6	0.37	0.28	

Notes:

1 The sample results were adjusted to account for background in accordance with Section 3.2.3 of Ecology's *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action, Draft October 2009.*

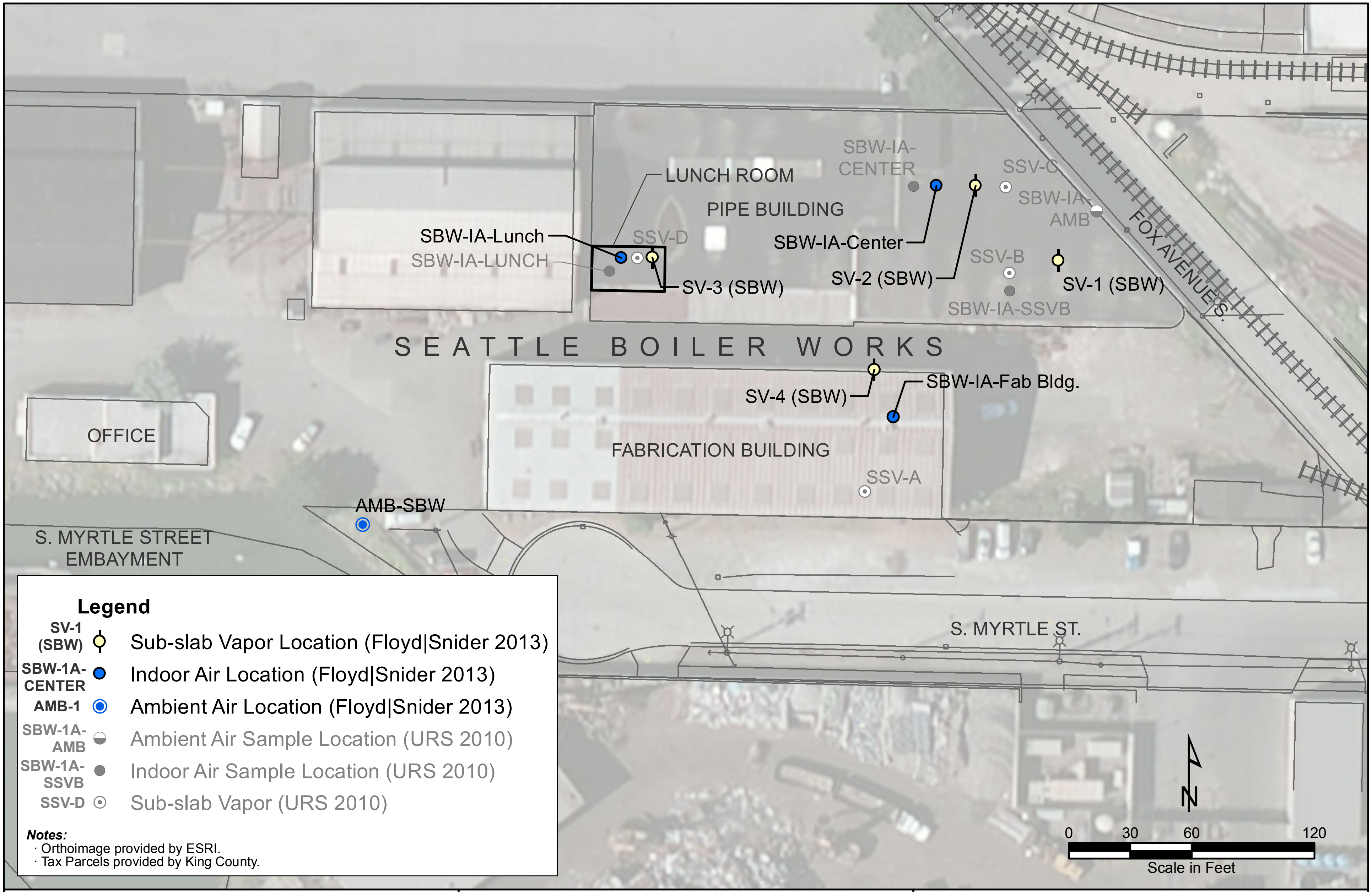
2 Seattle Boiler Works soil gas and indoor air sampling was performed by URS Corporation in February 2010. Data were presented in a Vapor Intrusion Assessment letter prepared by URS Corporation and dated February 2, 2011. Subsequent samples were collected by Floyd|Snider.

3 Indoor air CULs specified in the Cleanup Action Plan were adjusted to reflect current CLARC values based on an amendment to the Agreed Order, dated May 2013.

Abbreviations:

CLARC	Cleanup Levels and Risk Calculation
CUL	Cleanup level
E	East
Ecology	Washington State Department of Ecology
ID	Identifier
µg/m^3	Micrograms per cubic meter
MTCA	Model Toxics Control Act
ND	Not-detected greater than laboratory detection limit
NE	Northeast
SE	Southeast

Figure



Notes:
- Orthoimage provided by ESRI.
- Tax Parcels provided by King County.

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Vapor Intrusion Monitoring at
Seattle Boiler Works
Fox Avenue Site
Seattle, Washington

Figure 1
Soil Vapor And Indoor
Air Monitoring Locations
at Seattle Boiler Works

I:\GIS\Projects\FOXAVE-RA\MXD\Vapor Intrusion Memorandum\Figure 1 (VIM - Soil Vapor And Indoor Air Monitoring at Seattle Boiler Works).mxd
6/5/2013

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Two Union Square
601 Union Street, Suite 600
Seattle, WA 98101
tel: 206.292.2078 fax: 206.682.7867

Memorandum

To: Sunny Becker, Washington State Department of Ecology
Copies: Bob Code, Cascade Columbia Distribution
From: Tom Colligan and Jenny Graves, Floyd|Snider
Date: September 30, 2013
Project: Fox Ave-RA, Task 5
Re: **Vapor Intrusion Monitoring at Cascade Columbia: September 2013 Results**

Per the requirements of the final Engineering Design Report (EDR) dated October 9, 2012, this memorandum is being submitted to the Washington State Department of Ecology (Ecology) to document the final set of protection monitoring activities completed at the Cascade Columbia Distribution (Cascade Columbia) building. These samples were collected after shutdown of both the soil vapor extraction (SVE) system and the thermal heating system at the Fox Avenue Site (Site) located at 6900 Fox Avenue South in Seattle, Washington.

SOIL VAPOR SAMPLE COLLECTION AND RESULTS

On September 5, 2013, Floyd|Snider personnel collected the fourth and final set of soil vapor samples from the permanent vapor monitoring points inside the Cascade Columbia warehouse. The first set of samples was taken in March 2009 before the start of the SVE system. The second set was taken in November 2012, approximately 2 months after the SVE system had started operating but prior to thermal operations. The third set was taken in April 2013, approximately 3 months after the thermal system had started operating.

Prior to sample collection, the soil vapor points were purged using an SKC® hand pump for a minimum of 5 minutes (equivalent to a purge volume of approximately 5 liters) and field screened for volatile organic compounds (VOCs) with a RAE Systems photoionization detector (PID) prior to sample collection. PID readings were 1.3, 1.9, and 1.3 parts per million by volume (ppmv) at vapor points SV-1 through SV-3, respectively. Vapor samples were then collected into Tedlar® bags and submitted to Fremont Analytical, Inc. (Fremont) for VOC analysis by U.S. Environmental Protection Agency (USEPA) Method 8260. Refer to Figure 1 for the soil vapor sample locations and designations.

Laboratory analysis indicated detections of tetrachloroethylene (PCE) and trichloroethene (TCE) in all three vapor points. A copy of the soil vapor laboratory report is included in Attachment 1, and a summary of the analytical data from all events is provided in Table 1. The concentrations in the sub-slab samples from the office were generally consistent with the results from the prior samples collected during active SVE and thermal operations. The sample from the warehouse break room showed an increase; however, the increase was well below the concentrations detected prior to the start of remedial activities. Further the indoor air results were well below applicable standards (see next section).

INDOOR AIR SAMPLE COLLECTION AND RESULTS

On September 5, 2013, Floyd|Snider personnel collected three indoor air samples (8-hour composites) from inside the office near the kitchen area (IA-1), inside the office near the men's restroom (IA-2), and inside the warehouse break room (IA-3) to evaluate indoor air quality during thermal operations. One ambient air sample (AMB-CC, 8-hour composite) was collected upwind to evaluate background conditions. These four air samples were collected into Summa® canisters and submitted to ALS Environmental for VOC (PCE, TCE, and vinyl chloride) analysis by USEPA Method TO-15, low level. Refer to Figure 1 for the indoor air sample locations and designations. A copy of the indoor air laboratory report is included in Attachment 1, and the results from the indoor air sampling are provided in Table 2. In accordance with Section 3.2.3 of Ecology's *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action*, Draft October 2009, the specific concentrations shown for the compounds have been corrected to account for the background levels for each compound also detected in the ambient air samples.

DISCUSSION

Per the cleanup levels specified in the amendment to the Cleanup Action Plan (CAP) dated May 2013, current Model Toxics Control Act (MTCA) Method C cleanup levels for indoor air were applied to Cascade Columbia. Each compound is discussed separately below.

PCE—Results indicate detections in all samples; however none of the detections exceeded the MTCA Method C cleanup level. Concentrations in IA-1 and IA-2 have decreased significantly from previous concentrations measured in April 2013. The concentration in IA-3 has increased slightly; however, it is still significantly below the MTCA Method C cleanup level. This increase is probably due to the increase in soil vapor concentrations noted in the sub-slab sample.

TCE—Results indicate detections in all of the samples at concentrations well below the MTCA Method C cleanup level. Concentrations in all samples have decreased from previous concentrations measured in April 2013.

Vinyl chloride—Consistent with prior results, vinyl chloride was not detected in any of the samples.

CONCLUSIONS

Based on a review of both soil vapor and indoor air data collected after SVE and thermal operations were discontinued, there is no evidence of vapor intrusion at levels greater than the applicable cleanup levels at Cascade Columbia. PCE and TCE concentrations in indoor air have decreased significantly compared to the 2009 pre-remediation data. All concentrations were in compliance with the MTCA Method C cleanup levels.

PLANNED ACTIVITIES

No further activities are planned at this time. Monthly field screening with a PID of the vapor points at the Cascade Columbia facility will be discontinued, and no further indoor air sampling will be performed because the cleanup levels have been achieved.

ATTACHMENTS

Table 1	Sub-slab Soil Vapor Results, Cascade Columbia
Table 2	Indoor Air Sample Results, Cascade Columbia
Figure 1	Indoor Air Monitoring Locations at Cascade Columbia Site
Attachment 1	Laboratory Analytical Reports
Attachment 2	Sub-slab Data Validation Summary
Attachment 3	Indoor Air Data Validation Summary

Tables

Table 1
Sub-slab Soil Vapor Results, Cascade Columbia

Sample ID	Sample Date	Tetrachloroethene ($\mu g/m^3$)	Trichloroethene ($\mu g/m^3$)	Sample Location
Soil Vapor—Cascade Columbia				
SV-1	3/26/2009	47,000	1,600	In office, near sink area, sub-slab
	11/8/2012[1]	142	ND (100)	
	4/15/2013[1]	ND (100)	ND (100)	
	9/5/2013[1]	244	153	
SV-2	3/26/2009	43,000	940	In office, men's restroom, sub-slab
	11/8/2012[1]	280	ND (100)	
	4/15/2013[1]	137	ND (100)	
	9/5/2013[1]	550	198	
SV-3	3/26/2009	43,000	2,000	In warehouse break room, sub-slab
	4/15/2013[1]	ND (100)	ND (100)	
	9/5/2013[1]	8,380	756	

Note:

1 Soil vapor samples were collected using a Tedlar bag and analyzed using MTCA Method 8260.

Abbreviations:

$\mu g/m^3$	Micrograms per cubic meter
MTCA	Model Toxics Control Act
ND	Not detected at concentration greater than laboratory detection limited denoted in parentheses

Table 2
Indoor Air Sample Results, Cascade Columbia

Sample ID	Sample Date	Tetrachloroethene (µg/m^3)	Trichloroethene (µg/m^3)	Vinyl Chloride (µg/m^3)	Sample Location
Indoor Air—Cascade Columbia [1]					
IA-1	3/26/2009	**75**	1.1	NM	Inside office, near sink; collected before SVE and thermal operations
	4/15/2013	27	0.99	ND (0.14)	Inside office, near kitchen area; collected during SVE and thermal operations
	9/5/2013	12.8	0.25	ND (0.16)	Inside office, near kitchen area; collected after SVE and thermal operations
IA-2	3/26/2009	**53**	1	NM	Inside office, men's restroom; collected before SVE and thermal operations
	4/15/2013	32	1.2	ND (0.12)	Inside office, top of shelf near men's restroom; collected during SVE and thermal operations
	9/5/2013	12.8	0.26	ND (0.15)	Inside office, top of shelf near men's restroom; collected after SVE and thermal operations
IA-3	3/26/2009	6	0.52	NM	Inside warehouse break room; collected before SVE and thermal operations
	4/15/2013[2]	0.69	0.18	ND (0.12)	Inside warehouse break room; collected during SVE and thermal operations
	9/5/2013	1.7	0.13	ND (0.12)	Inside warehouse break room; collected after SVE and thermal operations
IA-4	3/26/2009	2.7	0.2	NM	Upstairs, at top of stairwell; collected before SVE and thermal operations
Ambient Air—Cascade Columbia					
AA-1	3/26/2009	0.46	<0.18	NM	Ambient outdoor, SW of facility
AA-2	3/26/2009	0.58	<0.17	NM	Ambient outdoor, NE of facility
AA-3	3/26/2009	0.37	<0.18	NM	Ambient outdoor, NW of facility
AA-4	3/26/2009	2	0.37	NM	Ambient indoor, center of warehouse
AMB-CC	4/15/2013	1.5	ND (0.12)	ND (0.12)	Ambient outdoor, SW of facility
AMB-CC	9/5/2013	0.17	ND (0.12)	ND (0.14)	Ambient outdoor, SW of facility
Applicable Regulatory Soil Gas Screening and Indoor Air CULs[3]					
MTCA Method C		**40**	**2**	**2.8**	Industrial Indoor Air CUL

Notes:

Bold Indicates an exceedance of appropriate MTCA standard.

[1] The sample results were adjusted to account for background in accordance with Section 3.2.3 of Ecology's *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action* , Draft October 2009.

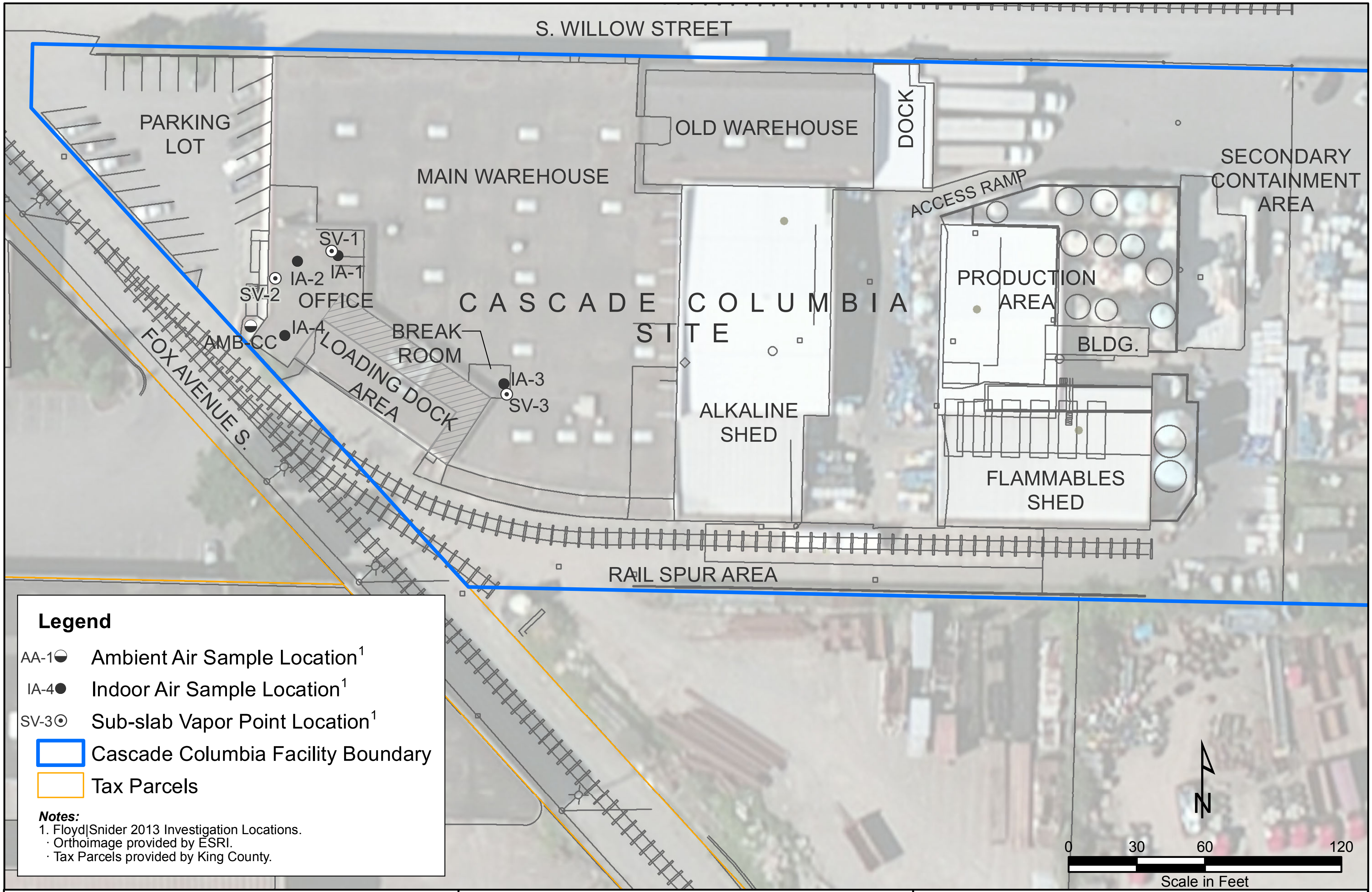
[2] Concentrations were less than both ambient/background concentrations; therefore, results were considered to be consistent with background and were not adjusted for background.

[3] MTCA Method C CULs based on current CLARC values were applied to Cascade Columbia assuming future industrial use.

Abbreviations:

CLARC	Cleanup Levels and Risk Calculation
CUL	Cleanup level
Ecology	Washington State Department of Ecology
ID	Identifier
µg/m^3	Micrograms per cubic meter
MTCA	Model Toxics Control Act
ND	Not detected at concentration greater than laboratory detection limit noted in parentheses
NE	Northeast
NM	Not measured
NW	Northwest
SVE	Soil vapor extraction
SW	Southwest

Figure



Legend

AA-1◒ Ambient Air Sample Location[1]
IA-4● Indoor Air Sample Location[1]
SV-3⦿ Sub-slab Vapor Point Location[1]
🟦 Cascade Columbia Facility Boundary
🟨 Tax Parcels

Notes:
1. Floyd|Snider 2013 Investigation Locations.
· Orthoimage provided by ESRI.
· Tax Parcels provided by King County.

FLOYD | SNIDER
strategy ▪ science ▪ engineering

Vapor Intrusion Monitoring at
Cascade Columbia
Fox Avenue Site
Seattle, Washington

Figure 1
Indoor Air Monitoring Locations
at Cascade Columbia Site

I:\GIS\Projects\FOXAVE-RA\MXD\Vapor Intrusion Memorandum\Figure 1 (VIM - Proposed Indoor Air Monitoring at Cascade Columbia Site).mxd
6/11/2013

Appendix B Soil Vapor Sampling Standard Operating Procedure

Vapor Monitoring Data Sheet

Date		Site Location	
Samplers		Well ID	
		Constructed Depth	

Sample Train Leak Test:

Zero Time Vacuum	
1-min Vacuum	
5-min Vacuum	

Or

Shroud Test:

Gas Used	
Elapsed Time	
Gas Detected	

Purge Volume:

Sample Train Length (ft)			
Tube Diameter (in)			
Volume (L)			

Volume Reference Table:

Hose Diameter (in)	Volume (L/ft)
0.125 (1/8)	0.0024
0.25 (1/4)	0.0096
0.375 (3/8)	0.0217
0.5 (1/2)	0.0386
1 (1)	0.1543

Vapor Sample Purge Data:

Time							
Flow Rate (mL/min)							
PID (note ppm or ppb)							
Oxygen							
Carbon Dioxide							
Trace Gas							

Sampling Data:

Time	
Sample ID	
Duplicate	
PID Reading	

Analyses Performed:

VOCs (8260/TO-15)	

Sampling Device:

Summa		Tedlar Bag	
Summa Flow Rate			
Summa Start Vacuum			
Summa End Vacuum			

Sampling Notes:

Indoor air sampling form

Site	Fox Avenue
Sampler	
Date	
Sample Building(s):	Cascade Colombia Distribution (CCD) – Office and breakroom in warehouse

Sample Name	Location	Analysis	Volume (Liters)	Summa #	Start: Time, Vacuum (HH:MM, "H_2O)	End: Time, Vacuum (HH:MM, "H_2O)	Total Time (Minutes)	Field Duplicate
SV-1_date	Office	TO-15	1 L					
SV-2_date	Bathroom	TO-15	1 L					
SV-3_date	Breakroom	TO-15	1 L					
IA-1_date	Office	TO-15	6 L					
IA-2_date	Office	TO-15	6 L					
Dup-2_date	Office	TO-15	6 L					IA-2
IA-3_date	Breakroom	TO-15	6 L					
AA-1_date	Ambient air/Outside	TO-15	6 L					

Notes: Weather, building condition, PID readings, airflow/draft, any other notes

Indoor air sampling form

Site	Fox Avenue
Sampler	
Date	
Sample Building(s):	Seattle Boiler Works (SBW) – Lunchroom and Pipe-shop

Sample Name	Location	Analysis	Volume (Liters)	Summa #	Start: Time, Vacuum (HH:MM, “H_2O)	End: Time, Vacuum (HH:MM, “H_2O)	Total Time (Minutes)	Field Duplicate
SBW PS-IA-1__date	Pipe-shop	TO-15	6 L					
SBWL IA-1_date	Lunchroom	TO-15	6 L					
Dup-2_date	Lunch	TO-15	6 L					SBWLIA-1
SBW-AA-1_date	Ambient air/Outside	TO-15	6 L					
SBWSV-2_date	Pipe-shop	TO-15	1 L					
SBWSV-3_date	Lunchroom	TO-15	1 L					

Notes: Weather, building condition, PID readings, airflow/draft, any other notes

VAPOR SAMPLING
CALIBRE STANDARD OPERATING PROCEDURES

1.0 POLICY

It is the policy of CALIBRE that any individual engaging in collection of vapor samples at job sites will abide by the procedures outlined in this document. These procedures are designed to meet or exceed guidelines set forth by the Environmental Protection Agency (EPA) for the collection of vapor samples.

2.0 PURPOSE

This Standard Operating Procedure (SOP) provides instructions that are to be followed in the collection of vapor samples (gas phase) for laboratory or field analysis of volatile organic compounds (VOCs). The purpose of this SOP is to define the use of several different air sampling techniques that can be used for soil gas monitoring, indoor air monitoring and remediation system monitoring of VOCs present as a vapor phase in air. The sampling methods discussed include sample collection with Tedlar bags, sample collection using SUMMA canisters and field testing using a Photo Ionization Detector (PID) and other vapor monitoring instruments.

3.0 INTRODUCTION

Vapor samples may be collected as part of remediation systems performance monitoring, soil gas monitoring or indoor air monitoring to provide a means of detecting volatile organic compounds (VOCs) in the specific sampling matrix. This SOP outlines the methods to be used for the collection of vapor samples using Tedlar bags and SUMMA canisters and measurement of organic vapor levels in samples using a PID.

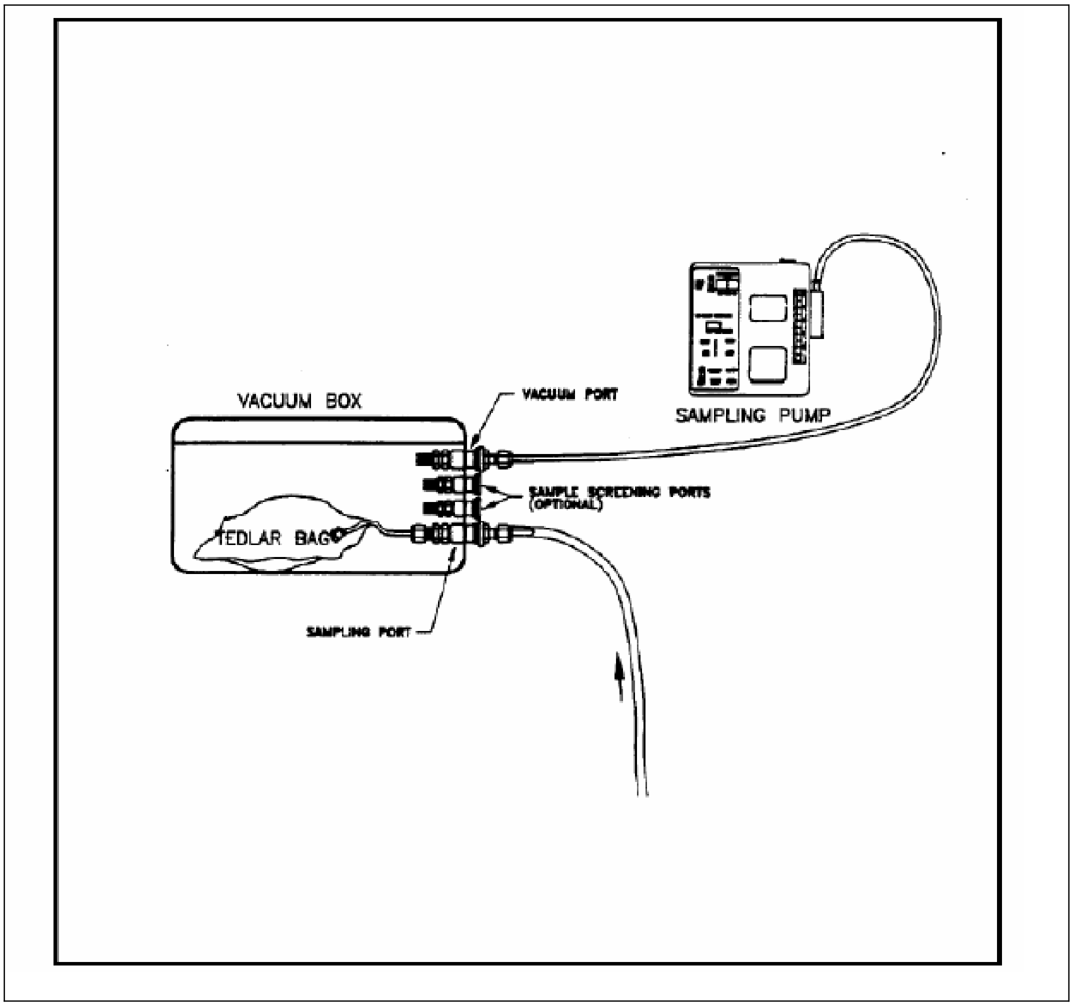
4.0 METHOD SUMMARY

The objective of the vapor sampling procedures described herein is to collect representative gas samples of the targeted media and analyze the gas for the presence of VOCs. Typically, a low volume air pump is used to pull a sample through the sampling train.

The sample may be collected in Tedlar bags using a vacuum box (see Figure 1), or directly to the Tedlar bag depending on the sampling point (lines under pressure do not need to use a vacuum box). An air pump is not required to fill a SUMMA canister; sampling is achieved by equilibration with the evacuated SUMMA canister, however a vacuum pump may still be necessary to flush the sampling train. The sample container may then be shipped to a laboratory for analysis of VOC present.

The common laboratory analytical procedures used for analysis of VOCs in gas samples are EPA methods 8260B, T015. Both of these analytical methods utilize a GC/MS analysis. Typical detection limits for the 8260B analysis are VOCs in the range of 5-100 ug/m^3. Typical detection limits for the T015 analysis are VOCs in the range of 1-10 ug/m^3. Typical detection limits for the PID analysis using a Rae Systems ppb PID are the range of 100-1,000 ug/m^3 (as total organic vapors).

Figure 1 Sampling setup using Tedlar bag in evacuated box



A PID employs the principle of photoionization to detect and quantify the concentration of organic vapors present in a gas phase sample. The analyzer will respond to most vapors that have an ionization potential (IP) less than or equal to that supplied by the ionization source used in the PID, an ultraviolet (UV) lamp. Photoionization occurs when an atom or molecule absorbs a photon of sufficient energy to release an electron and form a positive ion.

The ionization chamber exposed to the light source contains electrodes to create an electro-magnetic field in the chamber. Ions formed by the VOC adsorption of photons are driven to an electrode and the current produced is then measured and the corresponding concentration displayed on the meter, directly, in the units used for calibration, typically parts per million volume (ppmv) or parts per billion volume (ppbv). Though it can be calibrated to a particular compound, the instrument cannot distinguish between detectable compounds in a mixture of gases and, therefore, indicates an integrated response to the mixture (i.e., the measurement is for the total organic vapors present).

Field air monitoring devices include a Rae Systems ppb PID that reads in ppbv and a variety of other PID instruments that typically read in ppmv. Sampling with field instruments is typically completed with the sample first collected in a container, such as a Tedlar bag, and the PID instrument (or other) used to read the total organic vapor concentration in the sample.

5.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

5.1 Tedlar Bags

Vapor samples are generally collected in 1-liter (L) Tedlar bags. Bagged samples should be stored in the dark (i.e., in opaque containers) and protected from mechanical damage during transit to the laboratory. Further, samples should be maintained at ambient temperature by placing them in coolers, and out of direct ultra-violet (UV) light. Samples should be analyzed as soon as possible, particularly, if the stability of the compound is unknown. Under some conditions (typically considered to be high VOC concentrations), loss may occur either because of diffusion through the Tedlar bag or adsorption onto it.

A typical holding time for VOC analysis (using Tedlar bags for sampling) is no more than 48 hours. Because of this short holding-time, it is critical that the sampling event and shipping be coordinated with the laboratory prior to sample collection. In general, Tedlar bag samples collected for laboratory analysis must be collected on Monday/Tuesday and delivered by overnight courier to the laboratory (unless other specific arrangements have been made with the laboratory for the delivery date).

5.2 SUMMA Canisters

The SUMMA canisters used for vapor sampling have a 6-liter sample capacity and are certified clean by GC/MS analysis before being used in the field. An evacuated 6-liter SUMMA canister (<28 inches of mercury [Hg]) will provide a recoverable whole-gas sample of approximately 5.5 liters when allowed to fill to a vacuum of 2 inches of Hg. After sampling is completed, the samples are shipped in travel cases for off-site laboratory analysis. Most VOCs can be recovered from canisters with minimal loss up to 14 days.

5.3 Field Sampling with PID (and other instruments)

A PID instrument may be used for on-site testing of the sample collected. A PID is typically used in conjunction with sample collection in a Tedlar bag. Other field instruments that may be used (depending on the site conditions, contamination present and sampling objectives) include oxygen/lower explosive limit (O_2/LEL) meters, Flame Ionization Detectors (FIDs). Examples of other field air monitoring instruments include: combustible gas indicator (MSA CGI/0_2 Meter, Model 260), organic vapor analyzer (Foxboro OVA, Model 128, Thermo electron OVA model

580), and a variety of other instruments by various manufacturers. For any instrument used on a project, each must have the model-specific O&M manual which will specify the key details on calibration, resolution, interferences, etc.

6.0 INTERFERENCES AND POTENTIAL PROBLEMS

6.1 Factors Affecting the Sample Collected with Tedlar Bags or SUMMA Canisters

Standard laboratory analytical methods will detect VOCs at levels less than 1 part per billion volume (ppbv) in vapor phase samples. As a consequence, the potential for inadvertent sample contamination is a significant concern since many of the compounds in question are commonly used in commercial products, industries and residential settings. In order to minimize the risk of cross contamination, the following factors should be considered:

1) Proximity of the containers (bags/canisters) to source(s) of potential contamination during transportation and storage. Containers and the sampling train (tubing, pumps, or other) must be kept away from potential source(s) to the maximum extent feasible to minimize the chances of external contamination. All bags should remain in clean sealed containers until the time of use.

2) A variety of common products (many used in field sampling) will contain compounds that may be detected in the analysis. Examples include marking paint, marking pens (sharpies), fuel, adhesives, tape, and decontamination solutions from other sampling/well purging. The utmost care must be taken to minimize the potential for inadvertent contamination of the samples and sampling train.

3) Containers must be attached only to clean Teflon (or other acceptable) tubing.

4) For Tedlar bags, attach the sample label to the bag using a string or zip-tie through the eyelet on the Tedlar bag. Common adhesives found in the label may potentially permeate the bag if placed on the body of the bag.

5) Fill out labels using only a ballpoint pen; permanent markers contain volatile compounds that may contaminate the sample.

6) Due to the chemical structure of Tedlar, highly polar compounds may adhere to the inner surface of the bag. Also, low molecular weight compounds may permeate the bag.

6.2 PID Measurements

A number of factors specific to vapors associated with remediation systems and soil/indoor air vapor monitoring can affect the response of a PID. The most common problem in using a PID is rapid temperature fluctuations which may cause the PID lamp to fog; high humidity can also cause lamp fogging and decreased sensitivity. This can occur when the relative humidity of the sample collected is high such as soil vapor samples from moist/wet soils. The critical step to minimize problems associated with PID lamp fogging is to keep the PID warm (such as in the heated cab of a field vehicle) if ambient conditions are wet or cold. High and low temperature, and naturally occurring compounds, such as terpene hydrocarbons in wooded areas, can affect instrument response. Always follow instructions in the instrument manual. The manual for the specific PID used in a project must be included with equipment.

Specific considerations in the use of a PID include the following:

1) The PID is a nonspecific total organic vapor detector. It cannot be used to identify unknown substances; it can only quantify the total organic vapors (as calibrated to isobutylene response).
2) The PID must be calibrated to a specific compound (or more typically include a conversion factor for equivalent response as isobutylene).
3) The PID does not respond to certain low molecular weight hydrocarbons, such as methane and ethane, in addition, the PID does not detect a compound if the probe has a lower energy than the compound's IP. Specific compounds (e.g., carbon tetrachloride and hydrogen cyanide, have high IPs and cannot be detected with a PID.
4) Certain models of PID instruments are not designed for use in potentially flammable or combustible atmospheres.
5) The lamp window must be periodically cleaned to ensure effective ionization of the compounds by the probe (although this step has been largely eliminated with the self cleaning process implemented the Rae Systems ppb PID).
6) The PID measures concentration linearly over the calibrated range, any response outside of the calibrated range cannot be reliably quantified. The Rae Systems ppb PID requires special procedures for the zero calibration.
7) The instrument should not to be exposed to precipitation.
8) Do not use the instrument for head space analysis where liquids can inadvertently be drawn into the probe.

Transport of calibration gas cylinders by passenger and cargo aircraft must comply with International Air Transport Association (IATA) Dangerous Goods Regulations or the U.S. Code of Federal Regulations, 49 CFR Parts 100-177. A typical calibration gas included with a PID is isobutylene. It is classified as a non-flammable gas, UN #1556 and the proper shipping name is Compressed Gas. It must be shipped by cargo aircraft only.

6.3 Factors Affecting the Concentrations of Organic Compounds in Soil Gas

Concentrations of organic compounds in vapor can be affected by the physical and chemical characteristics of the soil, soil moisture, and nature of the target compound. Important factors to consider include the compounds' vapor pressure, solubility and soil partitioning (typically estimated from the organic carbon adsorption coefficient K_{oc}). Soil porosity and permeability will affect the movement of soil gas and the recharge rate of the soil gas into a well. The movement of organic vapors through fine textured soil may be very slow, thus limiting the sample volume available and the use of this technique.

The presence of a high or perched water table, or of an impermeable underlying layer (such as a clay lens or layer of buried slag) may interfere with the movement and sampling of the soil gas.

7.0 EQUIPMENT/APPARATUS

7.1 Tedlar Bag Sample Collection

The following equipment must be available and operational to perform Tedlar bag sampling:

1) Vacuum box must be clean, Teflon (or other acceptable) tubing replaced, and equipped with extra O-rings
2) Pump(s) must be charged, in good working order, and set with the appropriate flow rate of 3 liters per minute
3) Tedlar bags must be new.
4) Sample documentation (sample labels, field data sheets, logbook, chain of custody records, custody seals, etc.)
5) Small zip-ties to affix label through eyelet on bag
6) Air sampling worksheets
7) Opaque trash bags
8) PID or other field air monitoring devices
9) Cooler(s)

7.2 SUMMA Canister Sample Collection

The following equipment must be available and operational to perform sampling with SUMMA canisters:

1) 6-liter, stainless-steel SUMMA canisters;
2) Flow controllers (in the case of a prolonged time sample) with in-line particulate filters and vacuum gauges. Flow controllers are pre-calibrated to specified sample duration (e.g., 60 minutes) or flow rate (e.g., 100 milliliters per minute [mL/min]). Confirm with lab that flow controller comes with in-line particulate filter and pressure gauge;
3) ¼-inch tubing (Teflon, polyethylene, or similar);
4) Stainless steel “T” fitting (for connection to summa canisters and Teflon tubing to collect duplicate samples);
5) Portable vacuum pump (or syringe) capable of producing very low flow rates (e.g., 100-200 mL/min);
6) Helium gas canister;
7) Field helium detector;
8) Plastic sheeting;
9) Photoionization Detector (with a lamp of 11.7 eV);
10) 9/16-inch open-end wrench;
11) Chain-of-custody forms;
12) Soil-gas sample collection log; and
13) Field notebook.

7.3 Field Measurement of VOCs with PID (or other field instrument)

The following equipment must be available and operational to perform Field Testing of VOCs with a PID:

1) PID instrument, user’s manual, calibration gas and regulator, zero gas, or virgin charcoal tubing). The PID must be fully charged the night before (and include spare batteries if feasible).
2) Tedlar bags must be new.
3) Sample documentation (sample labels, field data sheets, logbook, chain of custody records, etc.).

4) Air sampling worksheets
5) Opaque trash bags
6) Any other equipment defined in section 6.1

8.0 REAGENTS

1) Calibration gases, typically isobutylene at 10 ppm for a Rae ppb PID or 100 ppm for other PIDs.
2) Materials required to zero the PID instrument (sealed virgin charcoal tubes for the Rae ppb PID or Ultra-zero grade compressed air for other PIDs).
3) Helium gas that can be used for sample shroud leak testing.

9.0 PROCEDURES

9.1 Leak Testing of the Sampling Train

Prior to sample collection from an installed vapor point, both the sample probe and the sampling train must be verified to be leak proof. If the constructed vapor sampling point allows for intrusion of vapors from other than the soil (i.e., leakage of ambient air from the ground surface), the point will not be considered a valid point for monitoring. Similarly, all connections of the sampling train must be verified to be leak proof. These two types of possible leaks (leakage to the sample collection point and sampling train) are most important when higher vacuums are required for vapor sample collection.

1) Leak testing of the vapor monitoring point: Helium will be used following probe installation to assess leakage from the ground surface to the soil vapor sampling interval. Briefly, helium (as a tracer) will be discharged from a pressurized tank into a shroud surrounding the well head of the soil vapor probe. A mini-pump will be used to sample the vadose zone/soil vapor and fill a Tedlar bag (extracting air through the installed soil vapor probe). A portable helium detector will then be used to analyze the contents of the Tedlar bag for helium. Helium concentrations less than 10 percent will be considered acceptable (ITRC 2007).
2) Leak testing of the sampling train: The set-up of the sampling train must include a leak test to verify that all connections are tight at each vapor sampling point; this is sometimes called a “shut in test”. The sampling train must include valves on both ends. For each sample set-up, use a hand pump or air pump to vacuum test the sampling equipment after assembly. The leak test is to be conducted by closing the end valves of the sampling train, using a hand pump (or other device) to create a vacuum in the sampling train, and monitoring for a period of no less than 1 minute that sufficient vacuum is maintained. The volume of a typical sampling train may be very small (~ 0.1 L, based on ¼ inch diameter tubing and 10 ft length) and even very minor leaks would be apparent as decreased vacuum levels in the test. The observed leakage rate (if any) can be calculated based on the pressure change, elapsed time and volume of sampling train. The sampling train must be sufficiently tight that any minor leaks (if any) represent no more than 5% of the targeted sample collection rate (typically ~ 100-200 ml/min).

9.2 Flushing the Volume of the Sampling Train

The sampling train and subsurface probe will contain a volume of ambient air that must be flushed from the system before the sample is collected. Calculate the volume of the sampling system by summing the volume of the probe screened interval (including filter pack void space, accounting for porosity of sand pack), the volume of tubing from the probe tip to the ground surface, and the volume of above ground tubing connecting the soil probe to the sample collection device. Purge the monitoring point until at least three volumes of the full sampling system have been evacuated. Purging should be conducted at flow rates and vacuum conditions similar to those for sample collection (typically targeted at 100 to 200 ml/min).

9.3 Sample Collection with Tedlar Bag

1) Follow Section 8.1, to evacuate the volume of the sampling train. If PID/FID readings were taken prior to taking a sample, additional evacuation is not necessary.
2) Use the vacuum box and sampling train (Figure 1) to collect the sample. The sampling train must be designed to minimize the introduction or loss of contaminants due to adsorption and other factors. All parts used are either Teflon (or other acceptable) or stainless steel, and a vacuum is drawn indirectly to avoid contamination from sample pumps.
3) Place the Tedlar bag inside the vacuum box, attach it to the sampling port and open the valve. The sample probe is attached to the sampling port via Teflon (or other acceptable) tubing and a "Quick Connect" fitting.
4) Draw a vacuum around the outside of the bag, using a pump connected to the vacuum box evacuation port, via Tygon tubing and a "Quick Connect" fitting. The negative pressure inside the box causes the bag to inflate, drawing the sample into the bag.
5) Break the vacuum by removing the Tygon line from the pump. Remove the bagged sample from the box and close the valve. Record the date, time, sample location identification, and the PID instrument reading (if used) on the sample bag's label, and on the appropriate data sheet or in the site logbook(s). Bags should not be labeled directly with a marker or pen (particularly those containing volatile solvents) or should adhesive labels be affixed directly to the bags. Inks and adhesive may diffuse through the bag material and contaminate the sample. Labels should be tied to the metal eyelets provided on the bags.
6) Complete chain of custody records.

This sampling approach (Tedlar bag sampling) is straightforward and relatively easy. However, there are several things to be aware of when sampling.

1) The seals of the vacuum box must be air tight in order for the sample collection system to work.
2) Check the O-ring gasket to see if it is in place with the proper fit. O-rings that have been stretched out will not remain in place, thus requiring constant realignment.
3) Check that all the fittings associated with the vacuum joints are securely in place. The fittings can be pushed loose when inserting the valve stem into the Teflon (or other acceptable) tubing.
4) Occasionally, a corner of the Tedlar bag will stick out between the two halves of the vacuum box causing a poor seal.
5) Since the Tedlar bags will only hold a finite volume (e.g. - liter Tedlar bag), over-inflation will burst the bag.

9.4 Sample Collection with SUMMA Canister

1) Follow Section 8.1, to evacuate the volume of the sampling train. If PID/FID readings were taken prior to taking a sample, additional evacuation is not necessary.
2) Attach a certified clean, evacuated 6-L SUMMA canister via the ¼" Teflon or acceptable tubing.
3) Open the valve on the SUMMA canister. The vapor sample is drawn into the canister by pressure equilibration.
4) Record the date, time, sample location identification, and the PID instrument reading (if used) on the sample label (use ball point pen only), and on the appropriate data sheet or in the site logbook(s).
5) Complete chain of custody records.

9.5 Remediation System Sampling

The sampling procedure to be used for a remediation system depends upon the sampling point.

1) If the sampling point is under vacuum (such as a sampling port at the well head on an SVE system); follow the sample collection procedure defined in Sections 8.2 or 8.3.
2) If the sampling point is under pressure (such as the discharge side of a blower for a SVE system); use the following procedure:
    a) Attach a piece of Teflon (or other acceptable) tubing to the sampling port.
    b) Open the valve on the sampling port.
    c) Flush the tubing in the line for an appropriate number of volumes.
    d) Connect Tedlar bag (or SUMMA canister) to the Teflon (or other acceptable) tubing and fill via the line pressure.
    e) Remove sample from the tubing. Record the date, time, sample location identification, and the PID instrument reading (if used) on the sample bag’s label, and on the appropriate data sheet or in the site logbook(s). Bags should not be labeled directly with a marker or pen (particularly those containing volatile solvents) nor should adhesive labels be affixed directly to the bags. Inks and adhesive may diffuse through the bag material and contaminate the sample. Labels should be tied to the metal eyelets provided on the bags.
    f) Complete chain of custody records.

9.6 Field Measurement of Organic Vapor Levels with PID

The manufacturers' manual must be consulted for the correct use and calibration of all instruments. Pumps should be calibrated prior to use in the field.

1) Collect a sample following the procedures defined in Sections 8.2 or 8.4.
2) Connect the PID probe to the sample container using a section of Teflon (or other acceptable) tubing
3) Use the PID to read the organic vapor level present in the sample.
4) Record the date, time, sample location identification, and the PID instrument reading on the appropriate data sheet or in the site logbook(s).
5) Repeat the sample collection and PID reading from the same sampling point to verify repeatability (the same Tedlar bag may be reused on this same sampling point for this repeat sampling).
6) Retest the instrument calibration after 4 hours of operation and at the end of day.

Readings may be above or below the range set on the field instrument. The range may be reset, or the response recorded as a greater than or less than the response range.

10.0 CALCULATIONS

10.1 Field Screening Instruments

Instrument readings are usually read directly from the meter. For example, PID readings are expressed in units of parts per million (ppmv) or part per billion (ppbv) depending on the PID unit. In some cases, it may be appropriate to subtract the background reading from the sample reading.

10.2 Correction Factors

A PID instrument will (typically) be calibrated to isobutylene as a calibration gas. Therefore a correction factor must be used when converting the PID response to the actual VOC concentration present in the sample. Using a PID, the instrument responds to the total organic vapors present in sample and conversion to a specific VOC concentration may be made when a specific compound present is known (based on prior sampling or other site operational knowledge). Typical PID correction factors for several for the common VOCs encountered are shown in Table 1. Appendix A includes a copy of Technical Note TN-106 from Rae Systems which presents a list of chemical compounds and their PID response correction factors (from conversion from isobutylene calibrated response to VOC concentration).

Table 1 Ionization Potential and Correction Factors for Common Compounds

Compound	Ionization Potential (eV)	Correction factor for response relative to isobutylene calibration (for 10.6 v lamp)
Acetone	9.71	1.1
Methyl ethyl ketone	9.51	0.5
Benzene	9.25	0.53
Ethylbenzene	8.77	0.52
Toluene	8.82	0.50
o-Xylene	8.56	0.59
Tetrachloroethene	9.32	0.57
Trichloroethene	9.47	0.54
Vinyl chloride	9.99	2.0
cis 1-2 dichloroethene	9.66	0.8
Isobutylene	9.24	1.0

10.3 Unit Conversions

Two common units are used to express vapor phase concentrations:

- mass per unit volume basis (e.g., ug/m^3 and ug/L); and
- volume/volume basis (ppbv, ppmv).

Field instrument readings (read directly from the meter) are typically on a volume/volume basis. Laboratory results may be presented in either units (or both).

The conversion between units is as follows:

$1 \text{ ug/m}^3 = [(273.3+T)*0.082/MW] \text{ ppbv}$

Where T is temperature in degrees C and MW is molecular weight.

11.0 QUALITY ASSURANCE/QUALITY CONTROL

11.1 Sample Probe Contamination

Sample probe contamination is checked between each sample by drawing ambient air through the probe using a vacuum pump (e.g., Gilian pump) and checking the response of the PID. If readings are higher than background, replacement or decontamination is necessary. Sample probes may be decontaminated simply by drawing ambient air through the probe until the PID reading is at background. Contamination can also be removed by decontaminating with methanol and deionized water, then air drying. For persistent contamination, use of a portable propane torch may be needed. Using a pair of pliers to hold the probe, run the torch up and down the length of the sample probe for approximately one to two minutes. Having multiple probes per sample team will reduce lag times between sample stations while probes are decontaminated.

11.2 Sample Train Contamination

The Teflon (or other acceptable) line forming the sample train from the probe to the Tedlar bag should be changed on a daily basis. If visible contamination (soil or water) is drawn into the sampling train, it must be changed immediately. When sampling in highly contaminated areas, the sampling train should be purged with ambient air, via a vacuum pump (e.g, Gilian pump), for approximately 30 seconds between each sample. After purging, the sampling train can be checked using a PID, or other field monitoring device, to establish the cleanliness of the Teflon line.

11.3 PID Calibration and Testing

1) All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan.
2) Equipment checkout and calibration activities must occur prior to sampling/operation, they must be documented.
3) All data must be documented on field data sheets and/or within site logbooks.

11.4 Trip Blanks, Field Blanks, Duplicates, Lot Blanks

The project QA plan needs to define the appropriate level of trip blanks, field blanks, duplicates, and lot blanks to meet the sampling objectives. Typical examples that should be considered in the QA plan development include;

- A trip blank or field blank to detect any sample contamination during shipping and storage.
- A trip standard used to determine any changes in concentrations of the target compounds during the course of the sampling day (e.g., migration through the sample bag, sample degradation, or adsorption to the bag's surface).

- A lot test sample from each lot of Tedlar bags to be used for sampling and checked for possible contamination (filled with ultra-zero grade air) and analyzed.
- A lot test of cleaned SUMMA canisters used for a GC/MS certification check. If the canister passes certification, it is re-evacuated and all canisters from that lot are available for sampling. If the chosen canister is contaminated, the entire lot of SUMMA canisters must be re-cleaned, and a single canister re-analyzed by GC/MS for certification.

12.0 DATA VALIDATION

If the same profile or pattern of VOCs found in the samples is observed in the blanks, the collection method and storage procedures must be evaluated. Depending on the levels observed, the data may be qualified as estimated or not usable (not valid).

13.0 REFERENCES

California Environmental Protection Agency, Department of Toxic Substances Control and California Regional Water Quality Control Board, Los Angeles Region, 2003, *Advisory – Active Soil Gas Investigations*, January 28, 2003.

Gilian Instrument Corp. 1983. Instruction Manual for Hi Flow Sampler: HFS113, HFS 113 T, HFS 113U HFS 113 UT.

International Air Transport Association Dangerous Goods Regulations

New Jersey Department of Environmental Protection. 1992. Field Sampling Procedures Manual.

U.S. Environmental Protection Agency. 1984. Characterization of Hazardous Waste Sites - A Methods Manual: Volume II. Available Sampling Methods. 2nd ed. EPA-600/4-84-076.

U.S. Environmental Protection Agency. 1995. Superfund Program Representative Sampling Guidance. Volume 2: Air (Short-Term Monitoring). EPA 540-R-95/140.

14.0 APPENDICES

Appendix A – Correction Factors, Ionization Energies, and Calibration Characteristics

Technical Note TN-106

Revised 08/2010

Correction Factors, Ionization Energies*, And Calibration Characteristics

Correction Factors and Ionization Energies

RAE Systems PIDs can be used for the detection of a wide variety of gases that exhibit different responses. In general, any compound with ionization energy (IE) lower than that of the lamp photons can be measured.* The best way to calibrate a PID to different compounds is to use a standard of the gas of interest. However, correction factors have been determined that enable the user to quantify a large number of chemicals using only a single calibration gas, typically isobutylene. In our PIDs, correction factors can be used in one of three ways:

1) Calibrate the monitor with isobutylene in the usual fashion to read in isobutylene equivalents. Manually multiply the reading by the correction factor (CF) to obtain the concentration of the gas being measured.

2) Calibrate the unit with isobutylene in the usual fashion to read in isobutylene equivalents. Call up the correction factor from the instrument memory or download it from a personal computer and then call it up. The monitor will then read directly in units of the gas of interest.

3) Calibrate the unit with isobutylene, but input an equivalent, "corrected" span gas concentration when prompted for this value. The unit will then read directly in units of the gas of interest.

* *The term “ionization energy” is more scientifically correct and replaces the old term “ionization potential.” High-boiling (“heavy”) compounds may not vaporize enough to give a response even when their ionization energies are below the lamp photon energy. Some inorganic compounds like* H_2O_2 *and* NO_2 *give weak response even when their ionization energies are well below the lamp photon energy.*

Example 1:

With the unit calibrated to read isobutylene equivalents, the reading is 10 ppm with a 10.6 eV lamp. The gas being measured is butyl acetate, which has a correction factor of 2.6. Multiplying 10 by 2.6 gives an adjusted butyl acetate value of 26 ppm. Similarly, if the gas being measured were trichloroethylene (CF = 0.54), the adjusted value with a 10 ppm reading would be 5.4 ppm.

Example 2:

With the unit calibrated to read isobutylene equivalents, the reading is 100 ppm with a 10.6 eV lamp. The gas measured is m-xylene (CF = 0.43). After downloading this factor, the unit should read about 43 ppm when exposed to the same gas, and thus read directly in m-xylene values.

Example 3:

The desired gas to measure is ethylene dichloride (EDC). The CF is 0.6 with an 11.7 eV lamp. During calibration with 100 ppm isobutylene, insert 0.6 times 100, or 60 at the prompt for the calibration gas concentration. The unit then reads directly in EDC values.

Conversion to mg/m^3

To convert from ppm to mg/m^3, use the following formula:

$$\text{Conc. (mg/m}^3) = \frac{[\text{Conc.(ppmv) x mol. wt. (g/mole)}]}{\text{molar gas volume (L)}}$$

For air at 25 °C (77 °F), the molar gas volume is 24.4 L/mole and the formula reduces to:

$$\text{Conc.(mg/m}^3) = \text{Conc.(ppmv) x mol. wt. (g/mole) x } 0.041$$

For example, if the instrument is calibrated with a gas standard in ppmv, such as 100 ppm isobutylene, and the user wants the display to read in mg/m^3 of hexane, whose m.w. is 86 and CF is 4.3, the overall correction factor would be 4.3 x 86 x 0.041 equals 15.2.

Correction Factors for Mixtures

The correction factor for a mixture is calculated from the sum of the mole fractions Xi of each component divided by their respective correction factors CFi:

$$CFmix = 1 / (X_1/CF_1 + X_2/CF_2 + X_3/CF_3 + \ldots Xi/CFi)$$

Thus, for example, a vapor phase mixture of 5% benzene and 95% n-hexane would have a CFmix of CFmix = 1 / (0.05/0.53 + 0.95/4.3) = 3.2. A reading of 100 would then correspond to 320 ppm of the total mixture, comprised of 16 ppm benzene and 304 ppm hexane.

For a spreadsheet to compute the correction factor and TLV of a mixture see the appendix at the end of the CF table.

TLVs and Alarm Limits for Mixtures

The correction factor for mixtures can be used to set alarm limits for mixtures. To do this one first needs to calculate the exposure limit for the mixture. The Threshold Limit Value (TLV) often defines exposure limits. The TLV for the mixture is calculated in a manner similar to the CF calculation:

$$\text{TLV mix} = 1 / (X_1/\text{TLV}_1 + X_2/\text{TLV}_2 + X_3/\text{TLV}_3 + \ldots X_i/\text{TLV}_i)$$

In the above example, the 8-h TLV for benzene is 0.5 ppm and for n-hexane 50 ppm. Therefore the TLV of the mixture is TLVmix = 1 / (0.05/0.5 + 0.95/50) = 8.4 ppm, corresponding to 8.0 ppm hexane and 0.4 ppm benzene. For an instrument calibrated on isobutylene, the reading corrsponding to the TLV is:

$$\text{Alarm Reading} = \text{TLVmix} / \text{CFmix} = 8.4 / 3.2 = 2.6 \text{ ppm}$$

A common practice is to set the lower alarm limit to half the TLV, and the higher limit to the TLV. Thus, one would set the alarms to 1.3 and 2.6 ppm, respectively.

Calibration Characteristics

a) Flow Configuration. PID response is essentially independent of gas flow rate as long as it is sufficient to satisfy the pump demand. Four main flow configurations are used for calibrating a PID:

1) **Pressurized gas cylinder (Fixed-flow regulator):** The flow rate of the regulator should match the flow demand of the instrument pump or be slightly higher.
2) **Pressurized gas cylinder (Demand-flow regulator):** A demand-flow regulator better matches pump speed differences, but results in a slight vacuum during calibration and thus slightly high readings.
3) **Collapsible gas bag:** The instrument will draw the calibration gas from the bag at its normal flow rate, as long as the bag valve is large enough. The bag should be filled with enough gas to allow at least one minute of flow (~ 0.6 L for a MiniRAE, ~0.3 L for MultiRAE).
4) **T (or open tube) method:** The T method uses a T-junction with gas flow higher than the pump draw. The gas supply is connected to one end of the T, the instrument inlet is connected to a second end of the T, and excess gas flow escapes through the third, open end of the T. To prevent ambient air mixing, a long tube should be connected to the open end, or a high excess rate should be used. Alternatively, the instrument probe can be inserted into an open tube slightly wider than the probe. Excess gas flows out around the probe.

The first two cylinder methods are the most efficient in terms of gas usage, while the bag and T methods give slightly more accurate results because they match the pump flow better.

b) Pressure. Pressures deviating from atmospheric pressure affect the readings by altering gas concentration and pump characteristics. It is best to calibrate with the instrument and calibration gas at the same pressure as each other and the sample gas. (Note that the cylinder pressure is not relevant because the regulator reduces the pressure to ambient.) If the instrument is calibrated at atmospheric pressure in one of the flow configurations described above, then 1) pressures slightly above ambient are acceptable but high pressures can damage the pump and 2) samples under vacuum may give low readings if air leaks into the sample train.

c) Temperature. Because temperature effects gas density and concentration, the temperature of the calibration gas and instrument should be as close as possible to the ambient temperature where the unit will be used. We recommend that the temperature of the calibration gas be within the instrument's temperature specification (typically 14° to 113° F or -10° to 45° C). Also, during actual measurements, the instrument should be kept at the same or higher temperature than the sample temperature to avoid condensation in the unit.

d) Matrix. The matrix gas of the calibration compound and VOC sample is significant. Some common matrix components, such as methane and water vapor can affect the VOC signal. PIDs are most commonly used for monitoring VOCs in air, in which case the preferred calibration gas matrix is air. For a MiniRAE, methane, methanol, and water vapor reduce the response by about 20% when their concentration is 15,000 ppm and by about 40% at 30,000 ppm. Despite earlier reports of oxygen effects, RAE PID responses with 10.6 eV lamps are independent of oxygen concentration, and calibration gases in a pure nitrogen matrix can be used. H_2 and CO_2 up to 5 volume % also have no effect.

e) Concentration. Although RAE Systems PIDs have electronically linearized output, it is best to calibrate in a concentration range close to the actual measurement range. For example, 100 ppm standard gas for anticipated vapors of 0 to 250 ppm, and 500 ppm standard for expected concentrations of 250 to 1000 ppm. The correction factors in this table were typically measured at 50 to 100 ppm and apply from the ppb range up to about 1000 ppm. Above 1000 ppm the CF may vary and it is best to calibrate with the gas of interest near the concentration of interest.

f) Filters. Filters affect flow and pressure conditions and therefore all filters to be used during sampling should also be in place during calibration. Using a water trap (hydrophobic filter) greatly reduces the chances of drawing water aerosols or dirt particles into the instrument. Regular filter replacements are recommended because dirty filters can adsorb VOCs and cause slower response time and shifts in calibration.

g) Instrument Design. High-boiling ("heavy") or very reactive compounds can be lost by reaction or adsorption onto materials in the gas sample train, such as filters, pumps and other sensors. Multi-gas meters, including EntryRAE, MultiRAE and AreaRAE have the pump and other sensors upstream of the PID and are prone to these losses. Compounds possibly affected by such losses are shown in green in the table, and may give slow response, or in extreme cases, no response at all. In many cases the multi-gas meters can still give a rough indication of the relative concentration, without giving an accurate, quantitative reading. The ppbRAE and MiniRAE series instruments have inert sample trains and therefore do not exhibit significant loss; nevertheless, response may be slow for the very heavy compounds and additional sampling time up to a minute or more should be allowed to get a stable reading.

Table Abbreviations:

CF = Correction Factor (multiply by reading to get corrected value for the compound when calibrated to isobutylene)
NR= No Response
IE = Ionization Energy (values in parentheses are not well established)
C = Confirmed Value indicated by "+" in this column; all others are preliminary or estimated values and are subject to change
ne = Not Established ACGIH 8-hr. TWA
C## = Ceiling value, given where 8-hr.TWA is not available

Disclaimer:

Actual readings may vary with age and cleanliness of lamp, relative humidity, and other factors. For accurate work, the instrument should be calibrated regularly under the operating conditions used. The factors in this table were measured in dry air at room temperature, typically at 50-100 ppm. CF values may vary above about 1000 ppm.

Updates:

The values in this table are subject to change as more or better data become available. Watch for updates of this table on the Internet at **http://www.raesystems.com**

IE data are taken from the CRC Handbook of Chemistry and Physics, 73rd Edition, D.R. Lide (Ed.), CRC Press (1993) and NIST Standard Ref. Database 19A, NIST Positive Ion Energetics, Vers. 2.0, Lias, et.al., U.S. Dept. Commerce (1993). Exposure limits (8-h TWA and Ceiling Values) are from the 2005 ACGIH Guide to Occupational Exposure Values, ACGIH, Cincinnati, OH 2005. Equations for exposure limits for mixtures of chemicals were taken from the 1997 TLVs and BEIs handbook published by the ACGIH (1997).

Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Acetaldehyde		75-07-0	C_2H_4O	NR	+	6	+	3.3	+	10.23	C25
Acetic acid	Ethanoic Acid	64-19-7	$C_2H_4O_2$	NR	+	22	+	2.6	+	10.66	10
Acetic anhydride	Ethanoic Acid Anhydride	108-24-7	$C_4H_6O_3$	NR	+	6.1	+	2.0	+	10.14	5
Acetone	2-Propanone	67-64-1	C_3H_6O	1.2	+	1.1	+	1.4	+	9.71	500
Acetone cyanohydrin	2-Hydroxyisobutyronitrile	75-86-5	C_4H_7NO					4	+	11.1	C5
Acetonitrile	Methyl cyanide, Cyanomethane	75-05-8	C_2H_3N					100		12.19	40
Acetylene	Ethyne	74-86-2	C_2H_2					2.1	+	11.40	ne
Acrolein	Propenal	107-02-8	C_3H_4O	42	+	3.9	+	1.4	+	10.10	0.1
Acrylic acid	Propenoic Acid	79-10-7	$C_3H_4O_2$			12	+	2.0	+	10.60	2
Acrylonitrile	Propenenitrile	107-13-1	C_3H_3N			NR	+	1.2	+	10.91	2
Allyl alcohol		107-18-6	C_3H_6O	4.5	+	2.4	+	1.6	+	9.67	2
Allyl chloride	3-Chloropropene	107-05-1	C_3H_5Cl			4.3		0.7		9.9	1
Ammonia		7664-41-7	H_3N	NR	+	9.7	+	5.7	+	10.16	25
Amyl acetate	mix of n-Pentyl acetate & 2-Methylbutyl acetate	628-63-7	$C_7H_{14}O_2$	11	+	2.3	+	0.95	+	<9.9	100
Amyl alcohol	1-Pentanol	75-85-4	$C_5H_{12}O$			5		1.6		10.00	ne
Aniline	Aminobenzene	62-53-3	C_7H_7N	0.50	+	0.48	+	0.47	+	7.72	2
Anisole	Methoxybenzene	100-66-3	C_7H_8O	0.89	+	0.58	+	0.56	+	8.21	ne
Arsine	Arsenic trihydride	7784-42-1	AsH_3			1.9	+			9.89	0.05
Benzaldehyde		100-52-7	C_7H_6O					1		9.49	ne
Benzenamine, N-methyl-	N-Methylphenylamine	100-61-8	C_7H_9N			0.7				7.53	
Benzene		71-43-2	C_6H_6	0.55	+	0.53	+	0.6	+	9.25	0.5
Benzonitrile	Cyanobenzene	100-47-0	C_7H_5N			1.6				9.62	ne
Benzyl alcohol	α-Hydroxytoluene, Hydroxymethylbenzene, Benzenemethanol	100-51-6	C_7H_8O	1.4	+	1.1	+	0.9	+	8.26	ne
Benzyl chloride	α-Chlorotoluene, Chloromethylbenzene	100-44-7	C_7H_7Cl	0.7	+	0.6	+	0.5	+	9.14	1
Benzyl formate	Formic acid benzyl ester	104-57-4	$C_8H_8O_2$	0.9	+	0.73	+	0.66	+		ne
Boron trifluoride		7637-07-2	BF_3	NR		NR		NR		15.5	C1
Bromine		7726-95-6	Br_2	NR	+	1.30	+	0.74	+	10.51	0.1
Bromobenzene		108-86-1	C_6H_5Br			0.6		0.5		8.98	ne
2-Bromoethyl methyl ether		6482-24-2	C_3H_7OBr			0.84	+			~10	ne
Bromoform	Tribromomethane	75-25-2	$CHBr_3$	NR	+	2.5	+	0.5	+	10.48	0.5
Bromopropane,1-	n-Propyl bromide	106-94-5	C_3H_7Br	150	+	1.5	+	0.6	+	10.18	ne
Butadiene	1,3-Butadiene, Vinyl ethylene	106-99-0	C_4H_6	0.8		0.85	+	1.1		9.07	2
Butadiene diepoxide, 1,3-	1,2,3,4-Diepoxybutane	298-18-0	$C_4H_6O_2$	25	+	3.5	+	1.2		~10	ne
Butanal	1-Butanal	123-72-8	C_4H_8O			1.8				9.84	
Butane		106-97-8	C_4H_{10}			67	+	1.2		10.53	800
Butanol, 1-	Butyl alcohol, n-Butanol	71-36-3	$C_4H_{10}O$	70	+	4.7	+	1.4	+	9.99	20
Butanol, t-	tert-Butanol, t-Butyl alcohol	75-65-0	$C_4H_{10}O$	6.9	+	2.9	+			9.90	100
Butene, 1-	1-Butylene	106-98-9	C_4H_8			0.9				9.58	ne
Butoxyethanol, 2-	Butyl Cellosolve, Ethylene glycol monobutyl ether	111-76-2	$C_6H_{14}O_2$	1.8	+	1.2	+	0.6	+	<10	25
Butoxyethanol acetate	Ethanol, 2-(2-butoxyethoxy)-, acetate	124-17-4	$C_{10}H_{20}O_4$			5.6				≤10.6	
Butoxyethoxyethanol	2-(2-Butoxyethoxy)ethanol	112-34-5	$C_8H_{18}O_3$			4.6				≤10.6	
Butyl acetate, n-		123-86-4	$C_6H_{12}O_2$			2.6	+			10	150
Butyl acrylate, n-	Butyl 2-propenoate, Acrylic acid butyl ester	141-32-2	$C_7H_{12}O_2$			1.6	+	0.6	+		10
Butylamine, n-		109-73-9	$C_4H_{11}N$	1.1	+	1.1	+	0.7	+	8.71	C5
Butyl cellosolve	see 2-Butoxyethanol	111-76-2									
Butyl hydroperoxide, t-		75-91-2	$C_4H_{10}O_2$	2.0	+	1.6	+			<10	1
Butyl mercaptan	1-Butanethiol	109-79-5	$C_4H_{10}S$	0.55	+	0.52	+			9.14	0.5
Carbon disulfide		75-15-0	CS_2	4	+	1.2	+	0.44		10.07	10
Carbon tetrachloride	Tetrachloromethane	56-23-5	CCl_4	NR	+	NR	+	1.7	+	11.47	5
Carbonyl sulfide	Carbon oxysulfide	463-58-1	COS							11.18	
Cellosolve see 2-Ethoxyethanol											
CFC-14 see Tetrafluoromethane											
CFC-113 see 1,1,2-Trichloro-1,2,2-trifluoroethane											

Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Chlorine		7782-50-5	Cl_2					1.0	+	11.48	0.5
Chlorine dioxide		10049-04-4	ClO_2	NR	+	NR	+	NR	+	10.57	0.1
Chlorobenzene	Monochlorobenzene	108-90-7	C_6H_5Cl	0.44	+	0.40	+	0.39	+	9.06	10
Chlorobenzotrifluoride, 4-	PCBTF, OXSOL 100 p-Chlorobenzotrifluoride	98-56-6	$C_7H_4ClF_3$	0.74	+	0.63	+	0.55	+	<9.6	25
Chloro-1,3-butadiene, 2-	Chloroprene	126-99-8	C_4H_5Cl			3					10
Chloro-1,1-difluoroethane, 1-	HCFC-142B, R-142B	75-68-3	$C_2H_3ClF_2$	NR		NR		NR		12.0	ne
Chlorodifluoromethane	HCFC-22, R-22	75-45-6	$CHClF_2$	NR		NR		NR		12.2	1000
Chloroethane	Ethyl chloride	75-00-3	C_2H_5Cl	NR	+	NR	+	1.1	+	10.97	100
Chloroethanol	Ethylene chlrohydrin	107-07-3	C_2H_5ClO					2.9		10.52	C1
Chloroethyl ether, 2-	bis(2-chloroethyl) ether	111-44-4	$C_4H_8Cl_2O$	8.6	+	3.0	+				5
Chloroethyl methyl ether, 2-	Methyl 2-chloroethyl ether	627-42-9	C_3H_7ClO			3					ne
Chloroform	Trichloromethane	67-66-3	$CHCl_3$	NR	+	NR	+	3.5	+	11.37	10
Chloro-2-methylpropene, 3-	Methallyl chloride, Isobutenyl chloride	563-47-3	C_4H_7Cl	1.4	+	1.2	+	0.63	+	9.76	ne
Chloropicrin		76-06-2	CCl_3NO_2	NR	+	~400	+	7	+	?	0.1
Chlorotoluene, o-	o-Chloromethylbenzene	95-49-8	C_7H_7Cl			0.5		0.6		8.83	50
Chlorotoluene, p-	p-Chloromethylbenzene	106-43-4	C_7H_7Cl					0.6		8.69	ne
Chlorotrifluoroethene	CTFE, Chlorotrifluoroethylene Genetron 1113	79-38-9	C_2ClF_3	6.7	+	3.9	+	1.2	+	9.76	5
Chlorotrimethylsilane		75-77-4	C_3H_9ClSi	NR		NR		0.82	+	10.83	ne
Cresol, m-	m-Hydroxytoluene	108-39-4	C_7H_8O	0.57	+	0.50	+	0.57	+	8.29	5
Cresol, o-	o-Hydroxytoluene	95-48-7	C_7H_8O			1.0				8.50	
Cresol, p-	p-Hydroxytoluene	106-44-5	C_7H_8O			1.4				8.35	
Crotonaldehyde	*trans*-2-Butenal	123-73-9 4170-30-3	C_4H_6O	1.5	+	1.1	+	1.0	+	9.73	2
Cumene	Isopropylbenzene	98-82-8	C_9H_{12}	0.58	+	0.54	+	0.4	+	8.73	50
Cyanogen bromide		506-68-3	CNBr	NR		NR		NR		11.84	ne
Cyanogen chloride		506-77-4	CNCl	NR		NR		NR		12.34	C0.3
Cyclohexane		110-82-7	C_6H_{12}	3.3	+	1.4	+	0.64	+	9.86	300
Cyclohexanol	Cyclohexyl alcohol	108-93-0	$C_6H_{12}O$	1.5	+	0.9	+	1.1	+	9.75	50
Cyclohexanone		108-94-1	$C_6H_{10}O$	1.0	+	0.9	+	0.7	+	9.14	25
Cyclohexene		110-83-8	C_6H_{10}			0.8	+			8.95	300
Cyclohexylamine		108-91-8	$C_6H_{13}N$			1.2				8.62	10
Cyclopentane 85% 2,2-dimethylbutane 15%		287-92-3	C_5H_{10}	NR	+	15	+	1.1		10.33	600
Cyclopropylamine	Aminocyclpropane	765-30-0	C_3H_7N	1.1	+	0.9	+	0.9	+		ne
Decamethylcyclopentasiloxane		541-02-6	$C_{10}H_{30}O_5Si_5$	0.16	+	0.13	+	0.12	+		ne
Decamethyltetrasiloxane		141-62-8	$C_{10}H_{30}O_3Si_4$	0.17	+	0.13	+	0.12	+	<10.2	ne
Decane		124-18-5	$C_{10}H_{22}$	4.0	+	1.4	+	0.35	+	9.65	ne
Diacetone alcohol	4-Methyl-4-hydroxy-2-pentanone	123-42-2	$C_6H_{12}O_2$			0.7					50
Dibromochloromethane	Chlorodibromomethane	124-48-1	$CHBr_2Cl$	NR	+	5.3	+	0.7	+	10.59	ne
Dibromo-3-chloropropane, 1,2-	DBCP	96-12-8	$C_3H_5Br_2Cl$	NR	+	1.7	+	0.43	+		0.001
Dibromoethane, 1,2-	EDB, Ethylene dibromide, Ethylene bromide	106-93-4	$C_2H_4Br_2$	NR	+	1.7	+	0.6	+	10.37	ne
Dichlorobenzene, o-	1,2-Dichlorobenzene	95-50-1	$C_6H_4Cl_2$	0.54	+	0.47	+	0.38	+	9.08	25
Dichlorodifluoromethane	CFC-12	75-71-8	CCl_2F_2			NR	+	NR	+	11.75	1000
Dichlorodimethylsilane		75-78-5	$C_2H_6Cl_2Si$	NR		NR		1.1	+	>10.7	ne
Dichloroethane, 1,2-	EDC, 1,2-DCA, Ethylene dichloride	107-06-2	$C_2H_4Cl_2$			NR	+	0.6	+	11.04	10
Dichloroethene, 1,1-	1,1-DCE, Vinylidene chloride	75-35-4	$C_2H_2Cl_2$			0.82	+	0.8	+	9.79	5
Dichloroethene, c-1,2-	*c*-1,2-DCE, *cis*-Dichloroethylene	156-59-2	$C_2H_2Cl_2$			0.8				9.66	200
Dichloroethene, t-1,2-	*t*-1,2-DCE, *trans*-Dichloroethylene	156-60-5	$C_2H_2Cl_2$			0.45	+	0.34	+	9.65	200
Dichloro-1-fluoroethane, 1,1-	R-141B	1717-00-6	$C_2H_3Cl_2F$	NR	+	NR	+	2.0	+		ne
Dichloromethane	see Methylene chloride										

Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Dichloropentafluoropropane	AK-225, mix of ~45% 3,3-dichloro-1,1,1,2,2-pentafluoropropane (HCFC-225ca) & ~55% 1,3-Dichloro-1,1,2,2,3-pentafluoropropane (HCFC-225cb)	442-56-0 507-55-1	$C_3HCl_2F_5$	NR	+	NR	+	25	+		ne
Dichloropropane, 1,2-		78-87-5	$C_3H_6Cl_2$					0.7		10.87	75
Dichloro-1-propene, 1,3-		542-75-6	$C_3H_4C_{12}$	1.3	+	0.96	+			<10	1
Dichloro-1-propene, 2,3-		78-88-6	$C_3H_4Cl_2$	1.9	+	1.3	+	0.7	+	<10	ne
Dichloro-1,1,1-trifluoroethane, 2,2-	R-123	306-83-2	$C_2HCl_2F_3$	NR	+	NR	+	10.1	+	11.5	ne
Dichloro-2,4,6-trifluoropyridine, 3,5-	DCTFP	1737-93-5	$C_5Cl_2F_3N$	1.1	+	0.9	+	0.8	+		ne
Dichlorvos *	Vapona; O,O-dimethyl O-dichlorovinyl phosphate	62-73-7	$C_4H_7Cl_2O_4P$			0.9	+			<9.4	0.1
Dicyclopentadiene	DCPD, Cyclopentadiene dimer	77-73-6	$C_{10}H_{12}$	0.57	+	0.48	+	0.43	+	8.8	5
Diesel Fuel		68334-30-5	m.w. 226			0.9	+				11
Diesel Fuel #2 (Automotive)		68334-30-5	m.w. 216	1.3		0.7	+	0.4	+		11
Diethylamine		109-89-7	$C_4H_{11}N$			1	+			8.01	5
Diethylaminopropylamine, 3-		104-78-9	$C_7H_{18}N_2$			1.3					ne
Diethylbenzene	See Dowtherm J										
Diethylmaleate		141-05-9	$C_8H_{12}O_4$			4					ne
Diethyl sulfide	see Ethyl sulfide										
Diglyme	See Methoxyethyl ether	111-96-6	$C_6H_{14}O_3$								
Diisobutyl ketone	DIBK, 2,2-dimethyl-4-heptanone	108-83-8	$C_9H_{18}O$	0.71	+	0.61	+	0.35	+	9.04	25
Diisopropylamine		108-18-9	$C_6H_{15}N$	0.84	+	0.74	+	0.5	+	7.73	5
Diketene	Ketene dimer	674-82-8	$C_4H_4O_2$	2.6	+	2.0	+	1.4	+	9.6	0.5
Dimethylacetamide, N,N-	DMA	127-19-5	C_4H_9NO	0.87	+	0.8	+	0.8	+	8.81	10
Dimethylamine		124-40-3	C_2H_7N			1.5				8.23	5
Dimethyl carbonate	Carbonic acid dimethyl ester	616-38-6	$C_3H_6O_3$	NR	+	~70	+	1.7	+	~10.5	ne
Dimethyl disulfide	DMDS	624-92-0	$C_2H_6S_2$	0.2	+	0.20	+	0.21	+	7.4	ne
Dimethyl ether	see Methyl ether										
Dimethylethylamine	DMEA	598-56-1	$C_4H_{11}N$	1.1	+	1.0	+	0.9	+	7.74	~3
Dimethylformamide, N,N-	DMF	68-12-2	C_3H_7NO	0.7	+	0.7	+	0.8	+	9.13	10
Dimethylhydrazine, 1,1-	UDMH	57-14-7	$C_2H_8N_2$			0.8	+	0.8	+	7.28	0.01
Dimethyl methylphosphonate	DMMP, methyl phosphonic acid dimethyl ester	756-79-6	$C_3H_9O_3P$	NR	+	4.3	+	0.74	+	10.0	ne
Dimethyl sulfate		77-78-1	$C_2H_6O_4S$	~23		~20	+	2.3	+		0.1
Dimethyl sulfide	see Methyl sulfide										
Dimethyl sulfoxide	DMSO, Methyl sulfoxide	67-68-5	C_2H_6OS			1.4	+			9.10	ne
Dioxane, 1,4-		123-91-1	$C_4H_8O_2$			1.3				9.19	25
Dioxolane, 1,3-	Ethylene glycol formal	646-06-0	$C_3H_6O_2$	4.0	+	2.3	+	1.6	+	9.9	20
Dowtherm A see Therminol® *											
Dowtherm J (97% Diethylbenzene) *		25340-17-4	$C_{10}H_{14}$			0.5					
DS-108F Wipe Solvent	Ethyl lactate/Isopar H/ Propoxypropanol ~7:2:1	97-64-3 64742-48-9 1569-01-3	m.w. 118	3.3	+	1.6	+	0.7	+		ne
Epichlorohydrin	ECH Chloromethyloxirane, 1-chloro2,3-epoxypropane	106-89-8	C_2H_5ClO	~200	+	8.5	+	1.4	+	10.2	0.5
Ethane		74-84-0	C_2H_6			NR	+	15	+	11.52	ne
Ethanol	Ethyl alcohol	64-17-5	C_2H_6O			10	+	3.1	+	10.47	1000
Ethanolamine *	MEA, Monoethanolamine	141-43-5	C_2H_7NO	5.6	+	1.6	+			8.96	3
Ethene	Ethylene	74-85-1	C_2H_4			9	+	4.5	+	10.51	ne
Ethoxyethanol, 2-	Ethyl cellosolve	110-80-5	$C_4H_{10}O_2$			1.3				9.6	5
Ethyl acetate		141-78-6	$C_4H_8O_2$			4.6	+	3.5		10.01	400
Ethyl acetoacetate		141-97-9	$C_6H_{10}O_3$	1.4	+	1.2	+	1.0	+	<10	ne
Ethyl acrylate		140-88-5	$C_5H_8O_2$			2.4	+	1.0	+	<10.3	5
Ethylamine		75-04-7	C_2H_7N			0.8				8.86	5

Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (Ev)	TWA
Ethylbenzene		100-41-4	C_8H_{10}	0.52	+	0.52	+	0.51	+	8.77	100
Ethyl caprylate	Ethyl octanoate	106-32-1	$C_{10}H_{20}O_2$		+	0.52	+	0.51	+		
Ethylenediamine	1,2-Ethanediamine; 1,2-Diaminoethane	107-15-3	$C_2H_8N_2$	0.9	+	0.8	+	1.0	+	8.6	10
Ethylene glycol *	1,2-Ethanediol	107-21-1	$C_2H_6O_2$			16	+	6	+	10.16	C100
Ethylene glycol, Acrylate	2-hydroxyethyl Acrylate	818-61-1	$C_5H_8O_3$			8.2				≤10.6	
Ethylene glycol dimethyl ether	1,2-Dimethoxyethane, Monoglyme	110-71-4	$C_4H_{10}O_2$	1.1		0.86		0.7		9.2	ne
Ethylene glycol monobutyl ether acetate	2-Butoxyethyl acetate	112-07-2	$C_8H_{16}O_3$			1.3				≤10.6	
Ethylene glycol, monothio	mercapto-2-ethanol	60-24-2	C_2H_6OS			1.5				9.65	
Ethylene oxide	Oxirane, Epoxyethane	75-21-8	C_2H_4O			13	+	3.5	+	10.57	1
Ethyl ether	Diethyl ether	60-29-7	$C_4H_{10}O$			1.1	+	1.7		9.51	400
Ethyl 3-ethoxypropionate	EEP	763-69-9	$C_7H_{14}O_3$	1.2	+	0.75	+				ne
Ethyl formate		109-94-4	$C_3H_6O_2$					1.9		10.61	100
Ethylhexyl □acrylate, 2-	Acrylic acid 2-ethylhexyl ester	103-11-7	$C_{11}H_{20}O_2$			1.1	+	0.5	+		ne
Ethylhexanol	2-Ethyl-1-hexanol	104-76-7	$C8H_{18}O$			1.9				≤10.6	
Ethylidenenorbornene	5-Ethylidene bicyclo(2,2,1)hept-2-ene	16219-75-3	C_9H_{12}	0.4	+	0.39	+	0.34	+	≤8.8	ne
Ethyl (S)-(-)-lactate see also DS-108F	Ethyl lactate, Ethyl (S)-(-)-hydroxypropionate	687-47-8 97-64-3	$C_5H_{10}O_3$	13	+	3.2	+	1.6	+	~10	ne
Ethyl mercaptan	Ethanethiol	75-08-1	C_2H_6S	0.60	+	0.56	+			9.29	0.5
Ethyl sulfide	Diethyl sulfide	352-93-2	$C_4H_{10}S$			0.5	+			8.43	ne
Formaldehyde	Formalin	50-00-0	CH_2O	NR	+	NR	+	1.6	+	10.87	C0.3
Formamide		75-12-7	CH_3NO			6.9	+	4		10.16	10
Formic acid		64-18-6	CH_2O_2	NR	+	NR	+	9	+	11.33	5
Furfural	2-Furaldehyde	98-01-1	$C_5H_4O_2$			0.92	+	0.8	+	9.21	2
Furfuryl alcohol		98-00-0	$C_5H_6O_2$			0.80	+			<9.5	10
Gasoline #1		8006-61-9	m.w. 72			0.9	+				300
Gasoline #2, 92 octane		8006-61-9	m.w. 93	1.3	+	1.0	+	0.5	+		300
Glutaraldehyde	1,5-Pentanedial, Glutaric dialdehyde	111-30-8	$C_5H_8O_2$	1.1	+	0.8	+	0.6	+		C0.05
Glycidyl methacrylate	2,3-Epoxypropyl methacrylate	106-91-2	$C_7H_{10}O_3$	2.6	+	1.2	+	0.9	+		0.5
Halothane	2-Bromo-2-chloro-1,1,1-trifluoroethane	151-67-7	$C_2HBrClF_3$					0.6		11.0	50
HCFC-22 see Chlorodifluoromethane											
HCFC-123 see 2,2-Dichloro-1,1,1-trifluoroethane											
HCFC-141B see 1,1-Dichloro-1-fluoroethane											
HCFC-142B see 1-Chloro-1,1-difluoroethane											
HCFC-134A see 1,1,1,2-Tetrafluoroethane											
HCFC-225 see Dichloropentafluoropropane											
Heptane, n-		142-82-5	C_7H_{16}	45	+	2.8	+	0.60	+	9.92	400
Heptanol, 4-	Dipropylcarbinol	589-55-9	$C_7H_{16}O$	1.8	+	1.3	+	0.5	+	9.61	ne
Hexamethyldisilazane, 1,1,1,3,3,3- *	HMDS	999-97-3	$C_6H_{19}NSi_2$			0.2	+	0.2	+	~8.6	ne
Hexamethyldisiloxane	HMDSx	107-46-0	$C_6H_{18}OSi_2$	0.33	+	0.27	+	0.25	+	9.64	ne
Hexane, n-		110-54-3	C_6H_{14}	350	+	4.3	+	0.54	+	10.13	50
Hexanol, 1-	Hexyl alcohol	111-27-3	$C_6H_{14}O$	9	+	2.5	+	0.55	+	9.89	ne
Hexene, 1-		592-41-6	C_6H_{12}			0.8				9.44	30
HFE-7100 see Methyl nonafluorobutyl ether											
Histoclear (Histo-Clear)	Limonene/corn oil reagent		m.w. ~136	0.5	+	0.4	+	0.3	+		ne
Hydrazine *		302-01-2	H_4N_2	>8	+	2.6	+	2.1	+	8.1	0.01
Hydrazoic acid	Hydrogen azide		HN_3							10.7	
Hydrogen	Synthesis gas	1333-74-0	H_2	NR	+	NR	+	NR	+	15.43	ne
Hydrogen cyanide	Hydrocyanic acid	74-90-8	HCN	NR	+	NR	+	NR	+	13.6	C4.7
Hydrogen iodide *	Hydriodic acid	10034-85-2	HI			~0.6*				10.39	
Hydrogen peroxide		7722-84-1	H_2O_2	NR	+	NR	+	NR	+	10.54	1
Hydrogen sulfide		7783-06-4	H_2S	NR	+	3.3	+	1.5	+	10.45	10
Hydroxypropyl methacrylate		27813-02-1 923-26-2	$C_7H_{12}O_3$	9.9	+	2.3	+	1.1	+		ne
Iodine *		7553-56-2	I_2	0.1	+	0.1	+	0.1	+	9.40	C0.1

Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Iodomethane	Methyl iodide	74-88-4	CH_3I	0.21	+	0.22	+	0.26	+	9.54	2
Isoamyl acetate	Isopentyl acetate	123-92-2	$C_7H_{14}O_2$	10.1		2.1		1.0		<10	100
Isobutane	2-Methylpropane	75-28-5	C_4H_{10}			100	+	1.2	+	10.57	ne
Isobutanol	2-Methyl-1-propanol	78-83-1	$C_4H_{10}O$	19	+	3.8	+	1.5		10.02	50
Isobutene	Isobutylene, Methyl butene	115-11-7	C_4H_8	1.00	+	1.00	+	1.00	+	9.24	Ne
Isobutyl acrylate	Isobutyl 2-propenoate	106-63-8	$C_7H_{12}O_2$			1.5	+	0.60	+		Ne
Isoflurane	1-Chloro-2,2,2-trifluoroethyl difluoromethyl ether, forane	26675-46-7	$C_3H_2ClF_5O$	NR	+	NR	+	48	+	~11.7	Ne
Isooctane	2,2,4-Trimethylpentane	540-84-1	C8H18			1.2				9.86	ne
Isopar E Solvent	Isoparaffinic hydrocarbons	64741-66-8	m.w. 121	1.7	+	0.8	+				Ne
Isopar G Solvent	Photocopier diluent	64742-48-9	m.w. 148			0.8	+				Ne
Isopar K Solvent	Isoparaffinic hydrocarbons	64742-48-9	m.w. 156	0.9	+	0.5	+	0.27	+		Ne
Isopar L Solvent	Isoparaffinic hydrocarbons	64742-48-9	m.w. 163	0.9	+	0.5	+	0.28	+		Ne
Isopar M Solvent	Isoparaffinic hydrocarbons	64742-47-8	m.w. 191			0.7	+	0.4	+		Ne
Isopentane	2-Methylbutane	78-78-4	C_5H_{12}			8.2					Ne
Isophorone		78-59-1	$C_9H_{14}O$					3		9.07	C5
Isoprene	2-Methyl-1,3-butadiene	78-79-5	C_5H_8	0.69	+	0.63	+	0.60	+	8.85	Ne
Isopropanol	Isopropyl alcohol, 2-propanol, IPA	67-63-0	C_3H_8O	500	+	6.0	+	2.7		10.12	200
Isopropyl acetate		108-21-4	$C_5H_{10}O_2$			2.6				9.99	100
Isopropyl ether	Diisopropyl ether	108-20-3	$C_6H_{14}O$			0.8				9.20	250
Jet fuel JP-4	Jet B, Turbo B, F-40 Wide cut type aviation fuel	8008-20-6 + 64741-42-0	m.w. 115			1.0	+	0.4	+		Ne
Jet fuel JP-5	Jet 5, F-44, Kerosene type aviation fuel	8008-20-6 + 64747-77-1	m.w. 167			0.6	+	0.5	+		29
Jet fuel JP-8	Jet A-1, F-34, Kerosene type aviation fuel	8008-20-6 + 64741-77-1	m.w. 165			0.6	+	0.3	+		30
Jet fuel A-1 (JP-8)	F-34, Kerosene type aviation fuel	8008-20-6 + 64741-77-1	m.w. 145			0.67					34
Jet Fuel TS	Thermally Stable Jet Fuel, Hydrotreated kerosene fuel	8008-20-6 + 64742-47-8	m.w. 165	0.9	+	0.6	+	0.3	+		30
Limonene, D-	(R)-(+)-Limonene	5989-27-5	$C_{10}H_{16}$			0.33	+			~8.2	Ne
Kerosene C10-C16 petro.distillate – see Jet Fuels		8008-20-6									
MDI – see 4,4'-Methylenebis(phenylisocyanate)											
Maleic anhydride	2,5-Furandione	108-31-6	$C_4H_2O_3$							~10.8	0.1
Mesitylene	1,3,5-Trimethylbenzene	108-67-8	C_9H_{12}	0.36	+	0.35	+	0.3	+	8.41	25
Methallyl chloride – see 3-Chloro-2-methylpropene											
Methane	Natural gas	74-82-8	CH_4	NR	+	NR	+	NR	+	12.61	Ne
Methanol	Methyl alcohol, carbinol	67-56-1	CH_4O	NR	+	NR	+	2.5	+	10.85	200
Methoxyethanol, 2-	Methyl cellosolve, Ethylene glycol monomethyl ether	109-86-4	$C_3H_8O_2$	4.8	+	2.4	+	1.4	+	10.1	5
Methoxyethoxyethanol, 2-	2-(2-Methoxyethoxy)ethanol Diethylene glycol monomethyl ether	111-77-3	$C_7H_{16}O$	2.3	+	1.2	+	0.9	+	<10	Ne
Methoxyethyl ether, 2-	bis(2-Methoxyethyl) ether, Diethylene glycol dimethyl ether, Diglyme	111-96-6	$C_6H_{14}O_3$	0.64	+	0.54	+	0.44	+	<9.8	Ne
Methyl acetate		79-20-9	$C_3H_6O_2$	NR	+	6.6	+	1.4	+	10.27	200
Methyl acrylate	Methyl 2-propenoate, Acrylic acid methyl ester	96-33-3	$C_4H_6O_2$			3.7	+	1.2	+	(9.9)	2
Methylamine	Aminomethane	74-89-5	CH_5N			1.2				8.97	5
Methyl amyl ketone	MAK, 2-Heptanone, Methyl pentyl ketone	110-43-0	$C_7H_{14}O$	0.9	+	0.85	+	0.5	+	9.30	50
Methyl bromide	Bromomethane	74-83-9	CH_3Br	110	+	1.7	+	1.3	+	10.54	1
Methyl t-butyl ether	MTBE, *tert*-Butyl methyl ether	1634-04-4	$C_5H_{12}O$			0.9	+			9.24	40
Methyl cellosolve	see 2-Methoxyethanol										
Methyl chloride	Chloromethane	74-87-3	CH_3Cl	NR	+	NR	+	0.74	+	11.22	50
Methylcyclohexane		107-87-2	C_7H_{14}	1.6	+	0.97	+	0.53	+	9.64	400
Methylene bis(phenyl-isocyanate), 4,4'- *	MDI, Mondur M		$C_{15}H_{10}N_2O_2$	Very slow ppb level response							0.005

Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Methylene chloride	Dichloromethane	75-09-2	CH_2Cl_2	NR	+	NR	+	0.89	+	11.32	25
Methyl ether	Dimethyl ether	115-10-6	C_2H_6O	4.8	+	3.1	+	2.5	+	10.03	Ne
Methyl ethyl ketone	MEK, 2-Butanone	78-93-3	C_4H_8O	0.86	+	0.9	+	1.1	+	9.51	200
Methylhydrazine	Monomethylhydrazine, Hydrazomethane	60-34-4	$C_2H_6N_2$	1.4	+	1.2	+	1.3	+	7.7	0.01
Methyl isoamyl ketone	MIAK, 5-Methyl-2-hexanone	110-12-3	$C_7H_{14}O$	0.8	+	0.76	+	0.5	+	9.28	50
Methyl isobutyl ketone	MIBK, 4-Methyl-2-pentanone	108-10-1	$C_6H_{12}O$	0.9	+	0.8	+	0.6	+	9.30	50
Methyl isocyanate	CH3NCO	624-83-9	C_2H_3NO	NR	+	4.6	+	1.5		10.67	0.02
Methyl isothiocyanate	CH3NCS	551-61-6	C_2H_3NS	0.5	+	0.45	+	0.4	+	9.25	ne
Methyl mercaptan	Methanethiol	74-93-1	CH_4S	0.65		0.54		0.66		9.44	0.5
Methyl methacrylate		80-62-6	$C_5H_8O_2$	2.7	+	1.5	+	1.2	+	9.7	100
Methyl nonafluorobutyl ether	HFE-7100DL	163702-08-7, 163702-07-6	$C_5H_3F_9O$			NR	+	~35	+		ne
Methyl-1,5-pentanediamine, 2- (coats lamp) *	Dytek-A amine, 2-Methyl pentamethylenediamine	15520-10-2	C6H16N2			~0.6	+			<9.0	ne
Methyl propyl ketone	MPK, 2-Pentanone	107-87-9	$C_5H_{12}O$			0.93	+	0.79	+	9.38	200
Methyl-2-pyrrolidinone, N-	NMP, N-Methylpyrrolidone, 1-Methyl-2-pyrrolidinone, 1-Methyl-2-pyrrolidone	872-50-4	C_5H_9NO	1.0	+	0.8	+	0.9	+	*9.17*	ne
Methyl salicylate	Methyl 2-hydroxybenzoate	119-36-8	C_8H_8O3	1.3	+	0.9	+	0.9	+	~9	ne
Methylstyrene, α-	2-Propenylbenzene	98-83-9	C_9H_{10}			0.5				8.18	50
Methyl sulfide	DMS, Dimethyl sulfide	75-18-3	C_2H_6S	0.49	+	0.44	+	0.46	+	8.69	ne
Mineral spirits	Stoddard Solvent, Varsol 1, White Spirits	8020-83-5 8052-41-3 68551-17-7	m.w. 144	1.0		0.69	+	0.38	+		100
Mineral Spirits - Viscor 120B Calibration Fluid, b.p. 156-207°C		8052-41-3	m.w. 142	1.0	+	0.7	+	0.3	+		100
Monoethanolamine - see Ethanolamine											
Mustard *	HD, Bis(2-chloroethyl) sulfide	505-60-2 39472-40-7 68157-62-0	$C_4H_8Cl_2S$			0.6					0.0005
Naphtha - see VM & P Naptha											
Naphthalene	Mothballs	91-20-3	$C_{10}H_8$	0.45	+	0.42	+	0.40	+	8.13	10
Nickel carbonyl (in CO)	Nickel tetracarbonyl	13463-39-3	C_4NiO_4			0.18				<8.8	0.001
Nicotine		54-11-5	$C_{10}H_{14}N_2$			2.0				≤10.6	
Nitric oxide		10102-43-9	NO	~6		5.2	+	2.8	+	9.26	25
Nitrobenzene		98-95-3	$C_6H_5NO_2$	2.6	+	1.9	+	1.6	+	9.81	1
Nitroethane		79-24-3	$C_2H_5NO_2$					3		10.88	100
Nitrogen dioxide		10102-44-0	NO_2	23	+	16	+	6	+	9.75	3
Nitrogen trifluoride		7783-54-2	NF_3	NR		NR		NR		13.0	10
Nitromethane		75-52-5	CH_3NO_2					4		11.02	20
Nitropropane, 2-		79-46-9	$C_3H_7NO_2$					2.6		10.71	10
Nonane		111-84-2	C_9H_{20}			1.4				9.72	200
Norpar 12	n-Paraffins, mostly C_{10}-C_{13}	64771-72-8	m.w. 161	3.2	+	1.1	+	0.28	+		ne
Norpar 13	n-Paraffins, mostly C_{13}-C_{14}	64771-72-8	m.w. 189	2.7	+	1.0	+	0.3	+		ne
Octamethylcyclotetrasiloxane		556-67-2	$C_8H_{24}O_4Si_4$	0.21	+	0.17	+	0.14	+		ne
Octamethyltrisiloxane		107-51-7	$C_8H_{24}O_2Si_3$	0.23	+	0.18	+	0.17	+	<10.0	ne
Octane, n-		111-65-9	C_8H_{18}	13	+	1.8	+			9.82	300
Octene, 1-		111-66-0	C_8H_{16}	0.9	+	0.75	+	0.4	+	9.43	75
Pentane		109-66-0	C_5H_{12}	80	+	8.4	+	0.7	+	10.35	600
Peracetic acid *	Peroxyacetic acid, Acetyl hydroperoxide	79-21-0	$C_2H_4O_3$	NR	+	NR	+	2.3	+		ne
Peracetic/Acetic acid mix *	Peroxyacetic acid, Acetyl hydroperoxide	79-21-0	$C_2H_4O_3$			50	+	2.5	+		ne
Perchloroethene	PCE, Perchloroethylene, Tetrachloroethylene	127-18-4	C_2Cl_4	0.69	+	0.57	+	0.31	+	9.32	25
PGME	Propylene glycol methyl ether, 1-Methoxy-2-propanol	107-98-2	$C_6H_{12}O_3$	2.4	+	1.5	+	1.1	+		100

Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
PGMEA	Propylene glycol methyl ether acetate, 1-Methoxy-2-acetoxypropane, 1-Methoxy-2-propanol acetate	108-65-6	$C_6H_{12}O_3$	1.65	+	1.0	+	0.8	+		ne
Phenol	Hydroxybenzene	108-95-2	C_6H_6O	1.0	+	1.0	+	0.9	+	8.51	5
Phosgene	Dichlorocarbonyl	75-44-5	CCl_2O	NR	+	NR	+	8.5	+	11.2	0.1
Phosgene in Nitrogen	Dichlorocarbonyl	75-44-5	CCl_2O	NR	+	NR	+	6.8	+	11.2	0.1
Phosphine (coats lamp)		7803-51-2	PH_3	28		3.9	+	1.1	+	9.87	0.3
Photocopier Toner	Isoparaffin mix					0.5	+	0.3	+		ne
Picoline, 3-	3-Methylpyridine	108-99-6	C_6H_7N			0.9				9.04	ne
Pinene, α-		2437-95-8	$C_{10}H_{16}$			0.31	+	0.47		8.07	ne
Pinene, β-		18172-67-3	$C_{10}H_{16}$	0.38	+	0.37	+	0.37	+	~8	100
Piperylene, isomer mix	1,3-Pentadiene	504-60-9	C_5H_8	0.76	+	0.69	+	0.64	+	8.6	100
Propane		74-98-6	C_3H_8			NR	+	1.8	+	10.95	2500
Propanol, n-	Propyl alcohol	71-23-8	C_3H_8O			5		1.7		10.22	200
Propene	Propylene	115-07-1	C_3H_6	1.5	+	1.4	+	1.6	+	9.73	ne
Propionaldehyde	Propanal	123-38-6	C_3H_6O			1.9				9.95	ne
Propyl acetate, n-		109-60-4	$C_5H_{10}O_2$			3.5		2.3		10.04	200
Propylamine, n-	1-Propylamine, 1-Aminopropane	107-10-8	C_3H_9N	1.1	+	1.1	+	0.9	+	8.78	ne
Propylene carbonate *		108-32-7	$C_4H_6O_3$			62	+	1	+	10.5	ne
Propylene glycol	1,2-Propanediol	57-55-6	$C_3H_8O_2$	18		5.5	+	1.6	+	<10.2	ne
Propylene glycol propyl ether	1-Propoxy-2-propanol	1569-01-3	$C_6H_{14}O_2$	1.3	+	1.0	+	1.6	+		ne
Propylene oxide	Methyloxirane	75-56-9 16088-62-3 15448-47-2	C_3H_6O	~240		6.6	+	2.9	+	10.22	20
Propyleneimine	2-Methylaziridine	75-55-8	C_3H_7N	1.5	+	1.3	+	1.0	+	9.0	2
Propyl mercaptan, 2-	2-Propanethiol, Isopropyl mercaptan	75-33-2	C_3H_8S	0.64	+	0.66	+			9.15	ne
Pyridine		110-86-1	C_5H_5N	0.78	+	0.7	+	0.7	+	9.25	5
Pyrrolidine (coats lamp)	Azacyclohexane	123-75-1	C_4H_9N	2.1	+	1.3	+	1.6	+	~8.0	ne
RR7300 (PGME/PGMEA)	70:30 PGME:PGMEA (1-Methoxy-2-propanol:1-Methoxy-2-acetoxypropane)	107-98-2	$C_4H_{10}O_2$ / $C_6H_{12}O_3$			1.4	+	1.0	+		ne
Sarin	GB, Isopropyl methylphosphonofluoridate	107-44-8 50642-23-4	$C_4H_{10}FO_2P$			~3					
Stoddard Solvent - see Mineral Spirits		8020-83-5									
Styrene		100-42-5	C_8H_8	0.45	+	0.40	+	0.4	+	8.43	20
Sulfur dioxide		7446-09-5	SO_2	NR		NR	+	NR	+	12.32	2
Sulfur hexafluoride		2551-62-4	SF_6	NR		NR		NR		15.3	1000
Sulfuryl fluoride	Vikane	2699-79-8	SO_2F_2	NR		NR		NR		13.0	5
Tabun *	Ethyl N, N-dimethylphosphoramidocyanidate	77-81-6	$C_5H_{11}N_2O_2P$			0.8					15ppt
Tetrachloroethane, 1,1,1,2-		630-20-6	$C_2H_2Cl_4$					1.3		~11.1	ne
Tetrachloroethane, 1,1,2,2-		79-34-5	$C_2H_2Cl_4$	NR	+	NR	+	0.60	+	~11.1	1
Tetrachlorosilane		10023-04-7	$SiCl_4$	NR		NR		15	+	11.79	ne
Tetraethyl lead	TEL	78-00-2	$C_8H_{20}Pb$	0.4		0.3		0.2		~11.1	0.008
Tetraethyl orthosilicate	Ethyl silicate, TEOS	78-10-4	$C_8H_{20}O_4Si$			0.7	+	0.2	+	~9.8	10
Tetrafluoroethane, 1,1,1,2-	HFC-134A	811-97-2	$C_2H_2F_4$			NR		NR			ne
Tetrafluoroethene	TFE, Tetrafluoroethylene, Perfluoroethylene	116-14-3	C_2F_4			~15				10.12	ne
Tetrafluoromethane	CFC-14, Carbon tetrafluoride	75-73-0	CF_4			NR	+	NR	+	>15.3	ne
Tetrahydrofuran	THF	109-99-9	C_4H_8O	1.9	+	1.7	+	1.0	+	9.41	200
Tetramethyl orthosilicate	Methyl silicate, TMOS	681-84-5	$C_4H_{12}O_4Si$	10	+	1.9	+			~10	1
Therminol® D-12 *	Hydrotreated heavy naphtha	64742-48-9	m.w. 160	0.8	+	0.51	+	0.33	+		ne
Therminol® VP-1 *	Dowtherm A, 3:1 Diphenyl oxide: Biphenyl	101-84-8 92-52-4	$C_{12}H_{10}O$ $C_{12}H_{10}$			0.4	+				1
Toluene	Methylbenzene	108-88-3	C_7H_8	0.54	+	0.50	+	0.51	+	8.82	50

Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Tolylene-2,4-diisocyanate	TDI, 4-Methyl-1,3-phenylene-2,4-diisocyanate	584-84-9	$C_9H_6N_2O_2$	1.4	+	1.4	+	2.0	+		0.002
Trichlorobenzene, 1,2,4-	1,2,4-TCB	120-82-1	$C_6H_3Cl_3$	0.7	+	0.46	+			9.04	C5
Trichloroethane, 1,1,1-	1,1,1-TCA, Methyl chloroform	71-55-6	$C_2H_3Cl_3$			NR	+	1	+	11	350
Trichloroethane, 1,1,2-	1,1,2-TCA	79-00-5	$C_2H_3Cl_3$	NR	+	NR	+	0.9	+	11.0	10
Trichloroethene	TCE, Trichoroethylene	79-01-6	C_2HCl_3	0.62	+	0.54	+	0.43	+	9.47	50
Trichloromethylsilane	Methyltrichlorosilane	75-79-6	CH_3Cl_3Si	NR		NR		1.8	+	11.36	ne
Trichlorotrifluoroethane, 1,1,2-	CFC-113	76-13-1	$C_2Cl_3F_3$			NR		NR		11.99	1000
Triethylamine	TEA	121-44-8	$C_6H_{15}N$	0.95	+	0.9	+	0.65	+	7.3	1
Triethyl borate	TEB; Boric acid triethyl ester	150-46-9	$C_6H_{15}O_3B$			2.2	+	1.1	+	~10	ne
Triethyl phosphate	Ethyl phosphate	78-40-0	$C_6H_{15}O_4P$	~50	+	3.1	+	0.60	+	9.79	ne
Trifluoroethane, 1,1,2-		430-66-0	$C_2H_3F_3$					34		*12.9*	ne
Trimethylamine		75-50-3	C_3H_9N			0.9				7.82	5
Trimethylbenzene, 1,3,5- - see Mesitylene		108-67-8									25
Trimethyl borate	TMB; Boric acid trimethyl ester, Boron methoxide	121-43-7	$C_3H_9O_3B$			5.1	+	1.2	+	10.1	ne
Trimethyl phosphate	Methyl phosphate	512-56-1	$C_3H_9O_4P$			8.0	+	1.3	+	9.99	ne
Trimethyl phosphite	Methyl phosphite	121-45-9	$C_3H_9O_3P$			1.1	+		+	*8.5*	2
Turpentine	Pinenes (85%) + other diisoprenes	8006-64-2	$C_{10}H_{16}$	0.37	+	0.30	+	0.29	+	~8	20
Undecane		1120-21-4	$C_{11}H_{24}$			2				9.56	ne
Varsol – see Mineral Spirits											
Vinyl actetate		108-05-4	$C_4H_6O_2$	1.5	+	1.2	+	1.0	+	9.19	10
Vinyl bromide	Bromoethylene	593-60-2	C_2H_3Br			0.4				9.80	5
Vinyl chloride	Chloroethylene, VCM	75-01-4	C_2H_3Cl			2.0	+	0.6	+	9.99	5
Vinyl-1-cyclohexene, 4-	Butadiene dimer, 4-Ethenylcyclohexene	100-40-3	C_8H_{12}	0.6	+	0.56	+			9.83	0.1
Vinylidene chloride - see 1,1-Dichloroethene											
Vinyl-2-pyrrolidinone, 1-	NVP, N-vinylpyrrolidone, 1-ethenyl-2-pyrrolidinone	88-12-0	C_6H_9NO	1.0	+	0.8	+	0.9	+		ne
Viscor 120B - see Mineral Spirits - Viscor 120B Calibration Fluid											
V. M. & P. Naphtha	Ligroin; Solvent naphtha; Varnish maker's & painter's naptha	64742-89-8	m.w. 111 (C_8-C_9)	1.7	+	0.97	+				300
Xylene, m-	1,3-Dimethylbenzene	108-38-3	C_8H_{10}	0.50	+	0.44	+	0.40	+	8.56	100
Xylene, o-	1,2-Dimethylbenzene	95-47-6	C_8H_{10}	0.56	+	0.46	+	0.43		8.56	100
Xylene, p-	1,4-Dimethylbenzene	106-42-3	C_8H_{10}	0.48	+	0.39	+	0.38	+	8.44	100
None				1		1		1			
Undetectable				1E+6		1E+6		1E+6			

* Compounds indicated in green can be detected using a MiniRAE 2000 or ppbRAE/+ with slow response, but may be lost by adsorption on a MultiRAE or EntryRAE. Response on multi-gas meters can give an indication of relative concentrations, but may not be quantitative and for some chemicals no response is observed.

Therminol® is a registered Trademark of Solutia, Inc.

Appendix I:
Example of Automatic Calculation of Correction Factors, TLVs and Alarm Limits for Mixtures
(Calculations performed using Excel version of this database, available on request)

Compound	CF 9.8 eV	CF 10.6 eV	CF 11.7eV	Mol. Frac	Conc ppm	TLV ppm	STEL Ppm
Benzene	0.55	0.53	0.6	0.01	1	0.5	2.5
Toluene	0.54	0.5	0.51	0.06	10	50	150
Hexane, n-	300	4.3	0.54	0.06	10	50	150
Heptane, n-	45	2.8	0.6	0.28	50	400	500
Styrene	0.45	0.4	0.42	0.06	10	20	40
Acetone	1.2	1.1	1.4	0.28	50	750	1000
Isopropanol	500	6	2.7	0.28	50	400	500
None	1	1	1	0.00	0	1	
Mixture Value:	2.1	1.5	0.89	1.00	181 ppm	56 ppm	172 ppm
TLV Alarm Setpoint when Calibrated to Isobutylene:	26 ppm	37 ppm	62 ppm				
STEL Alarm Setpoint, same Calibration	86 ppm	115 ppm	193 ppm				

Appendix C Recent Groundwater Sampling Data

2022 Annual Report

Fox Avenue Site

Seattle, Washington

Prepared for:
Fox Avenue Building LLC
6900 Fox Avenue S.
Seattle, Washington 98108

Prepared by:
CALIBRE Systems, Inc.
16935 SE 39th St.
Bellevue, Washington 98008

October 2022

Project No. T0014129

Table 3.1 - 2022 Summary of Volatile Organic Compound Data in Groundwater

	WBZ	Sample Depth	Analyte	PCE		TCE		cis-1,2-DCE		trans-1,2-DCE		Vinyl chloride		Total CVOCs	TOC	
Current CUL				***3.3***		***30***		***--***		***--***		***2.4***				
AWQC from WAC 173-201a-240				***7.1***		***0.86***		***--***		***--***		***0.26***				
Location		**ft bgs**	**Sample Date**	**µg/L**		**µg/L**		**µg/L**		**µg/L**		**µg/L**		**µg/L**	**mg/L**	
Source Area																
R0-IW02D	2nd	62	7/19/2022	<0.4	U	<0.5	U	18.8		<0.5	U	<0.2	U	**18.8**	--	
R0-IW3D	2nd	63	7/19/2022	7.11		<0.5	U	277		2.47		279		**566**	3,940	
R0-IW7D	2nd	63	7/19/2022	5.78		11.4		98.2		1.72		42.8		**160**	1,250	
MW-18S	1st	18	7/19/2022	3.20		0.873		41.6		1.06		52.8		**99.5**	--	
MW-16D	2nd	63	8/22/2022	0.41		<0.5	U	0.76		<0.5	U	<0.2	U	**1.16**	--	
Whitehead																
MW-10	2nd	28	7/19/2022	<0.4	U	<0.5	U	<0.5	U	<0.5	U	<0.2	U	**0**	--	
MW-9	1st	11	7/19/2022	<0.4	U	<0.5	U	19.0		1.10		45.8		**65.9**	8.45	
MW-9 (DUP)	1st	11	7/19/2022	<0.4	U	<0.5	U	19.2		1.58		57	E	**77.8**	--	
MW-7	1st	12	7/19/2022	<0.4	U	<0.5	U	0.523		<0.5	U	<0.2	U	**0.52**	--	
B-49	1st	13.5	7/19/2022	5.28		1.34		0.881		<0.5	U	2.23		**9.73**	--	
Northwest Corner																
NW1-1	1st	11	7/18/2022	<0.4	U	<0.5	U	47.3		<0.5	U	77.1		**124**	--	
B-22	1st	10	7/18/2022	86.2		19.1		79.9		0.663		4.94		**191**	--	
B-22 (DUP)	1st	10	7/18/2022	91.3		18.2		83.1		<5	U	<2	U	**193**	--	
R1-IW9	1st	11	7/18/2022	11.4		4.82		778		6.78		26.4		**827**	445	
R1-IW12	1st	11	7/19/2022	<0.4	U	<0.5	U	66.2		<0.5	U	72		**138**	26.6	
B-54	1st	12	8/22/2022	617	E	22		13.5		<0.5	U	<0.2	U	**653**	--	
B-54 (dupe)	1st	12	8/22/2022	602		21.8		14		<0.5	U	<0.2	U	**638**	--	
B-66	1st	14	8/22/2022	374	E	35		7.39		<0.5	U	<0.2	U	**416**	--	
Fox Avenue Row 1 Injection Transect																
R1-IW3a	1st	10	8/22/2022	0.62		<0.5	U	50.7	D	<0.5	U	14.6		**65.9**	--	
R1-IW4a	1st	11	7/18/2022	<0.4	U	<0.5	U	2.98		<0.5	U	2.66		**5.64**	16.0	
B-20a	1st	14	7/18/2022	<0.4	U	<0.5	U	35.0		1.54		4.83		**41.4**	--	
B-19	2nd	45	7/18/2022	<0.4	U	<0.5	U	8.96		<0.5	U	9.64		**18.6**	--	
B-18	1st	14	8/22/2022	0.54		<0.5	U	32		<0.5	U	73.8	D	**106**	--	
Fox Avenue Row 1 Monitoring Transect																
B-58	1st	11	7/18/2022	59	E	11.8		30.4		<0.5	U	7.62		**109**	--	
B-60	1st	11	8/22/2022	0.86		1.35		17.7		<0.5	U	0.48		**20.4**	--	
B-61	2nd	42	8/22/2022	<0.4	U	<0.5	U	<0.5	U	<0.5	U	<0.2	U	**0**	--	
B-62	1st	11	8/22/2022	1.11		<0.5	U	<0.5	U	<0.5	U	<0.2	U	**1.11**	--	
B-63	2nd	42	8/22/2022	<0.4	U	<0.5	U	<0.5	U	<0.5	U	<0.2	U	**0**	--	
Seattle Boiler Works																
R2-IW1	1st	17	7/13/2022	<0.4	U	<0.5	U	2.61		<0.5	U	0.811		**3.42**	350	
R2-IW1	2nd	45	7/13/2022	<0.4	U	<0.5	U	2.65		<0.5	U	0.864		**3.51**	389	
R2-IW2	1st	17	7/18/2022	<0.4	U	<0.5	U	<0.5	U	<0.5	U	<0.2	U	**0**	--	
R2-IW2	2nd	45	7/18/2022	<0.4	U	<0.5	U	3.22		<0.5	U	<0.2	U	**3.22**	--	
R2-IW9	1st	12	7/18/2022	<0.4	U	0.567		1.72		<0.5	U	<0.2	U	**2.29**	--	
R2-IW10	2nd	37	8/22/2022	<0.4	U	<0.5	U	1.66		<0.5	U	0.51		**2.17**	--	
MW-3	1st	10	7/18/2022	1.77		1.31		1.31		<0.5	U	<0.2	U	**4.39**	--	
MW-4	2nd	40	7/18/2022	<0.4	U	<0.5	U	<0.5	U	<0.5	U	<0.2	U	**0**	--	
MW-5	1st	13	8/22/2022	0.41		<0.5	U	<0.5	U	<0.5	U	<0.2	U	**0.41**	--	
MW-6	2nd	40	7/13/2022	9.23		8.0		57.6		0.596		0.943		**76.4**	--	
DUP (MW-6)	2nd	40	7/13/2022	10.1		8.2		62	E	0.791		1.09		**82.1**	--	
Myrtle St																
R2-IW6	2nd	45	7/18/2022	<0.4	U	<0.5	U	<0.5	U	<0.5	U	<0.2	U	**0**	--	
B-35	2nd	27	7/18/2022	<0.4	U	<0.5	U	<0.5	U	<0.5	U	<0.2	U	**0**	--	
B-64	1st	10	7/18/2022	<0.4	U	<0.5	U	1.15		<0.5	U	<0.2	U	**1.15**	--	
B-33a	2nd	30	7/18/2022	<0.4	U	<0.5	U	<0.5	U	<0.5	U	<0.2	U	**0**	--	

Table 3.1 - 2022 Summary of Volatile Organic Compound Data in Groundwater

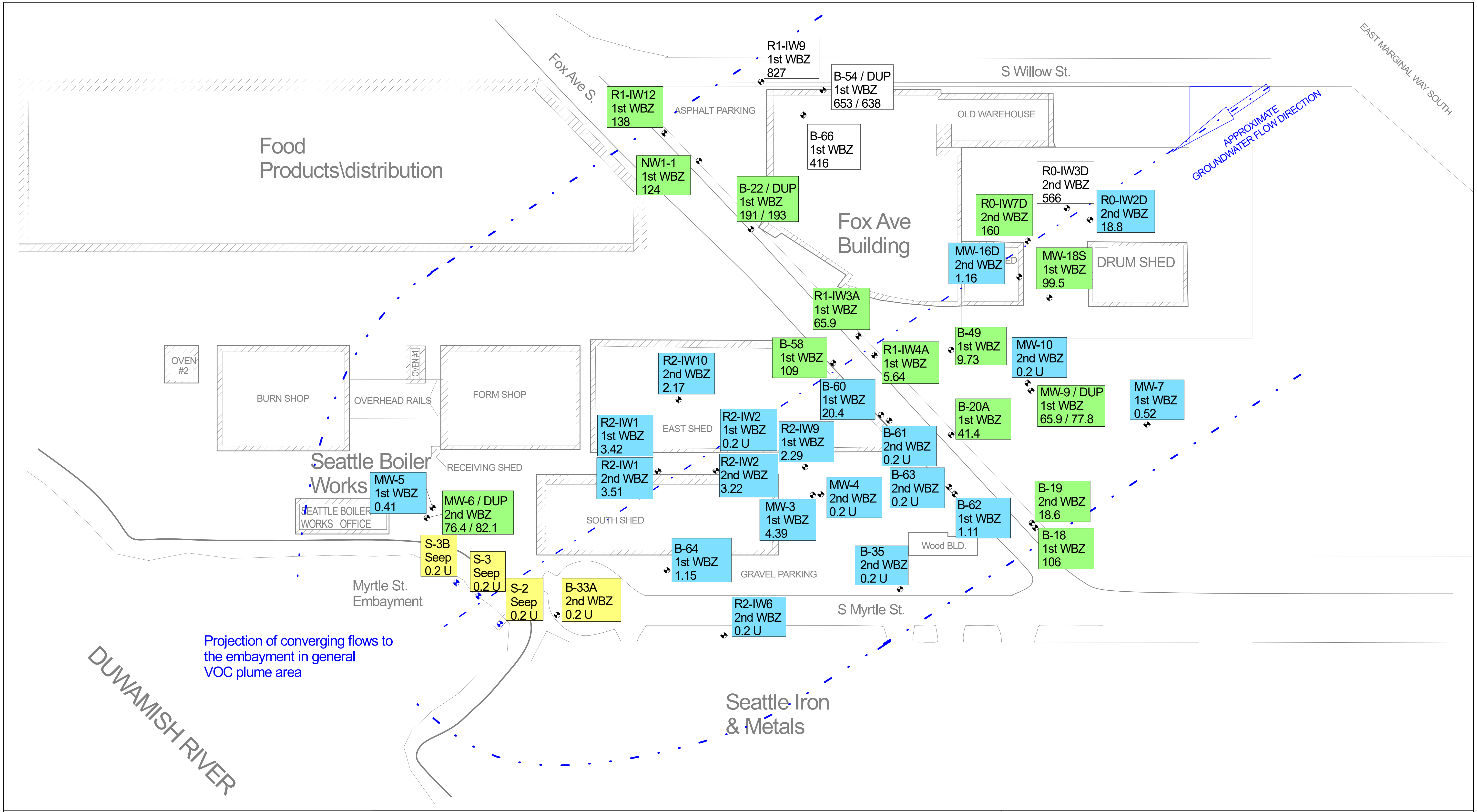
	WBZ	Sample Depth	Analyte	PCE		TCE		cis-1,2-DCE		trans-1,2-DCE		Vinyl chloride		Total CVOCs	TOC	
Current CUL				***3.3***		***30***		**--**		**--**		***2.4***				
AWQC from WAC 173-201a-240				***7.1***		***0.86***		**--**		**--**		***0.26***				
Location		**ft bgs**	**Sample Date**	**µg/L**		**µg/L**		**µg/L**		**µg/L**		**µg/L**		**µg/L**	**mg/L**	
Embayment Seeps																
SP-02	--	--	7/13/2022	<0.4	U	<0.5	U	0.581		<0.5	U	<0.2	U	**0.58**	--	
SP-03	--	--	7/13/2022	<0.4	U	<0.5	U	2.27		<0.5	U	<0.2	U	**2.27**	--	
SP-03b	--	--	7/13/2022	<0.4	U	<0.5	U	0.542		<0.5	U	<0.2	U	**0.54**	--	

Abbreviations:

--	Not analyzed or not established
DCE	Dichloroethene
PCE	Tetrachloroethene
TCE	Trichloroethene
TOC	Total Organic Carbon
µg/L	Micrograms per liter
ft bgs	feet below ground surface
WBZ	water bearing zone
CUL	Cleanup Level
AWQC	Ambient Water Quality Criteria

Qualifiers:

D	Sample was diluted
U	Non-detect
E	Value above quantitation range



CALIBRE

Legend

🟩 Text in green box represents CVOCs below Remediation Level of 250 ug/L.

🟦 Text in blue box represents CVOCs below Remediation Level and Cleanup Levels.

🟨 Text in yellow box represents VC below Cleanup Levels, data in boxes are 7/22 VC concentrations.

0 30' 60' 120'
SCALE IN FEET

N

Notes:
- Thermal treatment period from Jan-May 2013
- Total CVOCs include tetrachloroethene (PCE), trichloroethene (TCE), vinyl chloride (VC), and cis-1,2-dichloroethene (cis-DCE).

Data presented are from the July 2022 sampling event.

- All data in ug/L.

Figure 4.1
2022 Total CVOC Concentrations in Groundwater
1st and 2nd Water Bearing Zones
July/August 2022

STANDARD OPERATING PROCEDURE:
SOIL-GAS SAMPLING, SOIL VAPOR COLLECTION

1.0 PURPOSE

This standard operating procedure (SOP) for soil-gas sampling describes the procedures to collect soil-gas samples for the analysis of volatile organic compounds (VOCs) by United States Environmental Protection Agency (USEPA) Method TO-15 (TO-15). The TO-15 method uses a 1 to 6-liter SUMMA passivated stainless-steel canister. The procedures defined within this SOP will also apply for samples utilizing other collection containers such as Tedlar bags for use with alternate sampling methods (ie. 8260B). When using a Tedlar bag a vacuum pump will be required to fill the bag, see the Tedlar bag SOP.

An evacuated 6-liter SUMMA canister (<28 inches of mercury [Hg]) will provide a recoverable whole-gas sample of approximately 5.5 liters when allowed to fill to a vacuum of 2 inches of Hg. The whole-air sample will be analyzed for VOCs using a quadruple or ion-trap gas chromatograph/mass spectrometer (GC/MS) system to provide compound detection limits of 0.5 parts per billion volume (ppbv) or lower.

The following sections list the necessary equipment and provide detailed instructions for the installation of soil-gas probes and the collection of soil-gas samples for VOC analysis.

2.0 SOIL-GAS SAMPLING

EQUIPMENT LIST

Temporary Soil-Gas Probe

The equipment required to install a temporary soil vapor probe is presented below:

- hand auger with a one or two inch bucket, or rotohammer;
- preassembled soil vapor probe (Geoprobe or similar), or ¼ tubing with correct fitting on sample to container end;
- photoionization detector (with a lamp of 11.7 eV);
- ¼-inch tubing (Teflon, polyethylene, nylon, or similar);
- clean sand (or similar fill);
- bentonite or molding clay;
- air tight seal; and,
- wooden stake.

Soil-Gas Collection

The equipment required for soil-gas sample collection is presented below:

- stainless-steel SUMMA canisters 1 or 6-liter;
- flow controllers (in the case of a prolonged time sample) with in-line particulate filters and vacuum gauges. Flow controllers are pre-calibrated to specified sample duration (e.g., 60 minutes) or flow rate (e.g., 100 milliliters per minute [mL/min]). Confirm with lab that flow

controller comes with in-line particulate filter and pressure gauge;
- ¼-inch tubing (Teflon, polyethylene, or similar);
- stainless steel "T" fitting (for connection to summa canisters and Teflon tubing to collect duplicate samples);
- portable vacuum pump (or syringe) capable of producing very low flow rates (e.g., 100 mL/min);
- flow meter;
- helium gas canister;
- field helium detector;
- plastic sheeting;
- Photoionization Detector (with a lamp of 11.7 eV);
- 9/16-inch open-end wrench;
- chain-of-custody forms;
- soil-gas sample collection log; and
- field notebook.

2.1 SAMPLING CARE

Care will be used during all aspects of sample collection to ensure that sampling error is minimized and high-quality data are obtained. For example, care will be used to properly seal around the soil vapor probe at the ground surface to prevent leakage of atmospheric air into the probe during purging and sampling. Also, the sampling team will avoid actions (e.g., fueling vehicles, using permanent marking pens and wearing freshly dry-cleaned clothing or personal fragrances) which could potentially cause sample interference in the field.

2.2 HEALTH AND SAFETY CONSIDERATIONS

Field sampling personnel will follow and adhere to all procedures and requirements as outlined in the project-specific HASP.

2.3 PROCEDURES Temporary Soil-Gas Probe Installation

<u>Through slab (or asphalt) shallow</u>

1. Rotohammer hole through slab, about 5/8+ inch diam.
2. Drive blank rod about 1 ft into soil beneath slab to open hole (1/2 inch rebar is fine), move/rotate rod to clear hole, remove rod
3. Place blue tape at 6 inch marks on sample tubing (1/4 inch), Attach tubing assembly with an end fitting for sampling collection (Summa or Tedlar) and place into open hole, push into hole, verify depth.
4. Fill annular space between the assembled soil vapor tubing with clean sand to near slab if feasible. At surface seal with 3-4 layers of molding clay, pound into hole around tubing with hammer and rod, repear for at least 3 layers.
5. Allow at least 30 minutes to seal and proceed to soil vapor sample collection.
6. When soil vapor sampling is complete, remove the drive rods and backfill the boring with native soil or clean sand, repair/patch surface (~ 2 cups concrete redi-mix.)

With auger or Geoprobe (typically deeper)

1. Measure nearby upper surficial aquifer monitoring wells and calculate current water elevation. Advance a hand auger with a one or two inch-diameter to 1.5 -2 feet above the local water elevation.
2. Attach tubing to pre-assembled soil vapor probe and lower into borehole and hold probe upright until sand pack is added.
3. Fill annular space between the pre-assembled soil vapor probe with clean sand to approximately 1 foot above the vapor probe. Fill remaining borehole with bentonite.
4. Allow at least 30 minutes for bentonite mixture to hydrate and proceed to soil vapor sample collection.
5. When soil vapor sampling is complete, remove the drive rods and backfill the boring with native soil or clean sand.

Vapor Point Leak Testing

Prior to the sampling of an installed vapor point the probe must be verified to be leak proof. If the vapor well allows for intrusion of vapors from other than the soil the point will not be considered a valid point for monitoring. Helium will be used following probe installation to assess break-through. Briefly, helium will be expressed from a pressurized tank into a shroud surrounding the head of the soil vapor probe. A mini-pump will be used to fill a Tedlar bag through the installed soil vapor probe. A portable helium detector will then be used to analyze the contents of the Tedlar bag for helium. Helium concentrations less than 10 percent will be considered acceptable (ITRC 2007).

Soil-Gas Sample Collection

1. Record the following information in the field notebook and on the Field Sampling Logs from a suitable information source [e.g., weatherunderground.com], if samples are taken from within a building or structure estimates based on weather conditions data may be required:

- wind speed and direction;
- ambient temperature;
- barometric pressure; and
- relative humidity.

2. A tracer gas compound (helium) will be used during the soil-gas sampling process to evaluate potential leakage of atmospheric air into the SUMMA canisters used to collect the soil vapor samples. After the tubing has been connected with the SUMMA canister and purging is completed, place plastic sheeting around the borehole and begin to add helium underneath the sheeting near the top of the boring – next to the bentonite/clay sealed sampling point. Attach field helium detector to soil vapor probe to evaluate potential seal issues. If seal issues are identified (over 10%), then adjust as appropriate.

3. Connect a portable vacuum pump (or syringe) to the sample tubing. Purge 1 to 2 volumes (target 1.5 volumes) of air from the vapor probe and sampling line using a portable pump at a rate of approximately 100 mL/min. and measure organic vapor levels with a PID.

The purge volumes should be estimated using the following calculation:

Equation (1) Purge Volume = $1.5 \pi r^2 h$

Where:

Purge volume is in cubic feet,
π is 3.14159 (unitless),
r is radius of borehole (feet), and
h is height from bottom of borehole (feet).

4. Connect the flow controller with in-line particulate filter and vacuum gauge to the SUMMA canister. Do not open the valve on the SUMMA canister. Record the flow controller number with the appropriate SUMMA canister number in the field book. Duplicate samples will be collected sequentially.
5. Connect the sample collection tubing to the flow controller, and the SUMMA canister valve. Record in the field book the time sampling began and the canister pressure. The first samples collected will be carefully observed to ensure that the canister is filling at an appropriate rate (i.e., between 100 and 200 mL/min).
6. Arrive at the SUMMA canister location at least 15 minutes prior to the end of the sampling interval (30-60 minutes). Record the final vacuum pressure. Stop collecting the sample by closing the SUMMA canister valves. The canister should have a minimum amount of vacuum (approximately 2 inches of Hg or slightly greater). Leaving some vacuum in the canister provides a way to assess if the canister leaks while in transit to the laboratory.
7. Disconnect the sample collection tubing from the flow controller. Remove the flow controller with in-line particulate filter and vacuum gauge from the SUMMA canister. Package the canister and flow controller in the shipping container supplied by the laboratory for return shipment to the laboratory. The SUMMA canister does not require preservation with ice or refrigeration during shipment.
8. Complete the appropriate forms (e.g., chain-of-custody) and sample labels. Properly attach sample labels to each SUMMA canister and include all appropriate forms into shipping containers. Secure each shipping container (e.g., packing tape) and attach appropriate shipping labels.

All containers will be shipped via overnight courier. As soon as reasonably possible, verify laboratory receipt of the sample shipment.

3.0 WASTE MANAGEMENT

Field personnel will collect and remove all investigation-derived waste materials (including disposable equipment) for proper disposal.

4.0 DATA RECORDING AND MANAGEMENT

Measurements will be recorded in the field logbook and field sampling logs at the time of measurement with notations of project name, sample date, sample start and finish time, sample location, canister serial number, flow controller serial number, initial vacuum reading, and final pressure reading. Field sampling logs and chain-of-custody records will be referenced in the project report submitted to the Agencies.

5.0 QUALITY ASSURANCE/QUALITY CONTROL

Soil-gas sample analysis will be performed using USEPA TO-15 methodology. This method uses a quadruple or ion-trap GC/MS with a capillary column to provide optimum detection limits. The GC/MS system requires a 1-liter gas sample (which can easily be recovered from a 6-liter canister) to provide the specified detection limit. The 6-liter canister also provides several additional 1-liter samples in case subsequent reanalyses or dilutions are required. This system also offers the advantage of the GC/MS detector, which confirms the identity of detected compounds by evaluating their mass spectra.

Duplicate samples will be collected at a rate of 1 per 10 samples.

Additional information regarding Quality Assurance/Quality Control may be found in the site QAPP.

6.0 REFERENCES

- Environmental Protection Agency. 2002. *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)*.

From:	Schwarz, Julia (ECY)
To:	McKeon, Tom
Subject:	RE: Section 2.3 PROCEDURES Temporary Soil-Gas Probe Installation
Date:	Monday, February 27, 2023 12:50:00 PM

Tom,

You may collect the break room sub slab sample using a temporary probe. However, the leak detection threshold in your SOPs (including the ones in the existing plan) must be adjusted to 5%, consistent with Appendix D of Ecology's 2022 *Guidance for Evaluating Vapor Intrusion in Washington State*.

Please let me know if you have any questions.

Thanks,
Julia

Julia Schwarz, LHG (she/her)
Site Manager, Toxics Cleanup Program
Department of Ecology Northwest Region Office
Cell: 425-515-5992

From: McKeon, Tom <Tom.McKeon@calibresys.com>
Sent: Monday, February 27, 2023 12:33 PM
To: Schwarz, Julia (ECY) <jusc461@ECY.WA.GOV>
Subject: FW: Section 2.3 PROCEDURES Temporary Soil-Gas Probe Installation

Julie
re. Sub slab vapor probe break room only in Fox Ave
as we discussed,
the prior vapor-pin sub slab point in the break room at Fox Ave no longer exists (lost/covered/? sometime between 2014 and 2023)

attached is a revised SOP which include temporary probes, w' helium leak test, sample collection, then closure
it is an older SOP which Justin remembered

Request ECY approval to do this different sample collection procedure in one location (in break room) for the Fox Ave IA sampling

this is also the same sampling approach used by URS in the initial SBW IA/subslab sampling in ~ 2011, as copied in this 2023 Fox Ave IA workplan
& I have done maybe a hundred of them in 3 local aircraft manufac. plants

& no word back from SBW re. access

thx

Tom McKeon
CALIBRE
(O): 425 241 8449
www.calibresys.com

From: Neste, Justin <Justin.Neste@calibresys.com>
Sent: Monday, February 27, 2023 11:53 AM
To: McKeon, Tom <Tom.McKeon@calibresys.com>
Subject: Section 2.3 PROCEDURES Temporary Soil-Gas Probe Installation

Justin Neste
Environmental Scientist
CALIBRE
Tel: 360.981.5606
www.calibresys.com